Untangling operational performance implication of ambidextrous blockchain initiatives: An empirical investigation of Chinese manufacturers

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Abstract

Purpose - Blockchain has been considered as a disruptive technology and every industry stands to benefit from it. According to Deloitte, increasing number of managers claim that their firms will suffer loss in competitive advantage if they don't adopt blockchain. Despite this motivation, insufficient knowledge on how can blockchain add value inhibits the commitment to its adoption. To better understand the possible influence of blockchain, two dimensions (exploitation and exploration) of blockchain initiatives are distinguished. This research aims to examine the impact of ambidextrous blockchain initiatives on firms' operational efficiency, as well as the moderating role of unabsorbed slack and environmental munificence.

Design/methodology/approach – In this paper, secondary panel data were collected from multiple sources to test the proposed hypotheses. Content analysis was adopted to operationalise ambidextrous blockchain initiatives from firms' official announcements.

Findings - We find that firms' ambidexterity in blockchain initiatives have significantly positive impact on operational efficiency. Furthermore, when firms have lower unabsorbed slack or in more munificent environments, they may benefit from managing a balance between exploration and exploitation.

Originality/value – This research offers some insightful theoretical and managerial implications of ambidextrous blockchain initiatives. The findings of this study contribute to blockchain literature by providing theory-driven empirical research.

Keywords: blockchain; organisational ambidexterity; operational efficiency; unabsorbed slack; environmental munificence

1. Introduction

Blockchain – defined as 'a decentralized, distributed, shared, and immutable database ledger that stores registry of assets and transactions across a peer-to-peer network' (Khan and Salah, 2018, p.405) – is listed as one of the top 10 strategic technology trends, with the potential to provide significant business opportunity (Cearley and Burke, 2018). Manufacturing and operations management, in particular, are perceived as the most promising domains for adopting blockchain (Lohmer and Lasch, 2020). According to a report published by PwC (2019), blockchain is potential to revolutionise manufacturing in designing, engineering, making and scaling products. Realising such potentials, manufacturing firms are also being out front in developing blockchain (PwC, 2019). Growing interest has been shown in using blockchain to address operational challenges (Jabbar and Dani, 2020). Blockchain is anticipated to address the long-standing pain points in manufacturing industry such as materials provenance, counterfeit detection, engineering design for complex products and so on. For example, for aircraft manufacturers, blockchain can continuously update the condition of each part, which lead to shortened time on routine inspection and aircraft maintenance (PwC, 2019). More generally, blockchain is expected to benefit operations in many ways, including reducing costs, enhancing productivity and alleviating paper-trail inefficiencies.

Despite blockchain research continuously grow, the extant literature remains largely technical or conceptual, and has mostly been composed of theoretical expositions, framework proposals and case studies and shows a relative lack of quantitative empirical studies (Karakas *et al.*, 2021; Queiroz *et al.*, 2019). Since the application of blockchain is still at a rapid growth period, blockchain's capacity to help firms with value creation needs to be examined more closely. And according to Renee Ure, Lenovo's Chief Operating Officer, operational efficiencies can be seen through the use of blockchain.

In the light of this, this study aims to investigate the impact of blockchain initiatives, which refers to firms' use of blockchain, on firms' operational efficiency. Operational efficiency refers to a firm's managerial competence to transform diverse inputs into value-added outputs in the process of production, which is crucial to firms' success and must be taken seriously (Li *et al.*, 2010). Hasan *et al.* (2020) pioneered in addressing this issue by directly investigating the association between the adoption of blockchain and operational efficiency. However, due to the fact that blockchain is one of the primary information technology innovations (Clohessy and Acton, 2019), blockchain initiatives can manifest themselves as varied innovation activities, such as incremental innovation in daily operations and business processes, or more radical in product and service. As suggested by ambidexterity theory, different patterns of innovation, i.e. exploitation and exploration, should be considered. On the one hand, firms can adopt existing blockchain services or products to 'enhance, optimize, secure and streamline many existing business and industrial processes' (Al-Jaroodi and Mohamed, 2019, p.36500), which represents an exploitative orientation. On the other hand, they can also develop their own blockchain-based R&D projects to create new business opportunities, processes and product development (Benzidia *et al.*, 2021), which represents an exploratory orientation. However, there is still a lack of understanding on the business value associated with different patterns of blockchain initiatives. As noted by Queiroz and Wamba (2019), the inadequate understanding of blockchain's value will be the important barrier for firms to adopt blockchain. In addition, technology exploration and exploitation could cross-fertilise each other (Geerts *et al.*, 2018). The separation investigation of the two activities could jeopardise the understanding of blockchain's effect. To address this concern, this research takes a further step by distinguishing blockchain initiatives into two categories: exploitative and exploratory, and employs organisational ambidexterity theory as the research lens.

Following organisational ambidexterity theory, we focus on the influence of ambidextrous blockchain initiatives, which is a metaphor defined as a firm's ability to successfully pursue both exploitative blockchain initiatives (EtBI) and exploratory blockchain initiatives (ErBI). We distinguish EtBI and ErBI by adapting the definitions of exploitation and exploration. In the context of strategic alliances, exploitation refers to a situation wherein a firm can achieve incremental improvements in its current products and processes by leveraging its partners' existing specialised knowledge (Hoang and Rothaermel, 2010). Exploration, in contrast, involves the discovery of something new, such as the development of a new product. Thus, we propose that EtBI refers to the utilisation of existing blockchain knowledge, competencies and opportunities through applying existing blockchain services or products. In contrast, ErBI mainly focuses on the creation of new blockchain knowledge, competencies and opportunities through the development of blockchain-based R&D projects.

And in line with the literature on organisational ambidexterity (He and Wong, 2004), a firm can achieve an ambidextrous blockchain initiative in two ways. Accordingly, a complementary blockchain initiative occurs when a firm scores high on both EtBI and ErBI. It corresponds to the type of strategy fit – 'fit as moderating', which implies that EtBI and ErBI can mutually interact. In addition, a balanced blockchain initiative occurs when a firm places relatively equal emphasis on the two dimensions, and it harmonises another type of strategy fit – 'fit as matching', indicating the case of matched exploration and exploitation.

Moreover, to better explain the value creation mechanism of blockchain, contextual factors which condition the actual business value of blockchain initiatives should be investigated. As the least-absorbed organisational resource, unabsorbed slack, which can help firms to achieve their development goals, plays a particularly important role in firms' growth (Wang *et al.*, 2021). In addition, firms need to take their industry environment into account, as underlying performance among firms is likely to vary under different industry conditions. With regard to this concern, environmental munificence is quite crucial as it defines firms' growth possibilities (Dess and Beard, 1984). Particularly, unabsorbed slack and environmental munificence also exemplify the resource accessible to a firm from inside and outside the organisation, respectively. And prior research has also highlighted that a firm's ability to benefit from ambidexterity critically depends on its available resources (Cao *et al.*, 2009). However, it also remains unclear how resource-relevant factors can hamper or promote the value associated with blockchain initiatives. Thus, this research attempts to fill this gap by quantitatively investigating the impact of blockchain initiatives on firms' operational efficiency – as well as the moderation effect of two contingencies – from the perspective of organisational ambidexterity. We propose the following two research questions:

- RQ1: Can the implementation of ambidextrous blockchain initiatives promote firms' operational efficiency?
- RQ2: How do organisational and environmental contingencies–namely, unabsorbed slack (internal resources) and environmental munificence (external resources)–influence the relationship between ambidextrous blockchain initiatives and operational efficiency?

To answer these questions, we collected secondary data from firms' official announcements and the China Stock Market & Accounting Research Database (CSMAR). We select China market as the main data source since China is a key player in the development of blockchain in the world (Kuo and Shyu, 2021). Thus, studying the phenomenon of Chinese firms provides certain representative significance (Chen *et al.*, 2021).

Our research makes several significant contributions. First, since the power of blockchain has drawn increasing attention from academia and more theory-driven and rigorously empirical studies are called for (Rossi *et al.*, 2019), this study enriches the blockchain literature by providing empirical evidence on the positive effect of blockchain initiatives. Second, differing from prior studies which explore the influence of adopting blockchain (e.g. Chen *et al.*, 2021; Hasan *et al.*, 2020; Pan *et al.*, 2020), to our best knowledge, this research is the first attempt to apply the idea of organisational ambidexterity to distinguish among different types of blockchain implementations. Third, the inclusion of two moderators offers a more comprehensive understanding on the effect of contingencies in blockchain value creation. Finally, from a managerial perspective, this research sheds light on the importance of adopting blockchain– specifically, implementing blockchain in an ambidextrous manner – and provides insights for firms regarding how to derive better outcomes given specific internal and external resource conditions.

