Research article

# How does the data element-driven industry affect corporate cash holdings? Evidence from Chinese listed companies

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A B S T R A C T

The data element-driven industry (DEDI) generates large amounts of data, thereby mitigating information asymmetry. Does this affect corporate cash holdings? On the basis of theoretical analysis, this study empirically analyzes the impact of DEDI on enterprises' cash holdings and its transmission path using data of Chinese cities and A-share listed enterprises from 2008 to 2020. First, the results indicate that the DEDI reduces corporate cash holdings. As the development level of the DEDI improves, the corporate cash holdings gradually decrease. Second, the DEDI indirectly affects corporate cash holdings by influencing debt-financing and external credit supply capacities. Specifically, the DEDI increases the upstream corporate debt-financing and downstream corporate external credit supply capacities. Improvements in debt-financing and the external credit supply capacities can reduce corporate cash holdings. Third, the DEDI has a heterogeneous impact. For enterprise with CEO duality, small and medium-sized, and information technology enterprises, the impact of DEDI in reducing cash holdings is greater.

## 1. Introduction

Data elements are new and core production factors in the digital economy era, providing a vital advantage. Data elements' value has become a new focus in many countries that are focusing on the digital economy as a critical strategy. Countries worldwide are promoting the development of the data element industry and activating the value of data elements through strategic formulation, documentation, and bill issuance. The data element-driven industry (DEDI) is industry that realizes economic growth and obtains development momentum through the input of data elements and market demand for data. Growth in DEDI inevitably leads to a large amount of data. Data is crucial resource for enterprises [1]. It have strong externalities, which is not subject to factor scarcity, and is characterized by ease of reproduction, sharing, and access [2–4]. Furthermore, it can help enterprises reduce costs, improve production efficiency, more effectively allocate resources, and enhance enterprise value. Cash is crucial for enterprises' daily operations, future development, and crisis management. However, holding a large amount of cash leads to ineffective use of resources, hindering the enhancement of enterprise value. Therefore, reducing unnecessary cash holdings is crucial for enterprise development. Does this imply that the DEDI can reduce enterprises' cash holdings? This is the focus of the present study.

This study explores whether DEDI, as a core industry of the digital economy, significantly impacts cash holdings, which is important for enterprise development and risk management. If so, what is the pathway through which this takes effect? These findings provide decision-making support for DEDI development, enterprise development, and investors. DEDI improves data and information

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environments, reduces enterprise uncertainty, improves the accuracy of enterprises' decisions and forecasts, enhances enterprises' ability to cope with uncertainty, and increases their asset turnover. Thus, it impacts the motives for enterprises to hold cash. Therefore, we hypothesize that the DEDI reduces corporate cash holdings. The DEDI mitigates the information asymmetry, improves enterprises' profitability and repayment abilities, drives the inclusive development of financial institutions, and enhances enterprises' risk-taking ability. Therefore, we hypothesize that DEDI can improve enterprises' debt-financing and external credit supply capacities, thereby reducing their cash holdings.

According to the China Academy of Information and Communications Technology, China is the second largest country in the world in terms of the digital economy scale in 2022. Currently, the development of China's DEDI is at a world leading level, and the government places a great deal of importance on the role of data elements. China is also the second largest economy in the world, with a large number and diversity of enterprises. Given the rapid development of China's DEDI, enterprises are experiencing significant opportunities and challenges. Therefore, we think that China is an appropriate and ideal environment for studying the influence of DEDI on corporate cash holdings.

In this study, the urban DEDI's development level is an explanatory variable. National Bureau of Statistics of China (NBS) divides the DEDI into seven sub-industries (as shown in Table 2). We obtained 14 data items by constructing keywords and determining the number and registered capital of enterprises in each city for the seven sub-industries. These data were sourced from the State Administration of Market Supervision of China. We then used factor analysis to obtain the development index of the DEDI in the cities where the enterprises were located, which served as the proxy variable for DEDI's development level. *Cash* and *rCash* are the proxy variable of enterprises' cash holdings level, whose measurement are displayed in Section 3.2.

Based on the constructed DEDI development index and cash holding levels, we conduct the empirical test. We used the cash holdings level as the explained variable, DEDI development index of the city where the enterprise is located as the explanatory variable, and the two-way fixed-effects (TWFE) model for the enterprise and time to test the direct impact of the DEDI on corporate cash holdings. Using debt-financing and external credit supply capacities as intermediary variables, corporate cash holdings as explained variable, and DEDI development index as explanatory variable, we conducted mediation effect tests to explore how DEDI indirectly affects corporate cash holdings. Finally, we distinguished whether the enterprise has CEO duality, large or small and medium-sized enterprises (SMEs), and whether it belong to the information technology industry. We used the varying-coefficient individual fixed-effects model to test the heterogeneity.

First, our study deepens research on the digital economy. Through its technological and information advantages, the digital economy profoundly impacts the microeconomy by improving the efficiency of transactions, increasing the productivity of capital and labor, changing consumer behavior, reshaping business models, and exerting financial inclusion [2,5–7]. Numerous studies have examined the microeconomic impact of the digital economy in terms of corporate innovation, productivity, production and operational activities, and corporate governance. The digital economy promotes corporate innovation [4], green and technological innovations [5,8]. The digital economy and technologies enhance enterprises' productivity and innovation performance [6,9], having a nonlinear U-shaped effect on enterprise productivity [10]. Digital economy strategies affect enterprises' cash holdings [11], enhance investment efficiency [12], and affect corporate organizational structure [2], increasing new corporate governance challenges [13]. The digital economy affects enterprises' risk-taking [14] and ESG performance [15]. These studies have typically considered the entire digital economy. This is the first study to examine DEDI's economic impact, a segment of digital industrialization.

