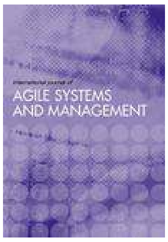

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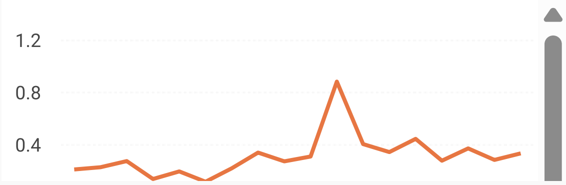
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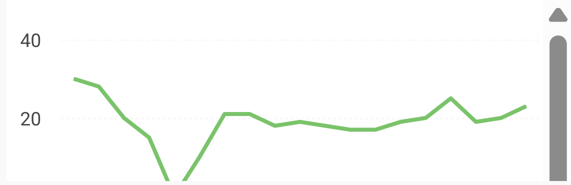
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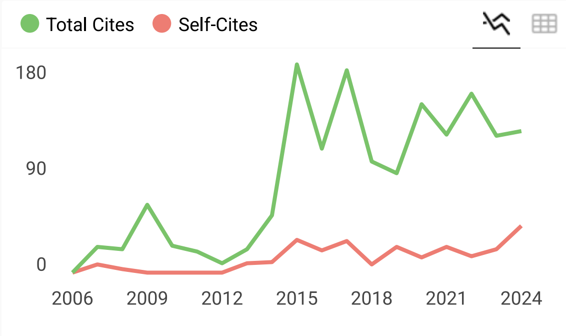
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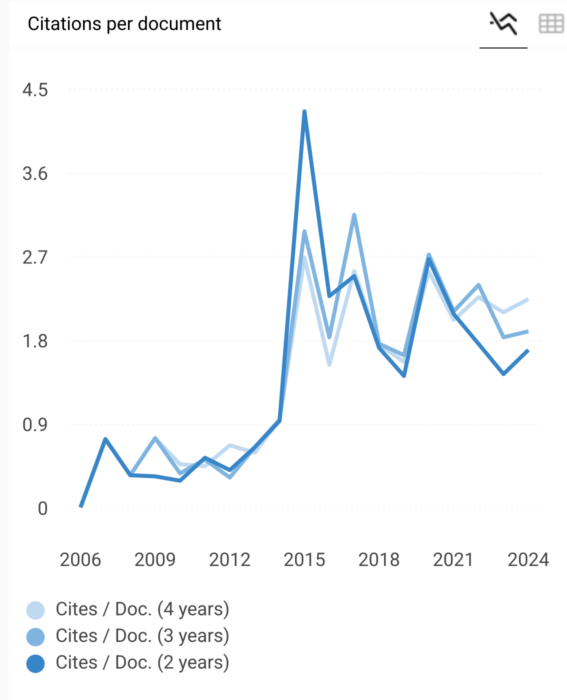
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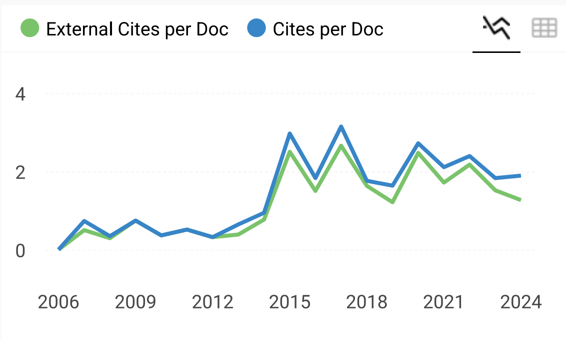
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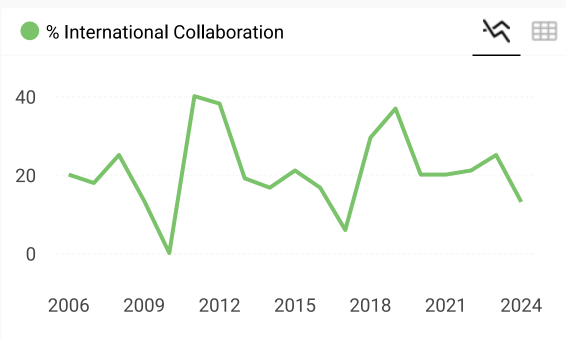
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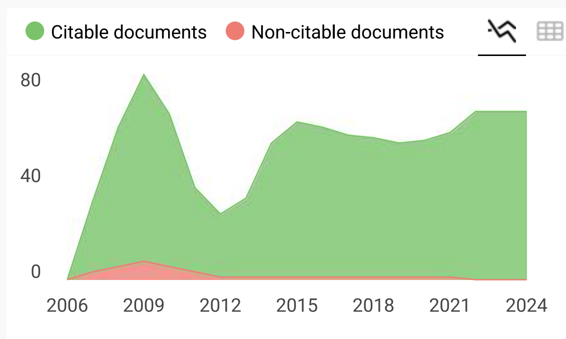
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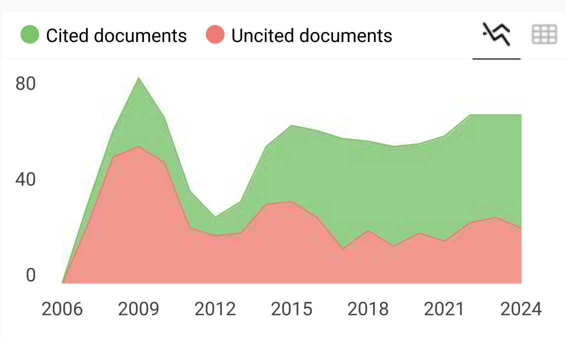
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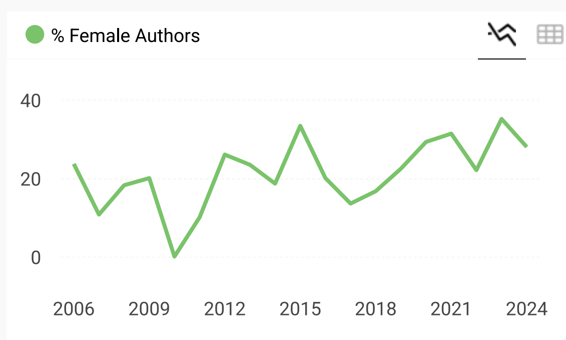
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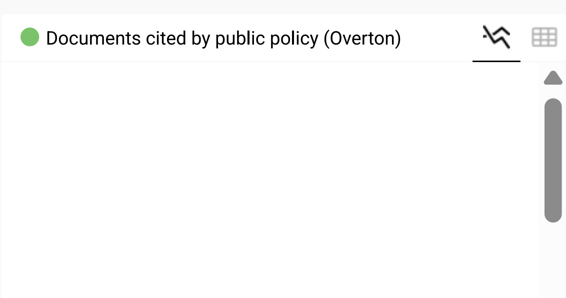
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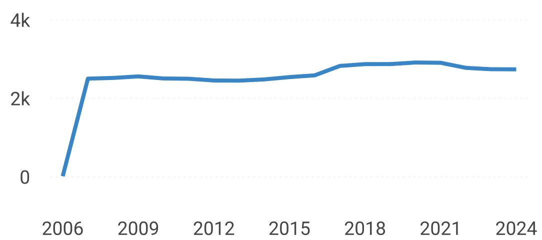