The remainder of this research is structured as follows. Section 2 outlines the relevant literature and develops research hypotheses. Section 3 describes the adopted methodology. The empirical results are presented in Section 4, and Section 5 offers a discussion.

2. Literature review and hypothesis development

2.1 Organisational ambidexterity

In brief, exploitation includes 'refinement, choice, production, efficiency, selection, implementation, and execution', while exploration is characterised by 'search, variation, risk taking, experimentation, play, flexibility, discovery, and innovation' (March, 1991, p.71). The concepts of exploitation and exploration have been applied and expanded in various contexts, including technology and innovation management (e.g. Gu *et al.*, 2021; Tai *et al.*, 2019)

Although exploration and exploitation have different underlying logics and tensions arise as they compete for scarce resources, they are also synergistic (He and Wong, 2004). Exclusive engagement in exploration will cause a firm to suffer from a lack of gains obtained through existing knowledge, whereas at the other extreme, exclusive involvement in exploitation will trap a firm in obsolescence (Levinthal and March, 1993). Thus, the optimal solution is an ambidextrous organisation that can simultaneously pursue exploitation and exploration (Tushman and O'Reilly, 1996). A fruitful stream of research offers insights and empirical evidence regarding the significant role of organisational ambidexterity in firms' performance. For example, analysing a sample of 206 manufacturing firms, He and Wong (2004) found that both complementary and balanced innovation strategies were positively related to firms' sales growth rates.

2.2 Ambidextrous blockchain initiatives and firms' operational efficiency

With respect to EtBI, manufacturing firms can directly leverage current blockchain services or products in the market, such as adopting or connecting with established blockchain platforms to integrate inventory, capital and information flows across companies. In this way, efficiency improvements can be gained through speeding up organisational processes, reducing operational costs and improving operating quality (Pan *et al.*, 2020). ErBI mainly manifest as innovative processes or products. Innovated processes can enhance efficiency by helping firms reduce process costs and time, and blockchain-driven ones have similar effects. For innovation in products, blockchain can be added as one key element of a new product, achieving product upgrading and differentiation, resulting in higher operational efficiency. However, implementing solely EtBI or ErBI may not achieve a favourable outcome. And the concept of organisational ambidexterity proposes that ambidextrous organisations which synchronously develop their exploration and exploitation capacities are optimal (March, 1991).

On the one hand, organisational ambidexterity theory supports that exploitation and exploration can complementarily interact with each other (Tushman and O'Reilly, 1996; Wong *et al.*, 2013). Accordingly, EtBI and ErBI can add value to each other and concurrent pursuit of them can lead to better results than implementing them separately. EtBI can stimulate ErBI, reducing the amount of time needed to develop blockchain R&D projects and increasing their success rate, and ErBI can expand the available blockchain-relevant resources for EtBI. Firms that successfully achieve a dual orientation of exploration and exploitation are more attuned to important opportunities to promote operational efficiency (Gedajlovic *et al.*, 2012). On the other hand, overemphasising one dimension at the expense of the other can be risky. In terms of McDermott and Prajogo (2012), firms with an extreme focus on EtBI could drive them into a 'success trap', ignoring the potential benefits derived from ErBI. And an over-reliance on EtBI indicates overdependence on external blockchain expertise and partners, which may lead to a loss of certain flexibility in decision-making, resulting in unnecessary additional management costs and redundant management procedures. Alternatively, firms that overemphasise ErBI are in intensive resource-consuming yet without immediate reward in sight, resulting a 'failure trap'. According to Melander (2018), to succeed in ErBI R&D projects, it is critical to have a supporting level of EtBI. Otherwise, it can be resource inefficient as the development cycle will be longer and the failure rate higher. Prior studies have also supported the efficiency-related synergies of ambidexterity (see Kortmann *et al.*, 2014). Based on the above discussion, we present the following hypothesis:

H1: Complementary blockchain initiatives are positively related to firms' operational efficiency.

H2: Balanced blockchain initiatives are positively related to firms' operational efficiency.

2.3 Organisational and environmental contingencies

Unabsorbed slack. Slack is defined as the pool of resources within an organisation and denotes an excess of the minimum level of resources needed for ordinary operations (Nohria and Gulati, 1996). Accordingly, unabsorbed slack, which is easy to reconfigure for various uses and assign to any purpose, refers to excess, uncommitted, available and ready-to-deploy liquid resources in organisations, such as cash and raw material inventory

Ample resources relax the tension between exploitation and exploration (Jin *et al.*, 2015) and resource availability is also a key constraint when using blockchain (Al-Jaroodi and Mohamed, 2019). For instance, Nandi *et al.* (2021) reasoned that firms with greater financial and slack capacity were more capable of building blockchain-enabled circular economy system. Since EtBI focuses on utilising existing blockchain knowledge, whereas ErBI emphasises the creation of new blockchain knowledge, simultaneous development of EtBI and ErBI is complex, as it requires fast absorption and coordination of diverse knowledge. Therefore, substantive resources need to be committed. Unabsorbed slack offers such uncommitted resources to facilitate complementary blockchain initiatives by flexibly and timely allocating resources whenever and wherever needed. As confirmed by Cao *et al.* (2009), the positive effect of combined ambidexterity is highly related to the availability and allocation of resources. Thus, we posit:

H3a: Unabsorbed slack positively moderates the relationship between complementary blockchain initiatives and firms' operational efficiency.

The loss in efficiency from overreliance on EtBI can be attributed to inflexibility in adjusting strategies and adapting to changing environments. However, organisational slack can promote advanced strategic initiatives, enabling firms to better adapt to complex and competitive situations (Jin *et al.*, 2015). On the other hand, exclusive engagement in ErBI is risky due to long R&D cycles and higher failure rates and is also inefficient in resource distribution. Nevertheless, slack can alleviate such risks, as it can facilitate search, experimentation and innovation and even avoid some serious consequences of failure (Lavie *et al.*, 2010). Consistent with Cao *et al.* (2009), we argue that, the risk of unbalanced EtBI and ErBI is less threatening when a firm has a larger resource base, as those resources can cushion such risks. Therefore, we posit:

H3b: Unabsorbed slack negatively moderates the relationship between balanced blockchain initiatives and firms' operational efficiency.

Environmental munificence. Munificent environments are characterised by low-level external threats, higher growth rates and abundant environmental resources (Bloom and Michel, 2002), whereas declining demand, fierce competition and high financial pressure depict the situation of less munificent environments (Choi *et al.*, 2020).

According to Heeley *et al.* (2006), firms in more munificent settings could realise greater returns from a given stock of resources devoted to blockchain initiatives. Consistent with this, as noted by Vitari and Raguseo (2020), munificent environment could expand the potential of complementary blockchain initiatives in promoting operational efficiency when such initiatives match the requirements of external environment. For example, adopting blockchain to store customer data can facilitate manufacturers' capacities to better manage their production. Such reductions in operational costs and cycle time are likely to be more pronounced in munificent industries with growing demand. On the contrary, firms in high-pressure environments may avoid implementing either EtBI or ErBI because, in such conditions, firms prefer to conserve resources. We hypothesise the following relationship:

H4a: Environmental munificence positively moderates the relationship between complementary blockchain initiatives and firms' operational efficiency.

Munificent environments provide firms with greater chances of survival, more opportunities to grow and more strategic choices (Li *et al.*, 2013). In such circumstances, firms can fully leverage the opportunities to balance EtBI with ErBI, resulting in the greatest efficiency. Conversely, as suggested by Moss *et al.* (2014), firms in more hostile environments will be more likely to flexibly change their strategic emphasis on EtBI or ErBI. Deploying ambidexterity can be dangerous for firms with low environmental munificence; in such conditions, firms are recommended to emphasise exploitation to better pursue efficiency (Dolz *et al.*, 2019). A struggle to maintain balanced blockchain initiatives may cause unexpected waste in resources and in turn lead to loss of efficiency. Thus, we present:

H4b: Environmental munificence positively moderates the relationship between balanced blockchain initiatives and firms' operational efficiency.

The conceptual framework of this study is shown in Figure 1.