Second, our study contributes to the literature on corporate cash holdings from the DEDI development perspective. Much research has been conducted on the factors influencing enterprise's cash holdings in terms of its motives and enterprises' internal and external factors. Enterprises hold cash primarily based on transaction, precautionary, agency, and tax motives [16]. Scholars have studied the impact of internal factors like corporate governance structure [17], specific characteristics like corporate CEO [18], CFO characteristics [19], and enterprise size [20] on corporate cash holdings. External factors like country-specific factors [20], macro policy uncertainty [21], political uncertainty [22], market competition [23], product market dynamics and predation risk [24], peer effects [25], and social trust [26] influence cash holdings. Financing constraints is an important factor [27]. The more severe the information asymmetry, the higher the level of uncertainty and financing constraints faced by enterprises and higher the level of cash holdings [28,29]. Few scholars have also investigated the digital economy's impact on corporate cash holdings [11,30]. Overall, scholars have not examined the DEDI's impact on Chinese corporate cash holdings.

Overall, this study contributes to the literature by examining DEDI's impact on corporate cash holdings from the perspective of digital economy's subsectors. This differs from research on the impact of the digital economy on enterprises. The DEDI focuses on driving generating and applying massive amounts of data through industry development and the impact of data as a production factor on enterprises' cash holdings. The digital economy's scope is larger than that of the DEDI, and its micro-impact on corporate cash holdings can be analyzed from multiple aspects, such as the digital technology [9], digital economy strategy [11], data elements, industrial development (digital industrialization, industrial digitization), and digital governance. Existing research has mostly considered the digital economy as a whole to study its micro-impacts and analyze its mechanisms from the multiple aspects mentioned above. This study focuses on the impact of DEDI, a core industry of digital economy focusing on data, on corporate cash holdings.

## 2. Testable hypotheses

### 2.1. Direct impacts

As shown in Fig. 1, DEDI reduces the precautionary and transaction motives of enterprises to hold cash by improving the information environment, reducing the uncertainty faced by enterprises, improving corporate decision accuracy, enhancing the ability of

enterprises to cope with uncertainty, and improving the efficiency of asset turnover through the advantage of a vast amount of data.

First, the development of the DEDI significantly improves the information environment and reduces enterprises' uncertainty. Internet platforms, Internet wholesale and retail, Internet finance, and other DEDIs have platform effects. With continuous data generation and accumulation in the trading and circulation stages of platforms, data sources have widely increased. Moreover, the DEDI can produce synergistic effects, and trading data resources and property rights can accelerate data resource flow. Therefore, it enhances data exchange. Data is a form of information [3]. A wide range of information sources and efficient information exchange significantly improve the information environment of enterprises, reduce information search, and transaction costs for enterprises [2]; this alleviates information asymmetry and reduces the macro-uncertainty faced by enterprises. Thus, the DEDI enables enterprises to better process data into information helpful for production and operation activities. Thus, enterprises more accurately seize market opportunities [31], thereby reducing production and operation uncertainty.

Second, DEDI development enhances the accuracy of enterprises' decisions and forecasts, enhancing their ability to cope with uncertainty. Applying massive data from DEDI drives the efficient information transmission of enterprises and helps establish real-time responsive production management systems. This enables enterprises to realize business intelligence analysis from rich, dynamic, and contextualized data, thereby improving decision-making timeliness [32] and accuracy. For example, enterprises can efficiently mine and identify customer demand [33] and analyze demand changes based on massive amounts of data accumulated on Internet platforms. Accordingly, it can reduce the business risks caused by delayed decisions and prediction mistakes.

The DEDI stimulates enterprises' insight and dynamic response ability, enhancing their ability to cope with uncertainty. First, using data stimulates enterprises' insights. Data-driven insights help enterprises predict future situations in a timely manner, predict the actions for optimal outcomes [1], and pertinently implement effective interventions [34]. Second, big-data-based analytics enhance enterprises' dynamic capabilities [35], enabling them to rapidly respond to changing environments by integrating and reconfiguring internal and external resources based on massive and diverse data.

Third, DEDI development promotes the improvement of enterprises' asset turnover efficiency. First, data elements help enterprises accurately determine the quantity and timing of demand for upstream products, order them in real time, improve their ability to allocate resources, such as raw materials, and increase asset turnover. Second, enterprises mine and analyze market information based on sales data, customer data, product after-sales feedback, et cetera, to better understand consumer preferences [31], identify product requirement changes, and rapidly adjust product inventories. Third, analyzing data, such as inventory and transportation, can improve enterprises' business processes [36] and enable them to more efficiently execute their processes in response to changes in market conditions, which can further improve their operational efficiency of enterprises [37]. Improvements in business processes and operational efficiency maximize the turnover of business assets.

Precautionary and transactional motives are the main motives for enterprises to hold cash [16,38]. First, the precautionary motive focuses on coping with uncertainty by holding cash. As mentioned above, DEDI development improves information transparency, reduces enterprise uncertainty, enhances the accuracy of enterprises' decisions and forecasts, and improves their ability to cope with uncertainty. Consequently, the level of cash required to manage uncertainty decreases. Second, the transactional motive focuses on the need to satisfy daily transactions by holding cash. DEDI development promotes higher asset turnover and utilization of liquid assets such as cash [33]. The turnover rate of assets, such as raw materials and enterprises' product inventory, increases. This avoids holding large amounts of cash to cope with uncertainty in raw material purchases. Moreover, enterprises can use data-driven production methods to minimize transactional friction, thereby reducing the cash holdings [30].

Thus, hypothesis H1 is proposed.

**H1**.  DEDI can reduce corporate cash holdings.

### 2.2. Indirect effects based on debt-financing capacity

Many enterprises heavily depend on debt financing for operations. The higher an enterprise's debt-financing capacity, the quicker and less costly it can obtain the required funds it needs, and the need for cash holdings is reduced.

On the one hand, DEDI improves corporate debt-financing capacity.