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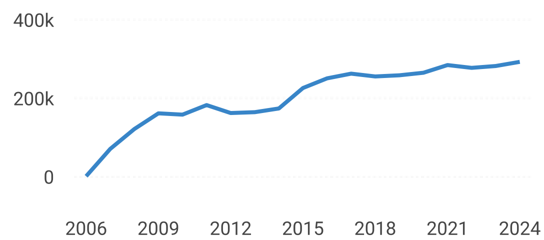

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The moderating role of blockchain technology in ESG disclosure and operational efficiency: evidence from the banking sector in ASEAN and European stock market

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Abstract: This paper aims to examine further how blockchain technology (BT) and environmental, social, and governance disclosure (ESGD) may be able to affect operational efficiency (OE). Additionally, examines BT as a moderating variable between ESGD and operational efficiency in the banking industry. The results revealed that BT positively affects OE. Moreover, one ESG pillar, governance (GOV) has a significant influence on OE. In terms of the moderation effects of BT, this paper shows that BT could moderate the relationship between social (SOC) and governance (GOV) on OE. The applications of BT have proven to benefit firms in information transparency, financial performance, and stability, hence creating operational efficiency. This paper contributes to the roles of BT, whether as an independent or as a moderating variable that could strengthen the relationship between ESGD and OE. The research also aligns with UN sustainability development goals (SDG) numbers 9 and 12.

Keywords: blockchain technology; ESGD; environmental, social, and governance disclosure; operational efficiency; ASEAN stock exchange; European stock exchange.

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Edward Christopher Kudrati is a Petra Christian University graduate majoring in international business accounting (IBAcc). During his studies, he obtained a Diploma in Accounting and Business from ACCA and completed CMA examinations. Currently, he works at Philip Morris Indonesia an affiliate of Philip Morris International as an Account Receivable Analyst.

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1 Introduction

In recent years, digital technology advancement has become more apparent. In the post-pandemic era, many firms started digitalising some of their business activities to simplify some business processes. Furthermore, some technology, such as blockchain, has proven to improve firm performance and reduce business risks (Almaqtari et al., 2022; Simmers et al., 2022). Blockchain technology has been closely examined in the past few years, mainly due to blockchain's disruptive nature, which may change how businesses run in the future. The emergence of blockchain technology brought several controversies in many business sectors, including energy (Chacra et al., 2021), healthcare (Nicolai et al., 2022), as well as the financial sector (Yoo, 2017). This entails that blockchain technology is an exciting topic to be studied further. Although there are lots of studies trying to define blockchain, in general, blockchain is a decentralised distributed ledger in the form of a block that contains transactions, information, or data in which each block will be linked to another block to create a series of chains (Oh and Shong, 2017). Blockchain promotes an immutable transaction process that cannot be altered to assure the credibility and auditability of a transaction (Martínez-Ríos et al., 2020). Moreover, by implementing blockchain technology, firms could improve their transparency, which will be the primary concern of this paper.

Apart from blockchain, ESGD has also been the focus for some businesses and scholars during and post-pandemic era. Prior papers have associated ESGD with corporate social responsibility or widely known as CSR. While CSR indicates a firm's strategy, ESGD provides quantitative data to reflect the firm's performance for investors. Accordingly, most papers use ESGD and CSR interchangeably (Gillan et al., 2021; Chang et al., 2022; He et al., 2022). However, as managers can disclose or conceal information about the firm's social performance, investors should be more sceptical of firms with high ESG scores. This indicates that the ESGD score does not reflect the actual firm's performance as the scores rely on information disclosed by the firms, implying that information asymmetry could change the firm's overall scores (Minutolo et al., 2019).

Alongside ESGD, operational efficiency is also often associated with managerial capability. Operational efficiency explains the management's ability to allocate resources effectively and reduce waste while still maintaining the quality of the goods or services given. In the past few years, scholars have argued that operational efficiency can explain long-term performance better than traditional performance measurements such as return on assets (ROA) and return on equity (ROE) (Aroul et al., 2022). Since then, operational efficiency has been used in many papers as one of the performance measurements. Recently, studies suggested that firms' efficiency could be enhanced through blockchain technology. Blockchain technology could reduce information asymmetry and improve efficiency in the supply chain (Hasan et al., 2020). Additionally, this technology can improve the supply chain to become more efficient while maintaining or even enhancing the products or services quality, resulting in higher operational efficiency (Macaulay, 2017). As blockchain technology progresses, many scholars argue that the banking sector could either benefit from or be disrupted by blockchain technology (Osmani et al., 2020). However, in recent years banks have started integrating some of their business activities using blockchain technology such as trade financing, to accommodate international or cross-border transactions, hence, this indicates that blockchain technology is beneficial for banks.