[Insert Figure 1 here]

3. Methods

3.1 Data collection

Secondary panel data were collected from multiple sources to test the proposed hypotheses. We derived information regarding firms' blockchain initiatives from firms' official announcements, which are more authoritative than newspaper reports (Liu *et al.*, 2020). Specifically, we searched for firms' official announcements from Wind Economic Database ('Wind'), as Wind contains all official announcements of listed firms. The data collection process is shown in Figure 2. The sample was limited to publicly listed manufacturing firms in China. First, we obtained a list of Chinese manufacturing firms from CSMAR, a leading data source for Chinese listed firms. We followed the industrial classification standard proposed by China Securities Regulatory Commission (CSRC), which resulted in 2,860 listed firms (two-digit CSRC codes C13-C43). Second, we manually searched Wind to determine whether each firm had released any official announcements with the keyword 'blockchain'. In this step, 1,490 blockchain-relevant official announcements from 302 firms were found. Lastly, by reading through all the announcements, we identified firms' blockchain initiatives. Similar to the filtering criteria in Xiong *et al.* (2021), who identified blockchain adoption in supply chains, we first eliminated announcements not related to firms' blockchain initiatives, such as the appointments of executives with blockchain background. Then, since same blockchain initiatives could be identified in different announcements, repeated records were dropped to avoid duplicates. Finally, we coded 141 firms with at least one blockchain initiative between 2015 and 2020. The reason for exploring the influence of blockchain initiatives between 2015 and 2020 is that in China, blockchain did advance in this period. The starting year of 2015 is chosen as this year has seen the turning point for firm digitisation under the encouragement of the government (Chen *et al.*, 2021).

[Insert Figure 2 here]

Descriptive statistics of the 141 firms are presented in Table 1. In particular, Panel A shows that the number of blockchain initiatives has continuously increased in recent years. The majority (85.686%) were launched in 2018, 2019 and 2020. These 141 manufacturing firms represent 21 industries based on two-digit CSRC codes, indicating that the firms are from a wide range of industries. Panel B of Table 1 shows the top 10 industries. The top five industries take 62.411% of the total industries, and interestingly, four of which are associated with equipment manufacturing. In addition, organisational characteristics in terms of sales, total assets, number of employees and age are provided in Panel C of Table 1.

[Insert Table 1 here]

Next, for other research variables, operational data were collected from CSMAR. Due to missing data, not all firms had the full six-year consecutive data. Therefore, the final sample consisted of 395 firm–year observations, which included data from 141 firms between 2015 and 2020. The dataset was an unbalanced panel data.

3.2 Variable measurements

The details of the measurement procedures are summarised in Table 2.

[Insert Table 2 here]

Ambidextrous blockchain initiatives. Scholars have developed a variety of approaches to operationalise exploration and exploitation, such as survey-based analyse (e.g. Gu *et al.*, 2021; He and Wong, 2004), and using proxies such as patent data (see Kang and Kim, 2020). These approaches have been challenged for lacking generalisability and applicability, as well as lack of clarity regarding whether they are consistent with the concept of exploration and exploitation (Uotila *et al.*, 2009). To address such concerns, this study employed content analysis for three reasons: 1) we can directly derive exploration and exploitation from official announcements; 2) using content analysis allowed us to operationalise data over an extended time period; 3) content analysis can ensure that research findings are applicable across different industries (Gatti *et al.*, 2015; Uotila *et al.*, 2009).

We classified EtBI and ErBI based on aforementioned definition. Some examples are shown in Table 3. Referencing Lam *et al.* (2016), we counted the numbers of the two types of initiatives to quantify EtBI and ErBI. To ensure the coding reliability of content analysis, the inter-coder reliability test was conducted. Considering that the collected announcements contain large texts needed to be coded, following Tangpong (2011), a subsample of 10% of the total text units was randomly selected and coded by another independent and well-trained coder. The results indicated adequate levels of inter-coder reliability for both EtBI (Cohen's kappa=0.845) and ErBI (Cohen's kappa=0.810).

[Insert Table 3 here]

Complementary blockchain initiative was measured as the interactive term: EtBI × ErBI (Wong *et al.*, 2013). Before generating this product, EtBI and ErBI were mean centred to avoid potential multicollinearity. Balanced blockchain initiatives was measured as the absolute difference between exploration and exploitation, which was reversed to facilitate interpretation: 3-|EtBI − ErBI|.

Operational efficiency. Stochastic frontier estimation (SFE) was adopted to measure operational efficiency by modelling a firm's relative efficiency in converting operational input resources into operational output (Li *et al.*, 2010). SFE provides a comprehensive measurement, as it considers various operational inputs rather than a single indicator; it also better fits the definition of operational efficiency from the perspective of the OM domain (Lam *et al.*, 2016). Taking an SFE approach, the efficiency score was calculated as follows:

$$\begin{aligned} \ln(Operating\ Income)_{it} = \beta_0 + \beta_1 \ln(Number\ of\ Employees)_{it} \\ + \beta_2 \ln(Cost\ of\ Goods\ Sold)_{it} \\ + \beta_3 \ln(Capital\ Expenditure)_{it} + \varepsilon_{it} - \eta_{it} \end{aligned} \quad (1)$$

where ε_{it} represents the purely stochastic random error term; η_{it} is the technical inefficiency. Thus, the operational efficiency of firm i in year t can be expressed as follows (Zhu *et al.*, 2021):

$$Operational\ efficiency_{it} = e^{-\widehat{\eta_{it}}} \quad (2)$$

The efficiency measurement ranges from 0 to 1; 0 denotes the lowest level of efficiency and 1 the optimal level in the conversion process.

Unabsorbed slack and environmental munificence. Consistent with Iyer and Miller (2008), we used the current ratio (i.e. current assets divided by current liabilities) as a proxy for unabsorbed slack. Following Goll and Rasheed (2005), we adopted 10-year average sales growth as the measurement for environmental munificence. For each industry and sample year, the industry-level total sales for the previous 10 years were regressed on time. Munificence was measured as the regression slope coefficient divided by the mean sales in the same time period (see Jacobs *et al.*, 2015).

Control variables. Four control variables – firm size, firm age, firm profitability and firm cash-to-cash cycle – were included because they might influence operational efficiency. Firm size was measured as the natural logarithm of a firm's sales (Lee and Huang, 2012). Firm profitability was operationalised as a firm's return on assets (Fong *et al.*, 2010). Firm age was defined as years since the firm's incorporation (Kotha *et al.*, 2011). In line with Lam (2018), firm cash-to-cash cycle was calculated as in Equation (3) and standardised based on its industry. Finally, year dummies were also controlled in consideration of unobserved time-specific effects.

$$\begin{aligned} Cash\ to\ cash\ cycle_{it} = {} & Days\ of\ inventory_{it} + Days\ of\ accounts\ receivables_{it} \\ & - Days\ of\ accounts\ payables_{it} \end{aligned} \tag{3}$$

3.3 Research modelling

The sample data represent a short unbalanced panel. In such cases, pooled regression is applicable and more likely to provide a reliable result (Ben-Jebara and Modi, 2021). Following He and Wong (2004), we analysed the effects of alternate ambidextrous blockchain initiatives in separate models, where only one of the two dimensions was included, as shown in Equation (4):

$$\begin{aligned} Operational\ efficiency_{i(t+1)} = {} & \beta_0 + \beta_1 Ambidextrous\ blockchain\ initiatives_{it} \\ & + \beta_2 Exploitative\ blockchain\ initiatives_{it} \\ & + \beta_3 Exploratory\ blockchain\ initiatives_{it} \\ & + \beta_4 Firm\ age_{it} + \beta_5 Firm\ size_{it} + \beta_6 Firm\ profitability_{it} \\ & + \beta_7 Firm\ cash - to - cash\ cycle_{it} + Year\ dummies + \varepsilon_{it} \end{aligned} \tag{4}$$

To test the moderating effect, we then added the two moderators and their interactions with ambidextrous blockchain initiatives in Equation (5) as follows:

$$
\begin{aligned}
Operational\ efficiency_{i(t+1)} = \beta_0 &+ \beta_1 Ambidextrous\ blockchain\ initiatives_{it} \\
&+ \beta_2 Moderator \\
&+ \beta_3 Ambidextrous\ blockchain\ initiatives \times Moderator \\
&+ \beta_4 Exploitative\ blockchain\ initiatives_{it} \\
&+ \beta_5 Exploratory\ blockchain\ initiatives_{it} \\
&+ \beta_6 Firm\ age_{it} + \beta_7 Firm\ size_{it} + \beta_8 Firm\ profitability_{it} \\
&+ \beta_9 Firm\ cash - to - cash\ cycle_{it} + Year\ dummies + \varepsilon_{it}
\end{aligned} \quad (5)
$$

To avoid multicollinearity, the independent variable and moderator were mean centred to compute the interaction. To reflect the causal relationship, all independent variables and control variables were lagged by one year from the dependent variable. In addition, to account for heteroscedasticity, cluster-robust standard error at the firm level was adopted in the study.

4. Results

The correlations, means and standard deviations of all variables are shown in Table 4. To exclude the potential influence of multicollinearity, the variance inflation factor (VIF) for each regression model is calculated and the results show that the VIF values for all models are less than 10, indicating no problems of multicollinearity. Furthermore, the normality of the residuals in all estimated models is tested through skewness and kurtosis tests. The results show that p-values are greater than 0.05, failing to reject the null hypotheses of the normally distributed residuals.