First, the DEDI enhances corporate debt-financing capacity by reducing information asymmetry between banks and enterprises. A major reason enterprises face difficult and expensive financing problems is information asymmetry between banks and enterprises [38]. DEDI increases the data content of economic activities, enabling enterprises and banks to collect large amounts of internal and external data and conduct data analyses. On the one hand, enterprises can reduce business uncertainty and risk, and gain a more
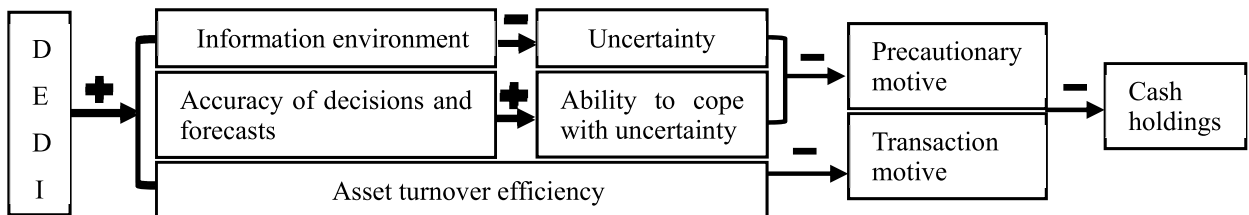


**Fig. 1.** Logic diagram of direct impacts.

comprehensive understanding of banks' preferences, prices, and other related information. On the other hand, banks can collect information on the production, sales, transactions, and financial situations of enterprises on platforms, such as Internet trading platforms, which can help banks more effectively assess the credit status and repayment ability of enterprises at lower costs [4]. Thus, it can decrease the asymmetry of information between banks and firms, and increase the matching level. Therefore, an enterprise's debt-financing capacity can be enhanced.

Second, the DEDI enhances enterprises' profitability and repayment ability, improving their debt-financing capacity. The DEDI reduces costs and increases efficiency. First, the DEDI lowers enterprises' costs. Effective use of Internet platforms by enterprises can reduce search, information-matching, and transaction costs. An analysis based on massive consumer data reduces customer acquisition costs for enterprises [35]. Processing decentralized data into effective information and using it in production management systems helps enterprises reduce their production costs [10]. Second, DEDI promotes the upgrading of intelligent production methods of enterprises and timeliness of enterprises decision-making, which help improve production efficiency [34] and enterprise performance [39]. This further increases enterprises' market value [40] and profitability, thereby enhancing their repayment abilities.

Third, the DEDI promotes inclusive development and risk management of financial institutions, which subsequently contributes to enhancing corporate debt-financing capacity. The DEDI encompasses the development of the Internet finance industry. Additionally, Internet and digital finance have inclusive characteristics that can help reduce financing costs and difficulties for enterprises and improve financing convenience [7]. With the empowerment of data elements and catfish effect of Internet finance, banks are actively improving and increasing traditional financial services. Banks can also comprehensively and dynamically grasp enterprises' information through the DEDI, enabling them to better control credit risks [41] and enhance risk management capabilities, which contribute to improving corporate debt-financing capacity.

On the other hand, an increase in enterprises' debt-financing capacity can reduce the amount of cash held by enterprises.

Enterprises hold cash in their operating processes to meet the daily transaction needs and manage future uncertainties [16]. Short-term bank debt-financing is a close substitute for cash [42]. A substitution effect exists between debt-financing capacity and cash holdings [20]. When an enterprise's debt-financing capacity increases, the enterprise can efficiently and cheaply finance when it needs cash; thus, the amount of cash held for transactions and precautionary motives decreases. The indirect impact of DEDI on corporate cash holdings through debt-financing capacity is shown in Fig. 2.

Overall, hypothesis H2 is proposed.

**H2.** The DEDI reduces corporate cash holdings by increasing enterprises' debt-financing capacities.

### 2.3. Indirect effects based on external credit supply

Trade credit supply is the prepayment generated by paying cash in advance when purchases and accounts receivable generated by deferred collections to finance customers during sales [43]. Supplying external trade credit in the form of prepayments and receivables possesses an enterprise's cash.

On the one hand, the DEDI promotes enterprises' ability to supply external credit.

First, the DEDI reduces the information asymmetry among enterprises in the supply chain and enhances enterprises' ability to supply external credit. Information is a critical factor that influences trade credit among enterprises, and there is information asymmetry in trade credit activities. DEDI development has promoted the digitization and transparency of the business processes of supply chain and has significantly alleviated information asymmetry among enterprises. For example, by relying on data from Internet platforms and wholesale and retail platforms, enterprises can dynamically grasp the operational status, credit status, and other risks of upstream and downstream enterprises. They can also conduct real-time supervision. Moreover, DEDI development has made supply chain-related data highly accessible, cost of information very low, and reduced the cost of pre-assessment and post-supervision of providing trade credit. Therefore, it strengthens enterprises' ability to supply external trade credit.

Second, the DEDI improves enterprise performance and enhances the ability to supply external credit. As previously analyzed, the development of DEDI reduces cost and increases efficiency. First, based on the Internet platform and other DEDI, enterprises can obtain a wide range of information at a low cost. The effective use of data can reduce production [10], transaction, and other costs for enterprises. Second, DEDI development improves enterprises' production and operational efficiency, and profit margins [34]. An increased level of business efficiency allows enterprises to have more adequate cash flow to support the external credit supply. Enterprises with higher profits can provide more credit to their customers.