This paper is on the financial sector, mainly the banking sector from the largest ASEAN stock markets, which are IDX, KLSE, SGX, and SET and the European stock markets which are LSE, BME, and EURONEXT. Although, in ASEAN countries, the idea of incorporating blockchain in the banking sector is still minimal. This research uses high market-cap European banks as the benchmark for blockchain-based bank operations since they are more technologically advanced than ASEAN countries' banks. Aside from blockchain technology, banks should also concern with operational efficiency as banks' operations mostly mainly of receiving and lending money, in other words, credit operations (Nguyen et al., 2018). Consequently, this paper analyses how blockchain technology could improve operational efficiency in the banking sector. Following previous papers, this study uses three control variables which are firm size, leverage, and firm age (Hasan et al., 2020; Ezzi et al., 2022).

Prior studies on this topic have examined the correlation between blockchain technology to ESGD/CSR (Martínez-Ríos et al., 2020; Rainero and Modarelli, 2021) and blockchain technology to operational efficiency (Hasan et al., 2020) separately. Additionally, previous studies have not considered blockchain technology as a moderating variable. Instead, blockchain technology is often used only as an independent variable. Even though most papers have stated that blockchain technology contributes to lowering information asymmetry, which would elevate firms' efficiency. In response, this study directly analyses the relationship between blockchain technology and operational efficiency. Besides that, on the other hand, this paper also tested the moderation effect of blockchain technology in strengthening or weakening the relationship of ESGD towards operational efficiency.

2 Methods

2.1 Transaction cost theory

Transaction cost theory has been widely examined in the past to determine how governance structure could reduce costs within the firm and the market (Schmidt and Wagner, 2019). Initially, this theory aims to analyse the cost of transactions that emerged from exchanging information, goods, or services within and outside the firm. Researchers have incorporated technology into the transaction cost theory as technology becomes more advanced. Moreover, since the adoption of the peer-to-peer platform, the focus of transaction cost theory has shifted toward transactions made by individuals rather than firms (Eckhardt et al., 2019; Rindfleisch, 2019). Nevertheless, opportunistic activities have seen to declined significantly in several firms due to transparency brought about by technology (Grassi et al., 2022).

2.2 Stakeholder theory

Stakeholder theory ensures that firms consider the expectations and interests of stakeholders. Essentially, stakeholder theory focuses on stakeholders as its main problems. According to Freeman, as mentioned by Jones et al. (2017), stakeholders are individuals or groups affected by firms' decisions or actions. Furthermore, under stakeholder theory, firms may use CSR programs to improve financial performance by reducing costs and gaining more profit (Naseem et al., 2019). Hence, this would help firms to manage their resources more efficiently.

2.3 Agency theory

Agency theory has been mentioned and analysed in many kinds of literature on CSR and ESGD topics. Agency theory illustrates the conflict of interest between the principal (the owner) and the agent (managers or directors) (Jeriji and Louhichi, 2020). The difference in interest between the two parties will raise an agency problem. To prevent or mitigate the agency problem, the principal will allocate a sum of resources to monitor and supervise the agent's activities which we call an agency cost (Vitolla et al., 2019; Tarigan et al., 2022). Theoretically, agency costs could be minimised by having a good CSR or better ESGD. However, some scholars argue that poor management could over-invest the CSR activity, which will incur additional expenses (Bhandari and Javakhadze, 2017; Liu and Tian, 2019).

2.4 Operational efficiency

Operational efficiency explains how management allocates its resources in an optimised way to reduce costs while maintaining the same or even better quality of goods and services. Hence, studies suggest operational efficiency as a tool to measure both short-term and long-term profitability (Aroul et al., 2022). Operational efficiency is undeniably significant in the banking sector. Some studies considered loans fundamental to banks' operational efficiency (Iosifidi et al., 2021). Higher loan demand will increase banks' economies of scale, which makes banks more efficient. This is in congruence with Allen and Rai's research in 1996, that proven better economies of scale can improve operational efficiency (Aroul et al., 2022). On the contrary, lower loan demand can affect banks to be inefficient, meaning that exogenous factors easily influence banks' efficiency. Nonetheless, management quality should also be the focus to achieve efficiency. Managers should have the potential to reallocate resources or transform resources to increase efficiency, hence managers could stabilise demands for loans in the market. Operational efficiency in the banking sector could also be achieved through cost efficiency, which is part of managerial ability and quality (Delis et al., 2019; Otero et al., 2020).

Past studies on operational efficiency mostly used the stochastic frontier approach (SFA) to measure operational efficiency (Gupta and Raman, 2020; Venkadasalam et al., 2020). Alongside SFA measurement, data envelopment analysis (DEA) introduced by Demerjian et al. has also been used to estimate operational efficiency in prior research (Khan et al., 2022). Similarly, this study will follow the DEA method to calculate operational efficiency.

$$max_v \theta = \frac{Interest\ Income}{v_1 PPE + v_2 SG\&A + v_3 R\&D + v_4 OtherIntan + v_5 Goodwill} \tag{1}$$

Each variable will be extracted from the firm's annual report, financial statements, and other trusted resources. As for firms that do not disclose R&D and SG&A expenses specifically, this study will assume non-interest and other operating expenses as equivalent to SG&A plus R&D expenses (Shu and Strassmann, 2005).

2.5 Blockchain technology

Research on blockchain technology has gained popularity in the past few years. Satoshi Nakamoto first developed blockchain technology in 2008, which provides a decentralised distributed ledger that is available to the public. At first, blockchain technology was invented as the backbone for Bitcoin or cryptocurrency databases. However, due to its functionalities, blockchain technology has been used in various sectors and concepts (Romano and Schmid, 2017). The immutable nature of blockchain technology has attracted many scholars. Since then, scholars have tried integrating blockchain technology to enhance transparency, visibility, and reliability (Wang et al., 2019). Several studies have found the benefits of blockchain technology in banks. Especially with the advancement of FinTech in the banking sector, most banks have tried to implement blockchain technology in their business process. Although blockchain technology may disregard banks as intermediaries, however, in fact, banks have used blockchain technology to improve their trade financing services. By adopting blockchain technology, banks could also minimise infrastructure costs and other costs related to transaction processes (Osmani et al., 2020).

Like previous studies on blockchain topics, this study assumes blockchain as a dummy variable (Hasan et al., 2020; Ezzi et al., 2022; Tian et al., 2022). With '1' indicates that the firm implements blockchain technology, and '0' indicates that the firm did not use blockchain technology or is still in the development process.