[Insert Table 4 here]

4.1 Impact of ambidextrous blockchain initiatives on operational efficiency

Table 5 presents the pooled regression outcomes of the main effect. Among the control variables, firm size and firm profitability remained positively significant across the three models, indicating that larger and more profitable firms tend to be more operationally efficient. In addition, firms with long cash turnover cycles are less efficient. The coefficients of complementary ($\beta = 0.087$, $p < 0.01$) and balanced ($\beta = 0.057$, $p < 0.05$) blockchain initiatives are both positively significant. These results suggest that firms' ambidextrous blockchain initiatives improve operational efficiency. Thus, H1 and H2 are supported.

[Insert Table 5 here]

4.2 Moderating effect of unabsorbed slack

Model (5) shows that the interaction between complementary blockchain initiatives and unabsorbed slack is not statistically significant ($\beta = 0.006$, $p > 0.1$), meaning that the impact of complementary dimension on operational efficiency does not rely on firms' unabsorbed slack. Thus, H3a is not supported. However, there is a negatively significant interaction between balanced dimension and unabsorbed slack ($\beta = -0.027$, $p < 0.05$), as shown in Model (7). Thus, H3b is supported.

[Insert Table 6 here]

To clearly demonstrate the moderating effect, we conducted simple slope analysis and plotted simple slopes at the high (+1 standard deviation above the mean) and low (−1 standard deviation above the mean) levels of unabsorbed slack. As shown in Figure 3, when a firm has a high level of unabsorbed slack, the simple slope is not statistically significant ($\beta = -0.063$, $p > 0.1$), whereas the simple slope is positively significant ($\beta = 0.124$, $p < 0.001$) with low unabsorbed slack. These results indicate an interference effect of unabsorbed slack.

[Insert Figure 3 here]

4.3 Moderating effect of environmental munificence

As shown in Model (9), the moderating effect of munificence on complementary blockchain initiatives is not significant ($\beta = -0.386$, $p > 0.1$). Thus, H4a is rejected. In contrast, the coefficient of the interaction between the balanced ambidexterity and munificence is positive and significant ($\beta = 0.853$, $p < 0.05$), suggesting a reinforcement effect of munificence. Thus, H4b is supported.

[Insert Table 7 here]

Consistent with our predictions, simple slope analysis (see Figure 4) shows that in a more munificent environment, balanced blockchain initiatives will lead to a higher level of operational efficiency ($\beta = 0.090$, $p < 0.05$). However, no significant influence on a firm's operational efficiency ($\beta = 0.011$, $p > 0.1$) is shown under a low level of environmental munificence.

[Insert Figure 4 here]

4.4 Robustness tests

We also employed alternative measurements of the dependent and control variables to check the robustness of our findings. Specifically, we generated alternative operational efficiency by replacing one input element (namely, cost of goods sold) with inventory. For the controls, we computed firm age as the number of years since IPO listing and firm size as the natural logarithm of total assets. Overall, the results of the robustness tests were consistent with our findings, further supporting our arguments.

5. Discussion

This study has two key findings. First, it confirms that a firm's ambidexterity in blockchain initiatives, whether complementary or balanced, is associated with increased operational efficiency. The result is consistent with prior empirical studies on the business value of using blockchain – to name a few, improved operational capabilities (Pan *et al.*, 2020), lower systemic risks and increased investment efficiency (Chen *et al.*, 2021) and increased stock returns (Xiong *et al.*, 2021). Our result also supports the benefits of ambidexterity in the realm of technology, which have been confirmed by extant research on enhanced supply chain resilience due to IT ambidexterity (Gu *et al.*, 2021), and increased operational support due to information systems ambidexterity (Tai *et al.*, 2019). This supports the credibility of both our findings and those of previous researchers.

Second, we empirically test the moderating effects of organisational and environmental contingencies (i.e. unobserved slack and environmental munificence). With regard to complementary blockchain initiatives, neither unobserved slack nor environmental munificence has a significant moderation effect. A possible explanation is that resources, whether obtained internally or externally, might affect EtBI and ErBI in opposite manners. Li *et al.* (2013) demonstrated that Chinese manufacturing firms have long preferred to absorb advanced knowledge through exploitation, whereas exploration is far from being fully realised due to a lack of resources and capabilities. However, product innovation advantage is one foremost concern for manufacturing firms, which indicates a significant role of exploration. Therefore, according to Li *et al.* (2013), when firms are situated in munificent environments or have more unabsorbed slack, they prefer to devote more resources and capabilities to ErBI, as the risk of failure in innovative programmes is reduced. As a result, the effectiveness of ErBI is improved, and the positive influence of ErBI on operational efficiency is enhanced. On the contrary, the marginal effect of EtBI on operational efficiency is comparatively lower, as exploitation has been leveraged in a previous long time. Consequently, manufacturing firms might ignore the influence of EtBI, thus weakening the efficiency promotion mechanism of EtBI. Taken together, the contradictory effects are neutralised. This aligns with Pan *et al.* (2018), who argue that higher environmental munificence erodes the complementary effect of exploitative technological diversification on firm performance. This finding is also similar to that of Lee *et al.* (2020), who confirmed that firm size (which represents the quantity of a firm's resources) did not significantly moderate the positive relationship between ambidextrous knowledge sharing and financial performance.

Furthermore, balanced blockchain initiatives generate greater operational efficiency under conditions of less unabsorbed slack or greater environmental munificence. Firms with more unabsorbed slack or in less munificent environments may not accrue efficiency promotion from the relative balance of EtBI and ErBI but would rather benefit from a more focused one-sided strategy.

5.1 Theoretical implications

The study contributes to the literature in several ways. First, given that blockchain initiatives can be classified into two categorises (i.e. exploitative and exploratory), and separated technology exploration and exploitation could hamper their synergies (Geerts *et al.*, 2018), an insufficient investigation on this issue could cause ambiguity and bias on understanding the actual magnitude of the effect of blockchain on operational efficiency. Therefore, instead of simply examining the effect of applying blockchain, this study further distinguished between two types of blockchain initiatives. This aligns with Zhu *et al.*'s (2021) suggestion to categorise big data and analytics implementations as exploration-oriented or exploitation-oriented when studying their value creation.

Second, the connotation of organisational ambidexterity is employed to explore the effect of blockchain initiatives on operational efficiency. This not only provides a better understanding of blockchain, providing a theoretical lens to explain the mechanism of how coordinating exploitation and exploration can be beneficial, but affirms the applicability of organisational ambidexterity in blockchain literature. While organisational ambidexterity has been widely used to investigate organisational-level phenomena (e.g. Luger *et al.*, 2018; Luo *et al.*, 2016), its application in the blockchain literature remains underexplored and its inclusion helps extend the knowledge in this area. In particular, our findings show that complementary and balanced blockchain initiatives are both positively associated with operational efficiency, reinforcing the theory of organisational ambidexterity. Moreover, this work can inform future research on how to integrate organisational ambidexterity theory when studying other emerging technologies.

Second, this study also examines under what conditions firms can achieve operational efficiency. Indeed, management practices which are optimal for all instances are non-existent, and the results of specific firm initiatives are actually dependent on the internal and external context of a firm. In this circumstance, to reach insightful conclusions, contextual factors need to be examined. Thus, we further investigated the role of two contingencies: an internal, organisational factor (unabsorbed slack) and an external, environmental factor (environmental munificence). Interestingly, whilst the benefit of complementing EtBI and ErBI does not vary across different levels of unabsorbed slack and environmental munificence, the efficiency promotion effect of the balanced dimension is moderated in opposite ways by these two factors. These results are different from those in traditional ambidexterity studies (e.g. Luo *et al.*, 2016; Wu and Liu, 2018), which have found that both unabsorbed slack and environmental munificence can improve the performance of complementarily ambidextrous organisations while weakening the benefits of balanced ambidexterity. The perspective of both internal and external contingencies provides a more comprehensive viewpoint when studying the effects of blockchain. On the other hand, this work also echoes Rossi *et al.* (2019), who called for more empirical effort in 'test[ing] existing theories that should be revisited in light of blockchain' (p.1396). This study thus suggests the necessity of grounding additional novel theories in future blockchain literature.

5.2 Managerial implications

The present research has several managerial implications. Given that efficiency is quite important for manufacturing firms, we suggest that decision-makers remain highly focused on implementing blockchain initiatives. Although firms have shown increasing interest in blockchain, they are still sceptical of its business value (Xiong *et al.*, 2021). However, performance expectancy is an important driver of adopting blockchain (Queiroz and Wamba, 2019), and doubt about blockchain's value can serve as an important barrier to its adoption. With respect to this concern, the empirical results of this study confirm that blockchain can have a positive impact on operational efficiency. Thus, this study provides decision-makers with justification for investing in blockchain.