Third, DEDI development enhances enterprises' risk-taking abilities, thereby enhancing their ability to supply external credit. First,
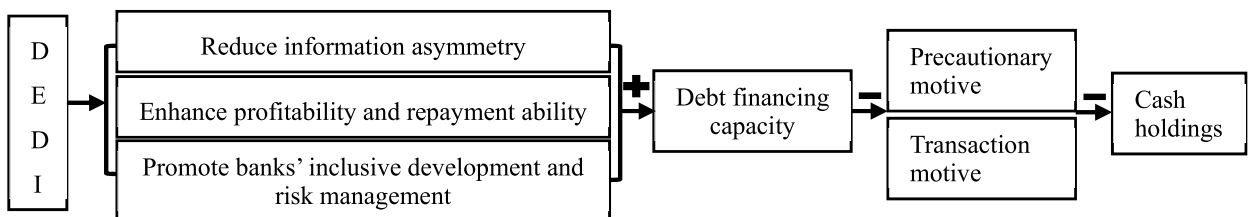


**Fig. 2.** Indirect effects of debt-financing capacity.

DEDI development helps enterprises collect and manage vast amounts of information cheaply and more accurately assess the risks of upstream and downstream enterprises. Second, the breadth, accessibility, accuracy, and low cost of data enhance enterprises' ability to predict future markets, enabling them to better predict the default risks of upstream and downstream enterprises and take timely intervention measures. Moreover, the more developed the DEDI is, the more conducive it is for enterprises to integrate resources in a timely manner to enhance their ability to cope with external uncertainties. Therefore, the enterprises' risk-taking abilities are enhanced. Providing external trade credit is risky for enterprises. Therefore, as enterprises' risk-taking ability increases, their willingness and ability to provide external credit also increase [44].

On the other hand, improving an enterprise's external credit supply capacity can reduce its cash holdings.

Enterprises supply external trade credit by reducing their cash holdings to increase the cash available to credit recipients [45]. If an enterprise offers trade credit to downstream enterprises in the form of accounts receivable, indicating that the enterprise delays the acceptance of cash [43]; if it offers trade credit to upstream enterprises as prepayment, it implies that the enterprise uses cash in advance to pay for the goods. In both cases, enterprises concede liquidity, which inevitably reduces their cash holdings as they supply trade credit. The indirect impact of DEDI on corporate cash holdings through external credit supply is shown in Fig. 3.

Overall, hypothesis H3 is proposed.

**H3.** The DEDI reduces corporate cash holdings by increasing enterprises' external credit supply capacity.

## 3. Methodology and data

### 3.1. Models setting

#### 3.1.1. Models of direct impacts

The Chinese government implements different policies to intervene in the economy every year to promote economic development, as its a state-led economy. These policies may affect enterprises' cash holdings. Therefore, annual fixed effects have to be taken into account. Meanwhile, each enterprise has some factors that cannot be observed and do not change with time but affect its cash holdings. Therefore, this requires controlling for the enterprises' fixed effects. Therefore, we refer to the extant literature [16,25,46] to construct the two-way fixed effects (TWFE) model:

$$Cash_{it} = \alpha_0 + \beta_1 * DEDI_{it} + \eta * X + \alpha_i + \lambda_t + \varepsilon_{it} \tag{1}$$

In this equation, $i$ and $t$ represent the subscripts of enterprise and year respectively; $\alpha_i$ represents the enterprise-specific fixed effects; $\lambda_t$ represents the capture of annual fixed effects; $\varepsilon_{it}$ represents the residual term. $Cash_{it}$ is the explained variable. $DEDI_{it}$ is the core explanatory variable. $\beta_1$ is the coefficient of $DEDI_{it}$. If it is significantly negative, then the DEDI has the effect of reducing enterprises' cash holdings. X represents all the control variables described below.

#### 3.1.2. Models of indirect impacts

To test indirect impacts, we designed the following models drawing upon existing literature on indirect impacts [41,47].

$$Cash_{it} = \alpha_0 + \beta_1 * DEDI_{it} + \eta * X + \alpha_i + \lambda_t + \varepsilon_{it} \tag{2}$$

$$MED_{it} = \alpha_0 + \theta * DEDI_{it} + \eta * Z + \alpha_i + \lambda_t + \varepsilon_{it} \tag{3}$$

$$Cash_{it} = \alpha_0 + \beta_1 * DEDI_{it} + \beta_2 * MED_{it} + \eta * X + \alpha_i + \lambda_t + \varepsilon_{it} \tag{4}$$

$MED_{it}$ is the intermediary variable, namely, debt-financing capacity (*Dfc*) and external credit supply capacity (*Bcrt*). X in Equations (2) and (4), and Z in Equation (3) represents the control variables.

The procedure for conducting the tests is as follows. First, an estimation of Equation (2) is conducted. If $\beta_1$ is significant, then the DEDI can affect corporate cash holdings; accordingly, we continue with the subsequent analysis. Second, Equation (3) is estimated to test the impact of the DEDI on the intermediary variables. Next, Equation (4) is estimated. If the coefficient $\theta$ of $DEDI_{it}$ in Equation (3) and coefficient $\beta_2$ of the intermediary variable in Equation (4) are both statistically significant, it can be concluded that a mediating effect is existing. If one of the coefficient $\theta$ and $\beta_2$ is statistically significant, then Sobel's test should be used to determine whether the mediating effect exists.
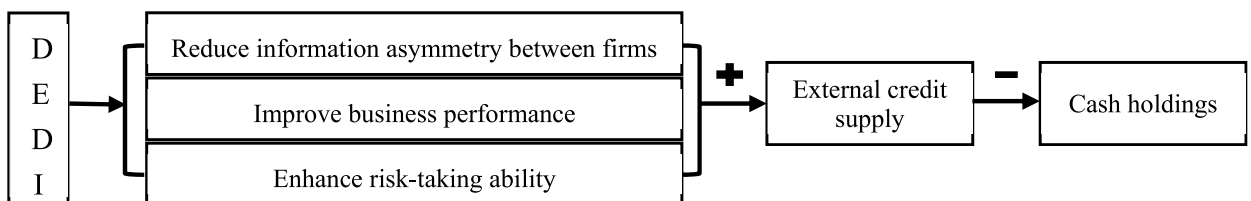


**Fig. 3.** Indirect effects of external credit supply capacity.

## 3.2. Variables description

The name, sign and measurement of explained, core explanatory, intermediary, and control variables are presented in Table 1.