2.6 Environmental, social, and governance disclosures (ESGD)

Environmental, social, and governance (ESG) disclosures have become an essential part of businesses to achieve sustainable growth. ESGD demonstrates the transparency level of information to increase a firm's performance and sustainable growth (Minutolo, 2019). Investors can examine the transparency level of a firm based on the ESGD scores provided by many analytical platforms such as Bloomberg. Previous studies showed that ESGD performance or disclosure could be enhanced through disruptive technologies. Disruptive technologies such as blockchain could lessen information asymmetry and improve the transparency level of information produced by the firm (Hasan et al., 2020).

The increase in transparency level will eventually restrict management intervention which further reduces biased information disclosures. Moreover, disruptive technologies such as blockchain technology could lessen governance issues and enhance transparency amongst stakeholders. Hence, as the nature of disruptive technologies improves transparency and visibility, this study attempts to examine ESGD disclosures for banks that implement blockchain technology. Additionally, to assess ESGD disclosures, this study uses the ESGD score from Bloomberg Terminal (Chang et al., 2022; He et al., 2022).

2.7 Blockchain technology and operational efficiency

Throughout the years, blockchain technology has been immensely studied in different forms. Prior research has tried to explain the effects of blockchain technology on firm performance and efficiency, which shows a positive relationship between the two variables. Along with the nature of blockchain technology, firms can reduce costs and employ faster transaction processes while still maintaining the quality of goods and services. Thus, firms could have better operational efficiency (Hasan et al., 2020). Blockchain also enables firms to have better cross-border transactions. Traditionally, cross-border transactions between firms are mostly done through an intermediary, which is somewhat inefficient and time-consuming. Moreover, cross-border transactions require documents commonly in hard copy format (Chang et al., 2019). Consequently, firms are encouraged to implement blockchain technology as it can digitalise documents, remove intermediary costs, and perform transactions in real time, improving operational efficiency (Liu and Li, 2019).

The emergence of blockchain technology has introduced intelligent contracts that bind two parties under one contract, the contract will execute itself whenever there are contract breaches (Singh et al., 2020). Additionally, under intelligent contracts, each party will have similar and equal rights that protect the interests of related parties (Macrinici et al., 2018). Concerning transaction cost theory, intelligent contracts hinder human intervention in constructing contracts. As such, they will reduce transaction costs and enhance efficiency (Savelyev, 2017). Nevertheless, blockchain technology adoption may restrict management's movement, thus lessening opportunistic behaviour. This study states the first hypotheses as the following:

H1: Blockchain technology positively influences operational efficiency significantly.

2.8 ESGD and operational efficiency

To assess the effects of each ESGD element on operational efficiency, this study will follow previous papers. Under the stakeholder theory approach, prior papers have divided social responsibility activities into internal and external CSR activities. External CSR endorses firms to be responsible towards the environment and community (Yoon and Chung, 2018). Accordingly, the external CSR activities in this study will be represented by the environmental and social scores of ESGD. Past studies have proven external CSR practices focusing on environmental and social issues to influence operational efficiency positively.

Internal CSR, or the internal governance mechanism, explains firm initiatives to improve employee morale, motivation, and participation in performing external activities (Duthler and Dhanesh, 2018). Studies have shown that internal CSR initiatives positively impact operational efficiency. Internal CSR activities such as workplace diversity will most likely increase motivation and productivity amongst internal stakeholders (Gutiérrez-Fernández and Fernández-Torres, 2020). As a result, firms could enhance firm performance, which further impacts operational efficiency (Yoon and Chung, 2018). To assess the internal CSR performance, this study assumes the governance score of ESGD as the measurement.

On the contrary, several papers argued that excessive investment in CSR initiatives, both internal and external, could potentially lower a firm's performance since it is seen as an inefficient use of resources (Ji et al., 2022). In certain cases, some firms deliberately increase investment in CSR activities to deceive and attract more investors and customers (Yoon and Chung, 2018). While this strategy may enhance the firm's performance in the short run, it may result in unsatisfactory performance in the long run because of the inefficient allocation of resources. As a result, the investment costs could be higher than the income gained from CSR activities (Guillamon-Saorin et al., 2018). Furthermore, information asymmetry from management intervention could lead to biased ESGD scores, which will reduce investors' trust and firm performance (Minutolo et al., 2019). This study states the second hypothesis as the following:

H2a: Environmental disclosures significantly influence operational efficiency.

H2b: Social disclosures significantly influence operational efficiency.

H2c: Governance disclosures significantly influence operational efficiency.

2.9 Blockchain technology, ESGD, and operational efficiency

Theoretically, implementing blockchain technology has a positive correlation between ESGD and Operational Efficiency. The adoption of blockchain technology introduced transparent and more secure transactions between parties. Hence, firms will be able to enhance the transparency of ESG reporting and improve the efficiency of information sharing (Chan et al., 2020). From an environmental perspective, increasing transparency ensures that firms consider their surroundings by eliminating unnecessary activities that generate more waste. Additionally, recently, investors are much more confident in investing in a firm with good ESGD performance. Accordingly, firms are encouraged to invest in greener products or activities to attract more investors and customers, resulting in higher income gained, which will offset the costs of investing (Zhang and Jin, 2022).

Blockchain technology could also improve firms' sustainability and the emergence of blockchain-based governance. Blockchain-based governance forces firms to build better corporate governance practices within the firm, which leads to good ESGD performance. Allowing stakeholders to observe management activities which will minimise management misconduct. In this manner, owners can reduce agency costs arising from monitoring and controlling activities (Van der Elst and Lafarre, 2017; Yermack, 2017). To address the principal-agent problems, blockchain technology introduced smart contracts to reduce monitoring costs and information asymmetry, which will lessen agency costs (Murray et al., 2019). Management will be able to allocate their excess resources more effectively and efficiently rather than investing excessively in monitoring operational performance. The reduction of agency costs would lead to an increase in operational efficiency (Nobanee and Abraham, 2017).