Furthermore, our results show that, rather than being contradictory, EtBI and ErBI mutually enhance one another in promoting operational efficiency. The synergistic effect of EtBI and ErBI further indicates the need for firms to pursue exploitation and exploration simultaneously. Thus, apart from simply embracing blockchain, manufacturing firms are also recommended to appropriately allocate resources to achieve the dual development of EtBI and ErBI. In terms of He and Wong (2004), if conditions permit, practitioners are recommended to manage the tension between EtBI and ErBI in a more continuous process, rather than focusing on just one dimension in discrete periods.

In the meantime, this study can advise blockchain executives to determine whether to maintain a balance between EtBI and ErBI under different organisational and environmental contexts. Our findings suggest that managers should evaluate their internal and external contingencies before making blockchain investments to determine their strategic emphasis. Firms with less unabsorbed slack and those in more munificent industry contexts, may benefit from balanced blockchain initiatives. Managers should also be cautious about maintaining a balance to avoid the risks associated with overemphasising one aspect. In this regard, despite the complexity and delicacy involved in pursuing such a balance, managers should endeavour to execute ambidexterity in using blockchain to seek better operational efficiency. To achieve it, purposeful training should be launched to foster employees' skills, competencies and desire to participate in challenging blockchain programmes. In addition, top management teams need to develop their capacity to wisely and timely adjust strategic focus, and take actions in resource orchestration.

5.3 Limitations and future research

Although this study makes some theoretical and practical contributions, some limitations should be considered in future research. First, the data used for empirical analysis were collected from listed Chinese manufacturing firms, which could reduce the generalisability of the results. The level of blockchain technological development and applications varies across countries and industries. The benefits of ambidextrous blockchain use can thus be different in different contexts. We therefore encourage future researchers to conduct studies in diversified settings. Second, although we used secondary data derived from different sources, which could deal with common method bias, our measurements still have limitations. We measured EtBI, ErBI and ambidexterity through firms' official announcements. However, as Luger *et al.* (2018) pointed, for the sake of confidentiality, firms have a tendency to withhold information of some exploratory initiatives rather than releasing them publicly. In the future, researchers can use additional data sources such as primary data through in-depth surveys and interviews to facilitate the information of secondary data. Finally, given the difficulties associated with collecting data about firms' blockchain adoption and application, content analysis was manually carried out by trained coders to measure the independent variables. Despite the effort to minimise biased coding, some degree of subjectivity is still inevitable. Inspired by extant studies adopting computer-aided text analysis to measure exploration and exploitation (e.g. Jancenelle, 2020), we recommend that future researchers attempt to advance our method of quantifying firms' different implementations of blockchain by improving objectivity in this manner.

5.4 Conclusion

In conclusion, blockchain initiatives can help firms reduce costs, shorten process time, eliminate the risks associated with human error and so on. Therefore, blockchain can provide firms with the opportunity to improve operational efficiency. Grounded in organisational ambidexterity, this study theorised and empirically tested the role of blockchain in improving operational efficiency and how the promotion effect was moderated by organisational and environmental contingencies. The empirical analysis shows that both complementary and balanced blockchain initiatives enable firms to be operationally efficient. In addition, the effect of balanced blockchain initiatives is contingent: it contributes to higher operational efficiency when firms operate with less unabsorbed slack or in more munificent environments. These findings provide a theoretical understanding of the benefits of blockchain from the perspective of organisational ambidexterity. This study also provides insights for manufacturing firms regarding how to promote operational efficiency via complementary and balanced blockchain initiatives as well as how to flexibly adjust their emphasis on ErBI and EtBI in light of their organisational characteristics and industry environments.

References

Al-Jaroodi, J. and Mohamed, N. (2019), "Blockchain in industries: A survey", *IEEE Access*, Vol.7, pp.6500-36515.

Ben-Jebara, M. and Modi, S.B. (2021), "Product personalization and firm performance: An empirical analysis of the pharmaceutical industry", *Journal of Operations Management*, Vol.67 No.1, pp.82-104.

Benzidia, S., Makaoui, N. and Subramanian, N. (2021), "Impact of ambidexterity of blockchain technology and social factors on new product development: A supply chain and Industry 4.0 perspective", *Technological Forecasting and Social Change*, Vol.169, p.120819.

Bloom, M. and Michel, J.G. (2002), "The relationships among organizational context, pay dispersion, and among managerial turnover", *Academy of Management Journal*, Vol.45 No.1, pp.33-42.

Cao, Q., Gedajlovic, E. and Zhang, H. (2009), "Unpacking organizational ambidexterity: Dimensions, contingencies, and synergistic effects", *Organization Science*, Vol.20 No.4, pp.781-796.

Cearley, D. and Burke, B. (2018), "Top 10 Strategic Technology Trends for 2019", available at: https://www.gartner.com/en/doc/3891569-top-10-strategic-technology-trends-for-2019 (accessed 3 August 2021)

Chen, W., He, K. and Wang, L. (2021), "Blockchain technology, macroeconomic uncertainty and investment efficiency", *International Journal of Emerging Markets*, Vol. ahead-of-print, doi:10.1108/IJOEM-10-2020-1250.

Choi, Y., Cui, L., Li, Y. and Tian, X. (2020), "Focused and ambidextrous catch-up strategies of emerging economy multinationals", *International Business Review*, Vol.29 No.6, p.101567.

Clohessy, T. and Acton, T. (2019), "Investigating the influence of organizational factors on blockchain adoption: An innovation theory perspective", *Industrial Management & Data Systems*, Vol.119 No.7, pp.1457-1491.

Dess, G.G. and Beard, D.W. (1984), "Dimensions of organizational task environments", *Administrative science quarterly*, Vol.29 No.1, pp.52-73.

Dolz, C., Iborra, M. and Safón, V. (2019), "Improving the likelihood of SME survival during financial and economic crises: The importance of TMTs and family ownership for ambidexterity", *BRQ Business Research Quarterly* 22 No.2, pp.119-136. doi:10.1016/j.brq.2018.09.004.

Fong, E.A., Misangyi, V.F. and Tosi, H.L. (2010), "The effect of CEO pay deviations on CEO withdrawal, firm size, and firm profits", *Strategic Management Journal*, Vol.31 No.6, pp.629-651.

Gatti, C., Volpe, L. and Vagnani, G. (2015), "Interdependence among productive activities: Implications for exploration and exploitation", *Journal of Business Research* Vol.68 No.3, pp.711-722.

Gedajlovic, E., Cao, Q. and Zhang, H. (2012), "Corporate shareholdings and organizational ambidexterity in high-tech SMEs: Evidence from a transitional economy", *Journal of Business Venturing*, Vol.27 No.6, pp.652-665.

Geerts, A., Leten, B., Belderbos, R. and Looy, B. (2018), "Does spatial ambidexterity pay off? On the benefits of geographic proximity between technology exploitation and exploration", *Journal of Product Innovation Management*, Vol.35 No.2, pp.151-163.

Goll, I. and Rasheed, A.A. (2005), "The relationships between top management demographic characteristics, rational decision making, environmental munificence, and firm performance", *Organization studies*, Vol.26 No.7, pp.999-1023.

Gu, M., Yang, L. and Huo, B. (2021), "The impact of information technology usage on supply chain resilience and performance: An ambidexterous view", *International Journal of Production Economics*. Vol. ahead-of-print, doi:10.1016/j.ijpe.2020.107956.

Hasan, M. R., Deng, S.M., Islam, M.A. and Hossain, M.Z. (2020), "Operational efficiency effects of blockchain technology implementation in firms: evidence from China", *Review of International Business and Strategy*, Vol.30 No.2, pp.163-181.

He, Z. L. and Wong, P.K. (2004), "Exploration vs. exploitation: An empirical test of the ambidexterity hypothesis", *Organization science*, Vol.15 No.4, pp.481-494.

Heeley, M.B., King, D.R. and Covin, J.G. (2006), "Effects of firm R&D investment and environment on acquisition likelihood", *Journal of Management Studies*, Vol.43 No.7, pp.1513-1535.

Hoang, H. A. and Rothaermel, F.T. (2010), "Leveraging internal and external experience: exploration, exploitation, and R&D project performance", *Strategic management journal*, Vol.31 No.7, pp.734-758.

Iyer, D.N. and Miller, K.D. (2008), "Performance feedback, slack, and the timing of acquisitions", *Academy of Management Journal*, Vol.51 No.4, pp.808-822.

Jabbar, A. and Dani, S. (2020), "Investigating the link between transaction and computational costs in a blockchain environment", *International Journal of Production Research*, Vol.58 No.11, pp.3423-3436.

Jacobs, B.W., Swink, M. and Linderman, K. (2015), "Performance effects of early and late Six Sigma adoptions", *Journal of Operations Management*, Vol.36, pp.244-257.