### 3.2.1. Explained variables

In this study, the explained variable is the level of corporate cash holdings (*Cash*). Referring to previous literature [16,25,46], this paper uses the measure mentioned in Table 1 to get *Cash*. Additionally, Florackis and Sainani [19] consider trading financial assets as cash. On the basis of existing literature [48], this study also obtains *rCash* using the measure mentioned in Table 1. *Cash* and *rCash* are proxy variable for the cash holding levels.

### 3.2.2. Core explanatory variables

The core explanatory variable is the development level of the urban DEDI (*DEDI*). At present, Data on urban DEDI in China is not publicly available. The NBS of China divides the DEDI into the following seven sub-industries in Table 2. We construct the following keywords based on the classification provided by the NBS (see Table 2). Furthermore, based on the business scope includes these keywords, we searched by city for the number and registered capital of enterprises in that city. We obtain 14 data items from the seven sub-industries. We then use factor analysis to generate an urban DEDI development index based on a total of 14 data items.

Before using factor analysis, the Kaiser-Meyer-Olkin (KMO) and Bartlett's spherical tests are necessary. The KMO test yields a KMO value of 0.802, exceeding the 0.6 threshold value. The Bartlett's test shows a chi-square statistic of 60080.768, and the p-value is less than 0.0001. Therefore, the 14 data items met the prerequisites of the factor analysis. Therefore, we use factor analysis and normalise data by $((X\text{-Min})/(\text{Max-Min})) \times 10$, and measure the DEDI development index in each city in each year to obtain the *DEDI*. This is used as a proxy variable for the urban DEDI. Next, we added 1 to *DEDI* and took the natural logarithm to get *rDEDI,* another proxy variable for the urban DEDI.

Fig. 4 reports the mean DEDI for all cities in China (blue), eastern cities (yellow), and central and western cities (gray) from 2008 to 2020. As shown in Fig. 4, since 2008, China's DEDI has shown a rapid upward trend. The DEDI index in 2008 was 0.999, reaching 21.6234 in 2020. Meanwhile, the DEDI in cities of the eastern area have always been highest. The gap between the eastern region and the central and western region is gradually widening.

### 3.2.3. Intermediary variables

The intermediary variables are debt-financing capacity (*Dfc*) and external credit supply capacity (*Bcrt*). The financial leverage of enterprises can reflect their debt-financing capacity. Therefore, we obtain *Dfc* as a proxy variable for debt-financing capacity as (total liabilities/total assets) $\times$ 100. In accounting, trade credit is the credit sales amount formed by enterprises' deferred collection when selling goods and providing labor services to downstream customers [43] and prepayments formed by prepayments to upstream customers. As stipulated in the Accounting Standards for Business Enterprises, the asset item on an enterprise's balance sheet is the net amount after deducting impairment provision (e.g., provision for bad debts). Therefore, this study refers to Chen et al. [49] and Wu [50] and obtains *Bcrt* as a proxy variable for an enterprise's trade credit supply capacity, based on the following equation: ((accounts receivable + notes receivable + prepayments + provision for bad debts)/total assets) $\times$ 100.

**Table 1**
Description of variables.

| Types | Name | Sign | Measurement |
|---|---|---|---|
| Explained variables | Cash holdings level | *Cash* | ((Cash + cash equivalents)/total assets) $\times$ 100 |
| | | *rCash* | ((Cash + trading financial assets)/(Total assets - cash and cash equivalents)) $\times$ 100 |
| Core explanatory variables | Data element-driven industry | *DEDI* | Urban DEDI development index is extracted using factor analysis based on 14 data items comprising the number of enterprises and registered capital on the Internet platform. |
| | | *rDEDI* | Ln (1+ *DEDI*) |
| Intermediary variables | Debt-financing capacity | *Dfc* | (Total liabilities/total assets) $\times$ 100 |
| | External credit supply capacity | *Bcrt* | ((Accounts receivable + notes receivable + prepayments + provision for bad debts)/Total assets) $\times$ 100 |
| Control variables | Tobin's Q | *TobQ* | Enterprise's market value/its book value |
| | Enterprise size | *Size* | Ln (enterprise's total assets) |
| | Enterprise age | *Eage* | Ln (1 + years in business) |
| | Shareholding concentration | *First* | Largest shareholder's shareholding ratio |
| | Growth | *Grow* | Operating revenue growth rate |
| | Profitability | *Roa* | EBIT/average total assets |
| | Asset turnover ratio | *Atr* | Operating income/average total assets |
| | Cash flow from operations | *Ocf* | (Net cash flows from operations of the enterprise/non-cash assets) $\times$ 100 |
| | payments of dividend and interest | *Dip* | (Cash paid for dividends distribution and interest/total assets) $\times$ 100 |
| | Economic development level | *Edl* | Ln (real GDP per head of the enterprise' city) |
| | Allocation level of lending resource | *Cra* | Banks' loans per head of the enterprise's city |

**Table 2**

Seven sub-industries of DEDI and our search keywords.