In addition, blockchain technology eliminates third-party confirmation and intermediaries' intervention, thus reducing costs and improving efficiency (Kshetri, 2018; Pan et al., 2020). Few papers have confirmed that there is some lag in the effects of blockchain technology on ESGD and CSR elements such as environment, social, and governance since blockchain technology and other green investment products just emerged recently (Ji et al., 2022). This entails that the effects of applying blockchain technology will materialise after specific years. In other words, blockchain technology could potentially benefit firms in the long run, not in the short run. This study states the third hypotheses as the following:

H3a: Blockchain technology moderates the relationship between environmental disclosures performance and operational efficiency.

H3b: Blockchain technology moderates the relationship between social disclosures performance and operational efficiency.

H3c: Blockchain technology moderates the relationship between governance disclosures performance and operational efficiency.

2.10 Research model

As shown in Figure 1, this research examines the relationship between ESGD and operational efficiency with blockchain technology as the mediating variable and firm size, leverage, and firm age as the control variables. Hence, formulates this research equation:

$$\mathrm{OE}_{it} = \alpha + \beta_1\mathrm{BT}_{it} + \beta_2\mathrm{ENV}_{it} + \beta_3\mathrm{SOC}_{it} + \beta_4\mathrm{GOV}_{it} + \beta_5\mathrm{SIZE}_{it} + \beta_6\mathrm{LEV}_{it} + \beta_7\mathrm{AGE}_{it} + \varepsilon_{it} \quad (2)$$

$$\mathrm{OE}_{it} = \alpha + \beta_1\mathrm{BT}_{it} + \beta_2\mathrm{ENV}_{it} + \beta_3\mathrm{SOC}_{it} + \beta_4\mathrm{GOV}_{it} + \beta_5\mathrm{BT{*}ENV}_{it} + \beta_6\mathrm{BT{*}SOC}_{it} + \beta_7\mathrm{BT{*}GOV}_{it} + \beta_8\mathrm{SIZE}_{it} + \beta_9\mathrm{LEV}_{it} + \beta_{10}\mathrm{AGE}_{it} + \varepsilon_{it} \quad (3)$$

where

OE_{it} = Operational efficiency of firm *i* in time *t*

BT_{it} = Blockchain technology of firm *i* in time *t*

ENV_{it} = Environmental disclosures of firm *i* in time *t*

SOC_{it} = Social disclosures of firm *i* in time *t*

GOV_{it} = Governance disclosures of firm *i* in time *t*

$BT*ENV_{it}$ = Interaction between blockchain technology of firm *i* in time *t* with environmental disclosures of firm *i* in time *t*

$BT*SOC_{it}$ = Interaction between blockchain technology of firm *i* in time *t* with social disclosures of firm *i* in time *t*

$BT*GOV_{it}$ = Interaction between blockchain technology of firm *i* in time *t* with governance disclosures of firm *i* in time *t*

$SIZE_{it}$ = Firm size of firm *i* in time *t*

LEV_{it} = Leverage of firm *i* in time

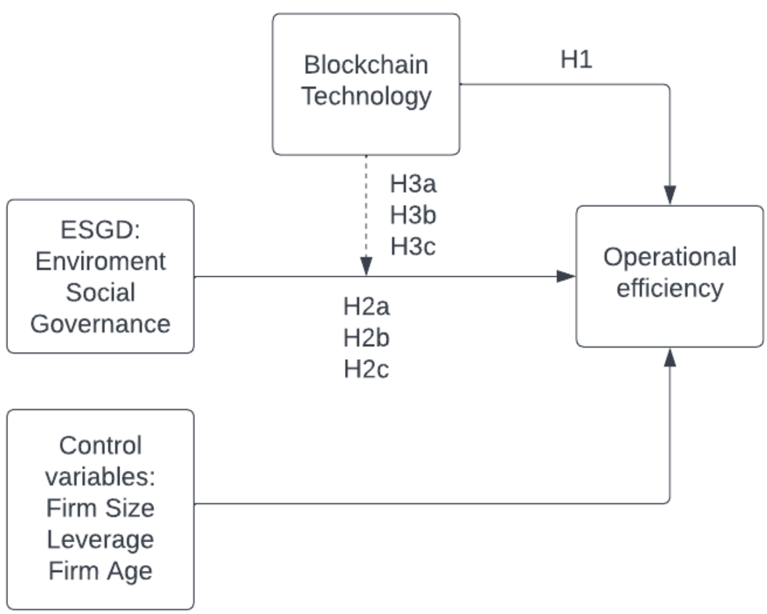
AGE_{it} = Firm age of firm *i* in time *t*

ε_{it} = Error of firm *i* in time *t*

α = Constant

β_{1-10} = Regression coefficient of each variable.

Figure 1 Research Model



2.11 Population, sample, and sampling technique

A population can be defined as the group of people, data, or information chosen from the study's sampling criteria. As shown in Table 1, the main population of this study consists of all banking firms listed in IDX, KLSE, SGX, and SET and European banks in the population. The European banks selected for this study are the 20 largest market capitalisation banks collected from S&P Global. Banking firms that are included in this study population are the ones that are still active from 2017 – 2021, which concludes 91 listed banks for this study's whole population. Based on the population, this study sample is captured by using a non-probability sampling technique. This study applies the following criteria:

1 Banks publicly listed and actively traded in IDX, KLSE, SGX and SET from 2017 to 2021.

2 European banks listed in LSE, BME, and EURONEXT from 2017 to 2021.

3 Banks that disclose and implement blockchain technology in the supply chain for 2017–2021.

4 Banks with complete ESGD scores and financial information from 2017 to 2021.

Table 1 Sample summary for ASEAN and European banks

Sampling criteria	*Number of firms*
Banking firms in IDX, KLSE, SGX, SET, and the 20 largest market capitalisation European banks from 2017 to 2021	91
Largest market capitalisation nominated banks listed in the European stock market outside LSE, BME, and EURONEXT	(7)
Banking firms that did not disclose blockchain technology for the year 2017 to 2021	(61)
Banking firms that did not have complete ESGD scores or financial information from 2017 to 2021	(3)
Banking firms that fulfil the criteria	20

3 Results and discussion

3.1 Descriptive statistics

Tables 2 and 3 interpret each variable's mean, median, minimum, maximum, and standard deviation provided by the GRETL analytical software.