Jancenelle, V. E. (2020), "Relative exploration and firm performance: Exploring curvilinear relationships and the role of industry, instability, and munificence", *Long Range Planning*, Vol.53 No.6, p.101926.

Jin, X., Wang, J., Chen, S. and Wang, T. (2015), "A study of the relationship between the knowledge base and the innovation performance under the organizational slack regulating", *Management Decision*, Vol.53 No.10, pp.2202-2225.

Kang, J. and Kim, S.J. (2020), "Performance implications of incremental transition and discontinuous jump between exploration and exploitation", *Strategic Management Journal*, Vol.41 No.6, pp.1083-1111.

Karakas, S., Acar, A.Z. and Kucukaltan, B. (2021), "Blockchain adoption in logistics and supply chain: a literature review and research agenda", *International Journal of Production Research*. Vol. ahead-of-print, doi:10.1080/00207543.2021.2012613.

Khan, M.A. and Salah, K. (2018), "IoT security: Review, blockchain solutions, and open challenges", *Future Generation Computer Systems*, Vol.82, pp.395-411.

Kortmann, S., Gelhard, C., Zimmermann, C. and Piller, F.T. (2014), "Linking strategic flexibility and operational efficiency: The mediating role of ambidextrous operational capabilities", *Journal of Operations Management*, Vol.32 No.7-8, pp.475-490.

Kotha, R., Zheng, Y. and George, G. (2011), "Entry into new niches: The effects of firm age and the expansion of technological capabilities on innovative output and impact", *Strategic Management Journal*, Vol.32 No.9, pp.1011-1024.

Kuo, C.C. and Shyu, J.Z. (2021), "A Cross-National Comparative Policy Analysis of the Blockchain Technology between the USA and China", *Sustainability*, Vol.13 No.12, pp.6893.

Lam, H.K. (2018), "Doing good across organizational boundaries: Sustainable supply chain practices and firms's financial risk", *International Journal of Operations & Production Management*, Vol.38 No.12, pp.2389-2412.

Lam, H.K., Yeung, A.C. and Cheng, T.E. (2016) "The impact of firms' social media initiatives on operational efficiency and innovativeness", *Journal of Operations Management*, Vol.47, pp.28-43.

Lavie, D., Stettner, U. and Tushman, M.L. (2010), "Exploration and exploitation within and across organizations", *Academy of Management annals*, Vol.4 No.1, pp.109-155.

Lee, C.Y. and Huang, Y.C. (2012), "Knowledge stock, ambidextrous learning, and firm performance", *Management Decision*, Vol.50 No.6, pp.1096-1116.

Lee, J.Y., Yang, Y.S. and Park, B.I. (2020), "Interplay between dual dimensions of knowledge sharing within globalized chaebols: The moderating effects of organization size and global environmental munificence", *International Business Review*, Vol.29 No.6, pp.101637.

Levinthal, D.A. and March, J.G. (1993), "The myopia of learning", *Strategic management journal*, Vol.14 No.S2, pp.95-112.

Li, S., Shang, J., and Slaughter, S.A. (2010), "Why do software firms fail? Capabilities, competitive actions, and firm survival in the software industry from 1995 to 2007", *Information Systems Research*, Vol.21 No.3, pp.631-654.

Li, Y., Wei, Z., Zhao, J., Zhang, C. and Liu, Y. (2013), "Ambidextrous organizational learning, environmental munificence and new product performance: Moderating effect of managerial ties in China", *International Journal of Production Economics*, Vol.146 No.1, pp.95-105.

Liu, W., Wei, W., Si, C., Xie, D. and Chen, L. (2020), "Effect of supply chain strategic collaboration announcements on shareholder value: an empirical investigation from China", *International Journal of Operations & Production Management*, Vol.40 No.4, pp.389-414.

Lohmer, J. and Lasch, R. (2020), "Blockchain in operations management and manufacturing: Potential and barriers", *Computers & Industrial Engineering*, Vol. ahead-of-print, doi:10.1016/j.cie.2020.106789.

Luger, J., Raisch, S. and Schimmer, M. (2018), "Dynamic balancing of exploration and exploitation: The contingent benefits of ambidexterity", *Organization Science*, Vol.29 No.3, pp.449-470.

Luo, B., Luo, C., Ge, J. and Zhang, D. (2016), "The moderating effects of slack on the relationship between ambidextrous strategy and performance: evidence from high-tech firms in China", *Journal of Business Economics and Management*, Vol.17 No.5, pp.734-748.

March, J.G. (1991), "Exploration and exploitation in organizational learning", *Organization science*, Vol.2 No.1, pp.71-87.

McDermott, C.M. and Prajogo, D.I. (2012), "Service innovation and performance in SMEs", *International Journal of Operations & Production Management* , Vol.32 No.2, pp.216-237.

Melander, L. (2018), "Improving green product innovation through collaboration", *IEEE Engineering Management Review*, Vol.46 No.2, pp.133-137.

Moss, T.W., Payne, G.T. and Moore, C.B. (2014), "Strategic consistency of exploration and exploitation in family businesses", *Family Business Review*, Vol.27 No.1, pp.51-71.

Nandi, S., Sarkis, J., Hervani, A. and Helms, M. (2021), "Do blockchain and circular economy practices improve post COVID-19 supply chains? A resource-based and resource dependence perspective", *Industrial Management & Data Systems*, Vol.121 No.2, pp.333-363.

Nohria, N. and Gulati, R. (1996), "Is slack good or bad for innovation?", *Academy of management Journal*, Vol.39 No.5, pp.1245-1264.

Pan, X., Chen, X. and Ning, L. (2018), "Exploitative technological diversification, environmental contexts, and firm performance", *Management Decision*, Vol.56 No.7, pp.1613-1629.

Pan, X., Pan, X., Song, M., Ai, B. and Ming, Y. (2020), "Blockchain technology and enterprise operational capabilities: An empirical test", *International Journal of Information Management*, Vol.ahead-of-print, doi:10.1016/j.ijinfomgt.2019.05.002.

PwC. (2019), "How can blockchain power industrial manufacturing?", available at: http://pwc.com/us/en/industries/industrial-products/library/blockchain-industrial-manufacturing.html (accessed August 5 2021)

Queiroz, M. M. and Wamba, S.F. (2019), "Blockchain adoption challenges in supply chain: An empirical investigation of the main drivers in India and the USA", *International Journal of Information Management*, Vol.46, pp.70-82.

Queiroz, M.M., Telles, R. and Bonilla, S.H. (2019), "Blockchain and supply chain management integration: a systematic review of the literature", *Supply Chain Management: An International Journal*, Vol.25 No.2, pp.241-254.

Rossi, M. Mueller-Bloch,C., Thatcher, J.B. and Beck, R. (2019), "Blockchain research in information systems: Current trends and an inclusive future research agenda", *Journal of the Association for Information Systems*, Vol.20 No.9, pp.1390-1405.

Tai, J.C., Wang, E.T. and Yeh, H.Y. (2019), "A study of IS assets, IS ambidexterity, and IS alignment: the dynamic managerial capability perspective", *Information & Management*, Vol.56 No.1, pp.55-69.

Tangpong, C. (2011), "Content analytic approach to measuring constructs in operations and supply chain management", *Journal of Operations Management*, Vol.29 No.6, pp.627-638.

Tushman, M.L. and O'Reilly III, C.A. (1996), "Ambidextrous organizations: Managing evolutionary and revolutionary change", *California management review*, Vol.38 No.4, pp.8-29.

Uotila, J., Maula, M., Keil, T. and Zahra, S.A. (2009), "Exploration, exploitation, and financial performance: analysis of S&P 500 corporations", *Strategic Management Journal*, Vol.30 No.2, pp.221-231.

Vitari, C. and Raguseo, E. (2020), "Big data analytics business value and firm performance: linking with environmental context", *International Journal of Production Research*, Vol.58 No.18, pp.5456-5476.

Wang, Y., Wang, X. and Xu, W. (2021), "How does negative performance feedback affect a firm's openness in its innovation search behaviour? The moderating role of organisational slack", *Technology Analysis & Strategic Management*, Vol. ahead-of-print, doi:10.1080/09537325.2021.1976405.

Wong, C.W., Wong, C.Y. and Boonitt, S. (2013), "The combined effects of internal and external supply chain integration on product innovation", *International Journal of Production Economics*, Vol.146 No.2, pp.566-574.

Wu, H. and Liu, Y. (2018), "Balancing local and international knowledge search for internationalization of emerging economy multinationals: Evidence from China", *Chinese Management Studies*, Vol.12 No.4, pp.701-719.

Xiong, Y., Lam, H.K., Kumar, A., Ngai, E., Xiu, C. and Wang, X. (2021), "The mitigating role of blockchain-enabled supply chains during the COVID-19 pandemic", *International Journal of Operations & Production Management*, Vol.41 No.9, pp.1495-1521.