| Serial Number | Sub-industry | Keyword |
|---|---|---|
| 1 | Internet platforms | Internet production service platform, industrial Internet platform, Internet bulk commodity trading platform, Internet cargo transport platform, Internet car-hailing service platform, Internet sports platform, Internet education platform, Internet social networking platform, Internet life services platform, Internet technology innovation platform, network maker platform, technology innovation network platform, scientific and technological achievements network promotion platform, intellectual property trading platform, open source community platform, Internet public security service platform, Internet environment protection platform, Internet data platform |
| 2 | Internet wholesale and retail | Internet wholesale, Internet retail, online wholesale, online retail, online mall |
| 3 | Internet finance | Online lending services, Payment services by non-financial institutions, and financial information services |
| 4 | Digital content and media | Radio, television, film and television programing, integrated broadcasting and control of radio and television, distribution of movies and radio and television programs, production of film projection recordings, digital content publishing, and digital advertising |
| 5 | Information infrastructure construction | Information infrastructure construction, network infrastructure construction, new technology infrastructure construction, wiring and equipment engineering construction, electrical installation |
| 6 | Data resources and property rights trading | Data transactions and data elements |
| 7 | Other digital element driven industries | Supply chain management services, security system monitoring services, digital technology research, and experimental development |
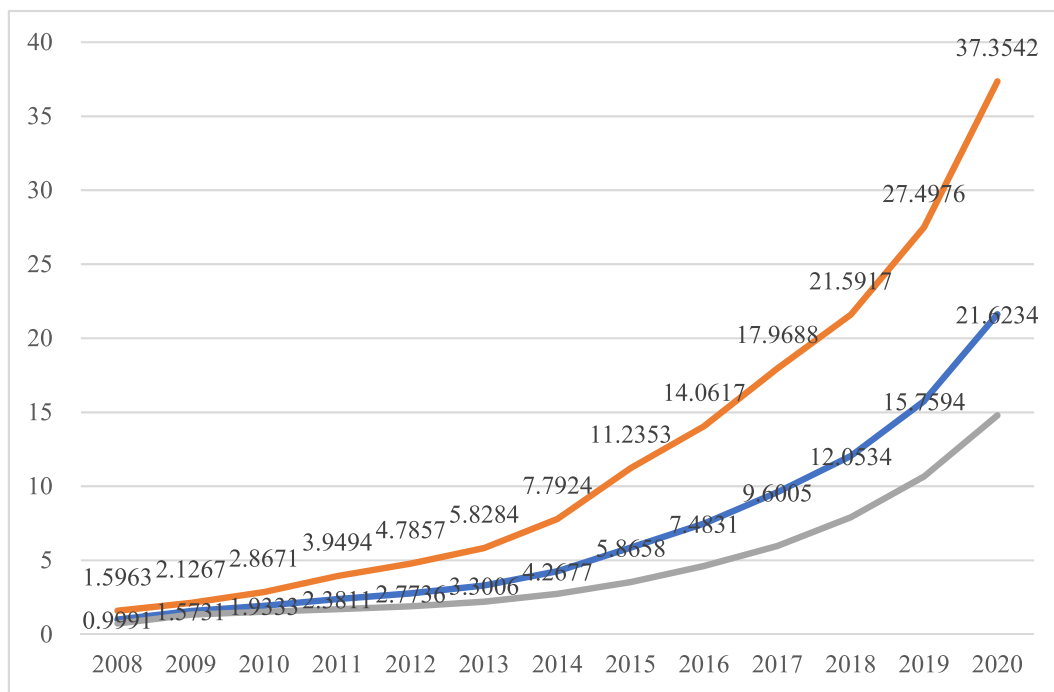


**Fig. 4.** Mean of DEDI in all cities, eastern and central western regions of China.

#### 3.2.4. Control variables

For Equations (1), (2) and (4), we control for enterprise Tobin's Q, enterprise size, enterprise age, shareholding concentration, growth, profitability, asset turnover ratio, operating cash flow, and dividend and interest payments, following the previous literature [16,25,46]. With reference to Li et al. [46], we controlled for economic development level and lending resource allocation level when investigating macro variables' impact on enterprises' micro-variables.

For Equation (3), when debt-financing capacity is the intermediary variable, following the existing literature [51,52], we controlled for enterprise size, profitability, growth, enterprise Tobin's Q, board independence, board size, CEO duality, institutional investor ownership, shareholding concentration, and asset turnover ratio. Similarly, we take the economic development level and lending resource allocation level as control variables. When external credit supply capacity is the intermediary variable, we controlled for enterprise size, profitability, growth, board size, enterprise age, and enterprise leverage with reference to literature [49]. Additionally, shareholding concentration, board independence, and CEO duality affect an enterprise's risk-taking [51], which may affect its

credit supply. Therefore, we controlled for shareholding concentration, board independence, and CEO duality. Institutional investors are beneficial for improving corporate performance [53], which may affect corporate credit supply. Therefore, this study controlled for institutional investor shareholdings. Board size is the natural logarithm of directors' number, board independence is measured in terms of (the number of independent directors/number of directors), and CEO duality takes the value 1 when the chairperson of the board is also the CEO; otherwise, it takes 0.

### 3.3. Data

#### 3.3.1. Sources of data

In recent years, the digital economy has attracted widespread attention [41,54]. Especially after 2008, digital technology and DEDI have entered the stage of commercial application in China rapidly. The China City Statistical Yearbook has disclosed data before 2020. Therefore, we use data from Chinese cities and A-share listed enterprises on the Shanghai and Shenzhen stock markets for the period 2008 to 2020 to conduct the empirical analysis. In this study, we process the data as follows: we exclude (1) the missing samples, (2) the samples of financial enterprises, and (3) the samples of enterprises with ST and *ST. Finally, we obtain 30,208 annual enterprise observations.

The data required for calculating the *DEDI* are from China's State Administration for Market Supervision, and other data are from the China City Statistical Yearbook and Wind database. We performed a Winsorized tail reduction of up and down 1 % on other continuous variables, except for the variable that takes the natural logarithm, to reduce the outliers' influence.

#### 3.3.2. Summary statistics

The summary statistics of the variables are shown in Table 3. First, the mean of corporate cash holding level (*Cash*) is 16.9212 %, minimum value is 0.5292 %, and the maximum is 71.8340 %. Second, the mean value of the DEDI (*DEDI*) is 7.3122, with a minimum value of only 0.0035 and a maximum of 44.3050. Third, the maximum value of *rCash* exceeds 100 % because the denominator is total assets minus cash and cash equivalents when calculating *rCash*, not total assets. Considering the missing data, there are 30,081 observations of external credit supply capacity (*Bcrt*).