The dependent variable, operational efficiency (OE), has a minimum of 0.13 from GLE in 2021, implying that the firm is still inefficient. On the contrary, the maximum score of a firm operational efficiency is 1, which illustrates the most efficient firm, such as BBCA, BNLI, BARC, KTB, and INGA in their respective year. The blockchain technology variable shows that banks have continuously utilised blockchain technology by the year. This result can be interpreted that banks see blockchain technology as a tool to enhance the effectiveness and efficiencies of their operations. Hence banks started to utilise blockchain technology to gain competitive advantages. Following that, the second independent variable, ESGD, is divided into three pillars, as previously mentioned in Chapters 2 and 3.

Table 2 Descriptive statistics summary

Variable	*Mean*	*Median*	*Minimum*	*Maximum*	*Std. Dev*
OE	0.69	0.71	0.13	1	0.23
ENV	31.08	34.22	7.43	47.45	10.20
SOC	37.80	37.41	20.19	54.66	9.54
GOV	84.79	87.36	22.41	98.62	15.93
SIZE	10.40	10.52	9.09	11.32	0.42
LEV	15.54	14.48	1.01	34.37	8.07
AGE	99.80	73.50	9	331	79.26

Source: GRETL output

Table 3 Descriptive statistics for BT variable

Blockchain technology									
2017		*2018*		*2019*		*2020*		*2021*	
"0"	"1"	"0"	"1"	"0"	"1"	"0"	"1"	"0"	"1"
16	4	10	10	5	15	4	16	0	20

Source: Author's compilation

On the environmental aspect, the statistics show a minimum of 7.4298, representing the lowest score of environmental disclosure that is obtained from OCBC's environmental score in 2017. As for the maximum, it shows 47.448 tracing back to UOB Bank in 2021. The social aspect of ESGD has a minimum of 20.193 from DBS in 2021 and a maximum of 53.658 from HSBA in 2018. While from the governance aspect, ESGD appears to have a minimum score of 22.41 from BBCA throughout the years and a maximum of 98.615 from INGA starting from 2018 to 2019. With an average of 84.79, it can be assumed that most banks have applied good corporate governance. As for the SIZE variable, BNLI portrays the lowest SIZE with 9.09 on the contrary, HSBA has the highest SIZE with 11.32. On the LEV variable, the minimum value is represented by BBCA with a value of 1.0082, and GLE represents the maximum value with 34.368. With the leverage value of GLE in 2021, it is expected that the firm will face inefficiency resulting in a low operational efficiency of 0.13418 in the corresponding year.

The third control variable, AGE, shows a minimum of 9, which is CABK in 2020, and a maximum of 331, which is BARC in 2021. As seen from Table 2, most listed banks that use blockchain technology are long-established banks with an average of 99.8 years. From the statistics, ENV, SOC, GOV, and AGE appear to have a high standard deviation, indicating that the variability of these variables is vast and comprehensive. Furthermore, as there are very few banking firms that disclose the usage of blockchain technology, it further restricted the sample to become smaller, hence affecting the standard deviation of some variables to be high.

3.2 Panel data model estimation method

After concluding the descriptive statistics of the dataset, the dataset will be analysed further by testing the collinearity, heteroskedasticity, and panel specification diagnostics. The data testing is operated for both models. As shown in Table 4, the first model analyses the dataset without interaction or moderating variables, and the second examines the dataset with moderating variables.

Table 4 Model 1 data testing specification

Collinearity test		
Variable	*Variance inflation factors (VIF)*	
BT	1.393	
ENV	2.235	
SOC	2.060	
GOV	1.444	
SIZE	1.845	
LEV	1.813	
AGE	1.508	
Heteroskedasticity (White's Test)		
p-value	0.000058	
Panel specification diagnostics		
Fixed Effect Estimator (A low p-value counts against the null hypothesis that the pooled OLS model is adequate, in favour of the fixed effects alternative.)	2.11E-29	*Fixed*
Breusch-Pagan Test (A low p-value counts against the null hypothesis that the pooled OLS model is adequate, in favour of the random effects alternative.)	1.00E-29	*Random*
Hausman Test (A low p-value counts against the null hypothesis that the random effects model is consistent, in favour of the fixed effects model.)	0.006469	*Fixed*

Source: GRETL output

The collinearity test shown in Table 4 illustrates that there is no collinearity problem within the first model. It is proven from the VIF of each variable that it is below 6. On the other hand, the heteroskedasticity test identifies a heteroskedasticity problem as the p-value is below 5%. A panel specification diagnostics test is taken to determine the best model further.

The second model, as portrayed in Table 5, appears to have a collinearity problem. However, after further examination, the collinearity problem arises from the interaction or moderating effects of BT and ESGD. Thus, the collinearity problem does not have any adverse effects on the model and can be safely ignored. Regarding the heteroskedasticity and panel specification diagnostics test, the second model has similar results to the first model. Based on the results, the first and second models will have the best outputs using the weighted least square (WLS) model.

Table 5 Model 2 data testing specification

Collinearity test		
Variable	*Variance inflation factors (VIF)*	
BT	43.994	
ENV	4.018	
SOC	7.536	
GOV	2.,55	
BTENV	19.501	
BTSOC	41.150	
BTGOV	46.307	
SIZE	1.881	
LEV	1.846	
AGE	1.525	
Heteroskedasticity (White's Test)		
p-value	0.004559	
Panel specification diagnostics		
Fixed effect estimator (A low p-value counts against the null hypothesis that the pooled OLS model is adequate in favour of the fixed effects alternative.)	1.90E-27	*Fixed*
Breusch-Pagan Test (A low p-value counts against the null hypothesis that the pooled OLS model is adequate in favour of the random effects alternative.)	5.90E-29	*Random*
Hausman Test (A low p-value counts against the null hypothesis that the random effects model is consistent in favour of the fixed effects model.)	0.028886	*Fixed*

Source: GRETL output

3.3 Hypothesis test

In this research, both models are tested using the WLS model, as shown in Table 6. The first model explains the relationship between independent and dependent variables. It shows that the model has a p-value of 4.97E-34 with an R^2 value of 82.94%. Indicates that the dependent variable could be explained by 82.94% through the independent variables, and other variables outside the research scope can explain the other 17.06%.