Zhu, S., Dong, T. and Luo, X. (2021), "A longitudinal study of the actual value of big data and analytics: the role of industry environment", *International Journal of Information Management*, Vol. ahead-of-print, doi:10.1016/j.ijinfomgt.2021.102389

Table 1. Descriptive statistics of 141 manufacturing firms

Panel A: Distribution of blockchain initiatives by year		
Year	Number of blockchain Initiatives	Percentage
2015	4	0.795%
2016	21	4.175%
2017	47	9.344%
2018	89	17.694%
2019	147	29.225%
2020	195	38.767%

Panel B: Distribution of firms across industries			
CSRC codes	Industries	Firms	Percentage
C39	Manufacturing of computers, communications and other electronic equipment	35	24.823%
C38	Electric machinery and equipment manufacturing	20	14.184%
C35	Special-purpose equipment manufacturing	13	9.220%
C26	Manufacturing of chemical raw materials and chemical products	11	7.801%
C34	General equipment manufacturing	9	6.383%
C18	Textile garment and apparel industry	8	5.674%
C22	Papermaking and paper product industry	6	4.255%
C29	Industry of rubber and plastic products	6	4.255%
C40	Instrument and meter manufacturing	5	3.546%
C15	Alcohol, beverage and refined tea manufacturing	4	2.837%
Other codes	Other industries	24	17.021%

Panel C: Characteristics of firms					
Variable	Unit	Mean	Standard deviation	Minimum	Maximum
Sales	Millions	12052.387	44061.962	155.322	408697.219
Total assets	Millions	16186.671	43748.110	382.652	301955.406
Number of employees	Thousands	7.219	21.606	0.118	209.671
Age	Years	19.035	4.939	4.000	39.000

Table 2. Variable descriptions

Variable name	Measurement	Data source	Reference
EtBI/ErBI	Identify and code a firm's blockchain initiative based on its announcement	Announcements	Developed
Ambidextrous blockchain initiative			
Complementary	Interaction: EtBI×ErBI	Announcements	Wong, Wong, and Boonitt (2013)
Balanced	Absolute difference (reversed): 3-|ErBI − EtBI|		
Operational efficiency	Technical efficiency calculated using stochastic frontier estimation	CSMAR	Li *et al.* (2010)
Munificence	Slope coefficient generated by regressing sales over 10-year time period/mean sales in same time period	CSMAR	Goll and Rasheed (2005), Jacobs, Swink, and Linderman (2015)
Unabsorbed slack	Current ratio	CSMAR	Iyer and Miller (2008)
Firm size	Natural logarithm of a firm's sales	CSMAR	Lee and Huang (2012)
Firm profitability	ROA	CSMAR	Fong, Misangyi and Tosi (2010)
Firm age	Number of years since incorporation	CSMAR	Kotha, Zheng, and George (2011)
Firm cash-to-cash cycle	Days of inventory + days of accounts receivables − days of accounts payables	CSMAR	Lam (2018)

Table 3. Examples of EtBI and ErBI

Company name	Text extracted from official announcements	Blockchain initiative type
China High-Speed Railway Technology	The firm's professional maintenance and inspection will be upgraded using blockchain to efficiently collect multi-dimensional comprehensive data on maintenance and inspection.	Exploitative
STEP	The firm further improved and upgraded its elevator control system manufacturing plant. Binding the elevator computer accessories to the original elevator manufacturer through a blockchain encryption algorithm.	
Julong	The firm upgraded for its serial number management system. Superimposing blockchain to launch an RMB circulation management solution, which enables parallel triggers and immutability.	
Linyang	Linyang continues to innovate product solutions based on blockchain. It completed the verification test of blockchain smart meters, which can be subsequently applied to power energy spot transactions.	Exploratory
Tellhow Sci-Tec	The firm developed the first Chinese blockchain-based power spot trading technical support system and became the core system supplier for power grid firms' power transactions.	
AISINO	AISINO completed the research and development of the electronic invoice system based on the full life cycle of the blockchain, and output 8 blockchain tax-related application solutions.	

*Note: The text in our examples was translated from Chinese to English. To provide useful examples, we paraphrased text from the announcements rather than quoting them directly, as the quotes are generally too long and difficult to understand out of context.

Table 4. Correlations and statistics of examined variables

Variables	1	2	3	4	5	6	7	8	9	10	11
1. Operational efficiency	1										
2. Complementary blockchain initiative	0.042	1									
3. Balanced blockchain initiative	0.073	-0.122**	1								
4. Exploitative blockchain initiative	-0.120**	0.487***	-0.346***	1							
5. Exploratory blockchain initiative	0.007	0.460***	-0.862***	0.318***	1						
6. Munificence	0.050	-0.058	0.099**	0.016	-0.108**	1					
7. Unabsorbed slack	0.019	0.040	0.024	-0.010	0.006	0.052	1				
8. Firm age	0.039	-0.038	0.007	-0.073	-0.023	0.039	-0.123**	1			
9. Firm size	0.197***	0.027	-0.049	-0.01	0.079	-0.129**	-0.283***	0.172***	1		
10. Firm profitability	0.396***	-0.135***	0.198***	-0.145***	-0.147***	0.065	0.077	-0.048	0.132***	1	
11. Firm cash-to-cash cycle	-0.088*	0.029	-0.049	0.0240	0.067	0.013	-0.112**	0.050	0.197***	-0.000	1
Mean	0.425	0.037	2.813	0.061	0.187	0.153	2.469	16.5	21.53	0.033	-0.032
Standard deviation	0.158	0.256	0.445	0.239	0.484	0.047	3.472	4.803	1.530	0.072	1.097

Notes: *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$ (two-tailed tests)

Table 5. Impact of ambidextrous blockchain initiatives on operational efficiency

Variable	Model (1)	Model (2)	Model (3)
Complementary blockchain initiative		0.087***	
		(3.199)	
Balanced blockchain initiative			0.057**
			(2.113)
Exploitative blockchain initiative		-0.076**	-0.034
		(-2.607)	(-1.144)
Exploratory blockchain initiative		0.018	0.077***
		(0.922)	(2.960)
Firm age	0.001	0.001	0.001
	(0.581)	(0.584)	(0.632)
Firm size	0.019**	0.017**	0.018**
	(2.346)	(2.232)	(2.235)
Firm profitability	0.807***	0.834***	0.797***
	(4.579)	(4.860)	(4.641)
Firm cash-to-cash cycle	-0.018***	-0.018***	-0.019***
	(-3.052)	(-3.083)	(-3.152)
Year dummies	Included	Included	Included
Cons	-0.022	-0.007	-0.176
	(-0.128)	(-0.040)	(-0.987)
N	395	395	395
Adjusted R^2	0.185	0.202	0.196
F	4.786	5.352	5.424

Notes: *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$ (two-tailed tests); *t*-statistics in parentheses; all independent variables and control variables one-year lagged.

Table 6. Moderating effect of unabsorbed slack

Variable	Model (4)	Model (5)	Model (6)	Model (7)
Complementary blockchain initiative	0.086***	0.085***		
	(3.116)	(3.161)		
Balanced blockchain initiative			0.057**	0.031
			(2.079)	(1.102)
Unabsorbed slack	0.001	0.001	0.001	0.013**
	(0.212)	(0.246)	(0.248)	(2.380)
Complementary blockchain initiative × unabsorbed slack		0.006		
		(0.657)		
Balanced blockchain initiative × unabsorbed slack				-0.027**
				(-2.550)
Exploitative blockchain initiative	-0.076**	-0.079**	-0.034	-0.035
	(-2.587)	(-2.546)	(-1.141)	(-1.362)
Exploratory blockchain initiative	0.018	0.017	0.076***	0.058**
	(0.919)	(0.875)	(2.928)	(2.209)
Firm age	0.001	0.001	0.001	0.001
	(0.602)	(0.564)	(0.653)	(0.476)
Firm size	0.018**	0.018**	0.018**	0.020**
	(2.173)	(2.186)	(2.187)	(2.405)
Firm profitability	0.829***	0.823***	0.791***	0.768***
	(4.747)	(4.673)	(4.551)	(4.555)
Firm cash-to-cash cycle	-0.018***	-0.018***	-0.019***	-0.017***
	(-3.106)	(-3.076)	(-3.173)	(-2.944)
Year dummies	Included	Included	Included	Included
Cons	-0.020	-0.017	-0.189	-0.055
	(-0.109)	(-0.093)	(-1.007)	(-0.315)
N	395	395	395	395
Adjusted R^2	0.200	0.199	0.194	0.204
F	4.914	4.760	4.986	5.796

Notes: $*p < 0.1$, $**p < 0.05$, $***p < 0.01$ (two-tailed tests); *t*-statistics in parentheses; all independent variables and control variables one-year lagged.