Table 4 reports the variance inflation factors (VIF) of variables. From Table 4, the maximum value of the VIF for these variables is 6.62, which is less than 10. Therefore, we can exclude the influence of multicollinearity on the estimation results.

## 4. Research results

### 4.1. Benchmark regression

When estimating Equation (1), we used Hausman test on the individual fixed effects (FE) and random effects (RE) estimation results. The Hausman test indicated that the FE should be used for estimation, because the chi-square statistic of the test was 1311.19, with a p-value less than 0.0001. Therefore, the control variables were gradually added to estimate Equation (1) with FE. Table 5 shows the results. From columns (1)–(5) of Table 5, the coefficients of *DEDI* are all significantly negative at the 1 % significance level, indicating that the DEDI reduces corporate cash holdings. So, hypothesis H1 is supported by the empirical results.

Fig. 5 is based on the estimated results in column (5) of Table 5. Under other unchanged conditions, the marginal impact of the DEDI on corporate cash holdings and their 95 % confidence interval are plotted. As shown in Fig. 5, with an increase in DEDI, corporate cash holding levels significantly decrease.

**Table 3**
Summary statistics.

| Variables | Obs. | Mean | Std. Dev. | Min | Max. |
|-----------|------|------|-----------|-----|------|
| Cash | 30,208 | 16.9212 | 13.6695 | 0.5292 | 71.8340 |
| rCash | 30,208 | 29.2829 | 34.8799 | 0.6270 | 254.0635 |
| DEDI | 30,208 | 7.3122 | 11.0513 | 0.0035 | 44.3050 |
| rDEDI | 30,208 | 1.3784 | 1.1730 | 0.0000 | 4.1344 |
| Dfc | 30,208 | 42.7064 | 20.9001 | 5.4582 | 97.1510 |
| Bcrt | 30,081 | 17.1457 | 12.3245 | 0.0000 | 59.1589 |
| TobQ | 30,208 | 2.5573 | 1.8826 | 0.8504 | 13.4454 |
| Size | 30,208 | 12.9106 | 1.3329 | 7.3092 | 19.4262 |
| Eage | 30,208 | 2.8692 | 0.3389 | 0.0000 | 4.1897 |
| First | 30,208 | 35.0439 | 15.0075 | 8.4800 | 80.6500 |
| Grow | 30,208 | 1.1751 | 0.4262 | 0.3868 | 3.9180 |
| Roa | 30,208 | 6.3208 | 7.1412 | −22.3258 | 45.6624 |
| Atr | 30,208 | 0.6758 | 0.4638 | 0.0286 | 2.7832 |
| Ocf | 30,208 | 6.6476 | 10.7620 | −25.3804 | 83.6991 |
| Dip | 30,208 | 2.3947 | 1.8561 | 0.0248 | 14.9493 |
| Edl | 30,208 | 3.8500 | 0.9949 | 0.5940 | 6.5136 |
| Cra | 30,208 | 1.1200 | 1.1031 | 0.0643 | 5.8720 |

**Table 4**
VIF of variables.

| Variables | VIF | 1/VIF |
|-----------|-----|-------|
| *rDEDI* | 6.62 | 0.1510 |
| *DEDI* | 6.05 | 0.1653 |
| *Edl* | 3.82 | 0.2619 |
| *Cra* | 3.67 | 0.2724 |
| *Size* | 1.81 | 0.5520 |
| *Dfc* | 1.71 | 0.5842 |
| *Roa* | 1.65 | 0.6070 |
| *Ocf* | 1.46 | 0.6865 |
| *TobQ* | 1.44 | 0.6927 |
| *rCash* | 1.38 | 0.7260 |
| *Bcrt* | 1.26 | 0.7963 |
| *Eage* | 1.23 | 0.8130 |
| *Dip* | 1.21 | 0.8243 |
| *Atr* | 1.21 | 0.8248 |
| *Grow* | 1.15 | 0.8724 |
| *First* | 1.12 | 0.8893 |

*4.2. Robustness checks*

1. Controlling endogeneity. The previous section show that the DEDI significantly affects corporate cash holdings. Conversely, corporate cash holdings (*Cash*) is a micro-variable, so it has very little impact on the DEDI development level *(DEDI)*, which is a macro-variable. However, it is possible that the DEDI development level is endogenous due to errors of measurement or factors that are difficult to be observed. Therefore, we calculate the average value of the DEDI of other cities in the same year, generating *ivDEDI,* and use it as an instrumental variable. First, *ivDEDI* is related to *DEDI*. The DEDI development levels across other cities and this city can be all affected by unobservable factors or measurement errors. Second, *ivDEDI* is exogenous because it is difficult for other cities' DEDI to affect the corporate cash holdings in this area. We take *ivDEDI* as the instrumental variable and use the instrumental variable method (IV) to estimate Equation (1). In weak instrumental variable test, the Cragg-Donald F-statistic is 650,000, and it is significantly greater