Table 6 Model 1 WLS result summary

Indicators	*Coefficient*	*Std. error*	*t-ratio*	*p-value*
Constant	1.0061	0.4086	2.4620	0.0157**
BT	0.0321	0.0190	1.6880	0.0949*
ENV	−0.00695129	0.0014	−4.921	<0.0001***
SOC	−0.00526153	0.0014	−3.642	0.0004***
GOV	−0.00112199	0.0006	−1.886	0.0624*
SIZE	0.0256	0.0380	0.6741	0.5019
LEV	−0.00846111	0.0018	−4.596	<0.0001***
AGE	0.0003	0.0002	1.4030	0.1639
R-squared		84.15%	*F*(7, 92)	69.7689
Adjusted R-squared		82.94%	*p-value* (F)	4.97E-34

Source: GRETL output

Model 1 describes the first and second hypotheses. The first hypothesis, BT has a significant positive influence on OE. The second hypotheses consist of three sub-hypotheses. The first sub-hypotheses, ENV to OE, show a significant negative influence on OE. Following that, the second sub-hypotheses, SOC to OE, has a significant influence on OE. The third sub-hypotheses, GOV to OE, also have a significant influence over OE. In conclusion, all hypotheses being tested under Model 1 are accepted. The control variables, SIZE and AGE proved insignificant in the model. However, if both control variables are taken out, it will affect the whole model. Thus, both variables are necessary. The hypothesis results from this testing can be illustrated with the t-test summary in Table 7.

Table 7 Model 1 t-test summary

Hypothesis	*Independent*	*Dependent*	*Hypothesis*	*T-test Result*	*Decision*
1	BT	OE	Positive significant	Positive significant	Accepted
2a	ENV	OE	Significant influence	Negative significant	Accepted
2b	SOC	OE	Significant influence	Negative significant	Accepted
2c	GOV	OE	Significant influence	Negative influence	Accepted

Source: Author's compilation

The second model is represented in Table 8. The purpose of model 2 is to examine the moderating impact of BT between ESGD pillars and OE. The model has a p-value of 6.26E-26 and an R^2 of 76.58%. Indicating that the model is sufficient to explain the effects of each variable. Furthermore, as this model solely analyses the moderating effects of BT, other variables' results, such as BT and ESGD pillars, are not considered.

Table 8 Model 2 WLS result summary

Indicators	*Coefficient*	*Std. error*	*t-ratio*	*p-value*
Constant	0.8913	0.4172	2.1360	0.0354**
BT	0.1565	0.0927	1.6890	0.0948*
ENV	−0.00745374	0.0018	−4.187	<0.0001***
SOC	0.0020	0.0027	0.7353	0.4641
GOV	−0.00311685	0.0009	−3.537	0.0006***
BTENV	−0.000375634	0.0024	−0.1587	0.8743
BTSOC	−0.00868468	0.0032	−2.752	0.0072***
BTGOV	0.0025	0.0010	2.3490	0.0210**
SIZE	0.0277	0.0389	0.7125	0.4780
LEV	−0.00689511	0.0020	−3.377	0.0011***
AGE	0.0002	0.0002	0.8916	0.3750
R-squared		78.95%	F(7, 92)	33.36986
Adjusted R-squared		76.58%	*p-value* (F)	6.26E-26

Source: GRETL output

Table 8 shows that two out of three moderating variables have a moderating effect between ESGD pillars and OE. Firstly, BTENV represents whether BT has a moderating influence over ENV and OE, but the result contradicts the hypothesis. BTSOC and BTGOV have a significant influence on OE, which signifies that BT can moderate the relationship of SOC or GOV towards OE. Accordingly, the hypothesis results are interpreted in Table 9.

Table 9 Model 2 for t-test summary

Hypothesis	*Independent*	*Dependent*	*Moderating*	*Hypothesis*	*T-test Result*	*Decision*
3a	ENV	OE	BT	Moderates	Insignificant	Rejected
3b	SOC	OE	BT	Moderates	Strengthen	Accepted
3c	GOV	OE	BT	Moderates	Weaken	Accepted

Source: Author's compilation

3.4 Discussion analysis and managerial implications

Consistent with previous studies, Table 9 shows a positive influence of BT over OE. This implies that as blockchain technology promotes transparency and secured transactions, it causes firms to be more efficient in managing their resources and operation (Hasan et al., 2020). As transparency increases, firms can minimise information asymmetry amongst stakeholders. Additionally, the development of smart contracts within blockchain technology has facilitated faster and more reliable transaction processes which reduce transaction costs and time consumed. Consequently, information or transaction that is posted through blockchain technology will be available to all stakeholders, allowing firms to eliminate third-party confirmation, accelerating the flow of information between stakeholders, and diminishing human errors in the transaction process (Liu and Li, 2019; Tian et al., 2022; Morkunas et al., 2019). Although blockchain technology removes intermediaries' confirmation, such as banks, this research has proven that banks would greatly benefit from using blockchain technology. As seen in Tables 2 and 3, most banks have tried to incorporate blockchain technology into the supply chain. According to Osmani et al. (2020), adopting blockchain technology allows banks to cut infrastructure costs. Thus, banks can free up some resources and improve efficiency. Furthermore, the positive influence of BT on OE is also in line with the transaction cost theory. By utilising blockchain technology, banks would significantly reduce transaction costs for information gathering, such as customers' credit ratings (Schmidt and Wagner, 2019). Besides, blockchain technology also improves information clarity. Thereafter, banks can eliminate certain transaction costs, increasing their operational efficiency.

As shown in Table 8, ENV significantly influences OE with a p-value below 1%. Although looking at the coefficient, ENV has a negative influence over OE. As such, ENV negatively affects OE significantly. Alongside ENV, SOC also has an adverse impact on OE. Thus, the second and third hypotheses are accepted. This aligns with a study that shows the negative influence of external disclosures on firm performance (Yoon and Chung, 2018). Management that tends to overinvest in external CSR activities is proven inefficient in managing its resources, hence limiting resources. However, since the research observation years are limited, there could be a lagged effect of environmental disclosures, which would lead to positive results in the future (Ji et al., 2022). Moreover, since most external CSR activities in environmental and social issues require substantial costs, there are limited effects on operational performance (Theodoulidis et al., 2017). In that sense, the effects of investing in external CSR activities cannot be seen in the short run, as the income cannot offset the investment cost. In terms of the banking industry, the industry has introduced green financing, such as green credit, in response to environmental problems. Green credit assures banks to consider the environmental hazards in the credit issuance process (Xiao et al., 2022). Banks that apply green credit have proven to have more competitive advantages, thus improving operational efficiency in the long run (Ji et al., 2022). The negative influence of ENV and SOC on OE could be temporary. In line with stakeholder theory, firms that can provide sustainable and green products generate more income resulting in higher operational efficiency. In conclusion, although the impact of ENV on OE appears to be negative in the short run, nevertheless, environmental activities have positive influences on long-term efficiency.