Table 7. Moderating effect of environmental munificence

Variable	Model (8)	Model (9)	Model (10)	Model (11)
Complementary blockchain initiative	0.090***	0.076**		
	(3.289)	(2.382)		
Balanced blockchain initiative			0.058**	0.051*
			(2.094)	(1.816)
Munificence	0.212	0.210	0.183	-0.108
	(1.045)	(1.041)	(0.883)	(-0.407)
Complementary blockchain initiative × munificence		-0.386		
		(-1.171)		
Balanced blockchain initiative × munificence				0.853**
				(1.985)
Exploitative blockchain initiative	-0.083***	-0.078**	-0.038	-0.030
	(-2.774)	(-2.556)	(-1.218)	(-0.945)
Exploratory blockchain initiative	0.018	0.017	0.078***	0.059**
	(0.919)	(0.857)	(2.923)	(2.021)
Firm age	0.001	0.001	0.001	0.001
	(0.465)	(0.434)	(0.530)	(0.571)
Firm size	0.018**	0.018**	0.018**	0.019**
	(2.286)	(2.291)	(2.278)	(2.395)
Firm profitability	0.827***	0.842***	0.790***	0.821***
	(4.820)	(4.651)	(4.587)	(4.615)
Firm cash-to-cash cycle	-0.019***	-0.018***	-0.019***	-0.019***
	(-3.106)	(-3.078)	(-3.169)	(-3.170)
Year dummies	Included	Included	Included	Included
Cons	-0.055	-0.021	-0.218	-0.069
	(-0.309)	(-0.119)	(-1.177)	(-0.398)
N	395	395	395	395
Adjusted R^2	0.203	0.202	0.196	0.203
F	5.277	5.065	5.270	4.458

Notes: *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$ (two-tailed tests); *t*-statistics in parentheses; all independent variables and control variables one-year lagged.

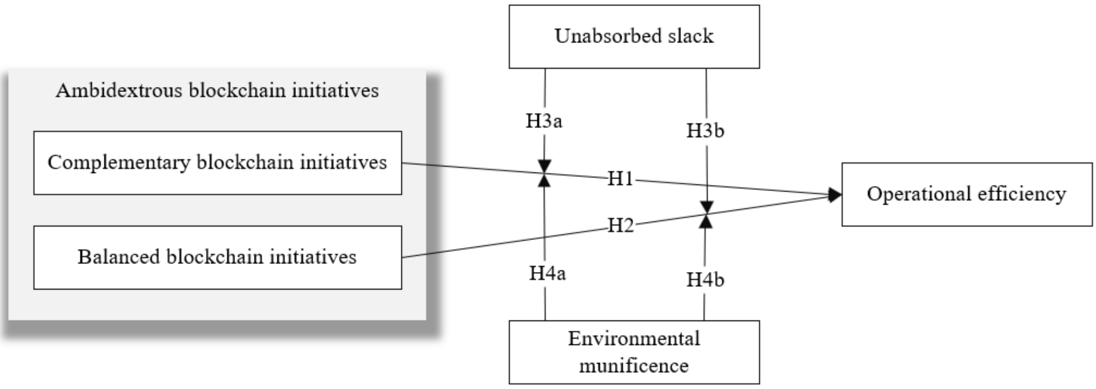

Figure 1. Conceptual framework

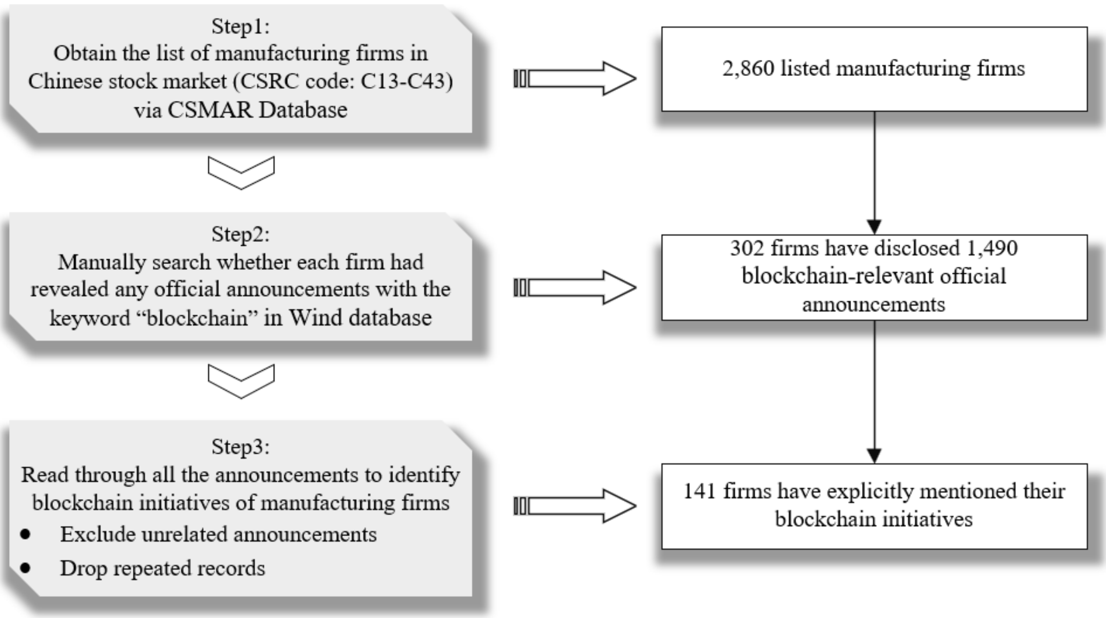

Figure 2. Data collection process

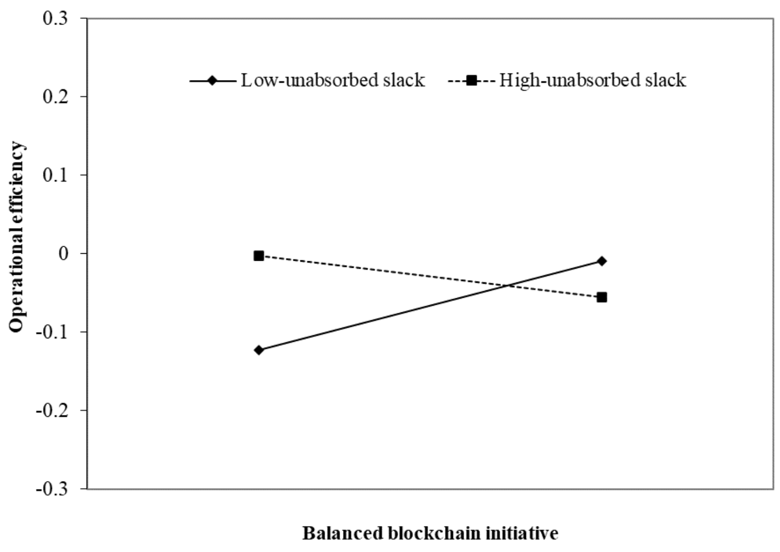

Figure 3. Simple slope analysis of unabsorbed slack

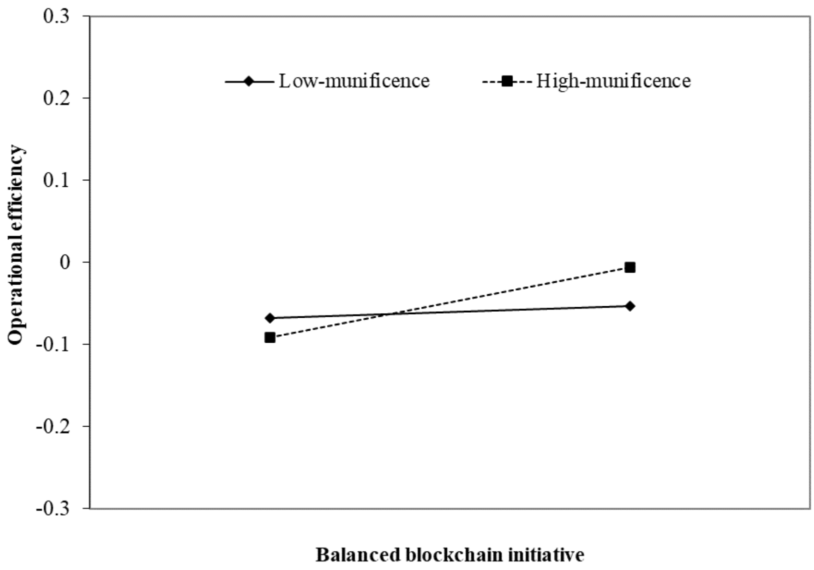

Figure 4. Simple slope analysis of environmental munificence