From the governance aspect of ESGD, the result implies that GOV has a significant negative influence on OE, implying that the fourth hypothesis is accepted. Prior study has also stated that governance does improve firms' efficiency to a certain degree (Lotto, 2018). That said, governance could positively and negatively influence efficiency through employee satisfaction and welfare. Although, it can be argued that the negative influence of governance may be caused by biased disclosure from management (Minutolo et al., 2019). As such, the influence of governance on operational efficiency can be positive if firms are socially responsible for all their stakeholders. Furthermore, under stakeholder theory, firms must consider stakeholders' demands and expectations to enhance firm performance and improve efficiency (Yoon and Chung, 2018).

Even though in the previous model, ENV has a strong negative influence on OE, the incorporation of BT has no moderating effects between ENV disclosures and OE ever so slightly. As there is still less to no evidence and papers that explain the moderation effects of BT, this result cannot fully reflect the moderation effects of BT on ENV and OE. It is suggested that since environmental activities cultivate over time, the effects are less visible from the short-term perspective (Ji et al., 2022). This implies that the nature of ENV disclosures can cause the moderating effect of BT. Thus, this result only describes a temporary effect. Before discussing the moderation effect of BT on SOC and OE, it is more appropriate to see the moderation effect of BT on GOV first. From the perspective of GOV, BT can positively moderate the correlation between GOV and OE, which in the previous model, GOV does not influence OE. Blockchain-based governance has proven to reduce agency costs by preventing agents from acting solely out of self-interest (Van der Elst and Lafarre, 2017). In addition, smart contracts also limit agents' movement, which reduces information asymmetry. This entails that blockchain technology enhances governance, increasing financial stability and efficiency (Nobanee and Abraham, 2017). Furthermore, in accordance with agency theory, this result shows that blockchain technology can eliminate agency problems. Related to the banking industry, banks with stringent internal corporate governance can strengthen stability and improve operational efficiency (Lotto, 2018). However, as governance becomes more rigid, employee satisfactions are at risk. As displayed in Table 8, the moderating of BT between SOC and OE has a negative influence. The negative results describe when banks employ strict governance or regulations using blockchain technology, which affects the social aspects of the business. It is consistent with Lee (2021) research that corporate governance influences employee welfare and stability. Stakeholder theory also suggests that in constructing better corporate governance, firms must consider all stakeholders and risks associated with the decisions.

This research has a variety of findings that contributes to some implications. Firstly, the adoption of blockchain technology suggests that firms have long-term profits rather than focusing on short-term profits. Short-term profits such as ROA and ROE do not represent appropriate measures for firms' efficiency. Instead, firms must concentrate on efficiency to be consistent and survive current economic conditions. To enhance efficiency, this study suggests that firms consider applying blockchain technology to their supply chain. Blockchain technology provides better and faster transactions flow with a sophisticated security system. Every transaction that is posted in blockchain technology is immutable. This means that every transaction cannot be altered once posted.

Aside from efficiency, firms must be able to be socially responsible towards their actions and decisions. Especially with current world economic conditions that worsen daily, investors seek out firms with stable and sustainable growth. With that said, blockchain technology offers firms to have better and more transparent information disclosures. As such, stakeholders will have a better understanding of the current firm's performance to improve the decision-making process. Besides, since blockchain technology gives transparency to information or transaction flow, it will minimise information asymmetry that arises from the principal-agent dilemma. Firms can improve operational efficiency to attract more investors and enhance investors' confidence levels.

4 Conclusion, limitations, and recommendations

4.1 Conclusion

This study aims to provide some solutions for firms to sustain themselves in post COVID-19 era by utilising blockchain technology to stimulate financial stability. Therefore, firms may adopt blockchain technology to reduce scepticism and information asymmetry, increasing the firm's performance and investors' confidence. Adopting blockchain technology could greatly enhance firms' operational efficiency as proven in this study. It is aligned with previous studies that blockchain technology could reduce transaction costs and eliminate manual information transfer errors, hence operational efficiency can be improved further (Morkunas et al., 2019). Financial institutions such as a bank could save up some of their resources by having blockchain technology to improve operational efficiency. Aside from saving costs and increasing operational efficiency, blockchain technology ensures transaction transparency using its immutable transaction system, thus enhancing reliability and gaining customers' trust even. However, investing in new technology could potentially bring inefficiency for the firms in the short run, especially if most employees are yet to understand the technology. Thus, better governance must be imposed, which increases costs and limits resources. In that sense, the adoption of blockchain technology could reduce transaction costs and possibly improve firm performance.

4.2 Limitations and recommendations

In general, blockchain technology is still a relatively new topic and only a few papers have tried to associate blockchain technology with ESGD/CSR and operational efficiency. Not to mention, from numerous literature reviews, no papers have yet to analyse the moderating effects of blockchain technology. Consequently, this paper encountered various limitations in collecting the data for the blockchain. Moreover, as blockchain technology data is extracted from annual reports, it is highly subjected to subjectivity. Some firms may not disclose their blockchain technology information, leading to an incomplete dataset. In terms of the sample, most ASEAN banks have yet to implement blockchain technology, causing the sample to be minor, with only 10 banks from IDX, KLSE, SGX, and SET. Aside from blockchain technology, most data can still be obtained through Bloomberg Terminal with high credibility. For future reference, considers a broader sample consisting of Asia, Europe, Australia, and America. Additionally, future studies may also analyse each ESGD pillar in-depth, mainly the governance aspect, such as board structure, board diversity, or CEO tenure.

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