**Table 5**
FE estimation results of Equation (1).

| Variables | (1) | (2) | (3) | (4) | (5) |
|-----------|-----|-----|-----|-----|-----|
| | Cash | Cash | Cash | Cash | Cash |
| *DEDI* | −0.1425*** | −0.1245*** | −0.1220*** | −0.1012*** | −0.0830*** |
| | (0.0121) | (0.0119) | (0.0119) | (0.0114) | (0.0131) |
| *TobQ* | | 0.6204*** | 0.6115*** | 0.2103*** | 0.2122*** |
| | | (0.0617) | (0.0617) | (0.0580) | (0.0580) |
| *Size* | | −1.2603*** | −1.3594*** | −1.5696*** | −1.5369*** |
| | | (0.1524) | (0.1518) | (0.1488) | (0.1487) |
| *Eage* | | −26.5622*** | −25.3559*** | −24.1124*** | −24.3708*** |
| | | (1.4115) | (1.3985) | (1.2626) | (1.2638) |
| *First* | | | 0.0842*** | 0.0776*** | 0.0755*** |
| | | | (0.0102) | (0.0095) | (0.0095) |
| *Grow* | | | | −0.8611*** | −0.8672*** |
| | | | | (0.1607) | (0.1607) |
| *Roa* | | | | 0.2229*** | 0.2225*** |
| | | | | (0.0133) | (0.0132) |
| *Atr* | | | | −2.9074*** | −2.8450*** |
| | | | | (0.2863) | (0.2852) |
| *Ocf* | | | | 0.2754*** | 0.2761*** |
| | | | | (0.0087) | (0.0087) |
| *Dip* | | | | −0.2514*** | −0.2454*** |
| | | | | (0.0465) | (0.0464) |
| *Edl* | | | | | 4.0425*** |
| | | | | | (0.7524) |
| *Cra* | | | | | −0.8322*** |
| | | | | | (0.2163) |
| *Constant* | 18.9679*** | 97.0699*** | 92.1991*** | 93.0483*** | 80.3230*** |
| | (0.2702) | (3.8360) | (3.8588) | (3.5250) | (4.2503) |
| Enterprise FE | Yes | Yes | Yes | Yes | Yes |
| Time FE | Yes | Yes | Yes | Yes | Yes |
| Obs. | 30,208 | 30,208 | 30,208 | 30,208 | 30,208 |
| $R^2$ | 0.1322 | 0.1701 | 0.1725 | 0.2495 | 0.2511 |

Notes: Robust standard errors are in parentheses; ***$p < 0.01$, **$p < 0.05$, and * $p < 0.1$. The same below.
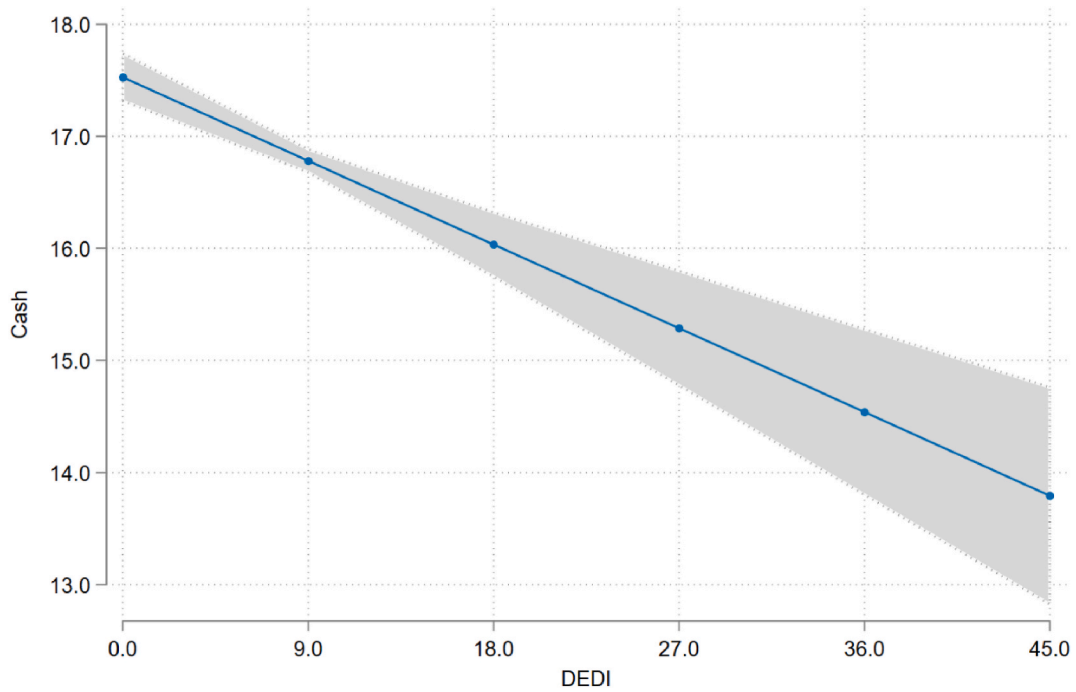
**Fig. 5.** Marginal impact of DEDI on corporate cash holdings and its 95 % confidence interval.

than the critical value under the 10 % bias. Therefore, we conclude that *ivDEDI* is a suitable instrumental variable.

Equation (1) is estimated using IV with *ivDEDI* as the instrumental variable, resulting in column (1) of Table 6. Column (1) shows that DEDI reduces the cash holdings. Therefore, after excluding endogeneity, we conclude that H1 is robust.

Lagging the explanatory variable by one period alleviates endogeneity. So, we use the explanatory variable lagged by one period and the FE to re-estimate Equation (1). The results are presented in column (2) of Table 6. Column (2) shows that the coefficient of lagging explanatory variable is significantly negative. Thus, we conclude that H1 remains robust.

2. Other robustness test. We use the following method to conduct the robustness test. First, we change the explained variable with *rCash*, resulting in column (3) of Table 6. Second, we replace the explanatory variable with *rDEDI*, and column (4) of Table 6 displays the results of replacing the explanatory variable. Third, we change the estimation model. Previous literature (e.g., Ref. [19]) also estimates the level of cash holdings, controlling for industry- and time-fixed effects. We re-estimate Equation (1) by adding industry- and time-fixed effects, resulting in column (5) of Table 6. Fourth, we use the maximum likelihood estimation (MLE) method to re-estimate Equation (1) to reduce the bias introduced by the estimation method, resulting in column (6) of Table 6.

Columns (3)–(6) of Table 6 show that DEDI has a significant negative impact on corporate cash holdings, indicating the robustness of the benchmark regression results. So, we conclude that H1 is robust.

**Table 6**
Robustness test result of Equation (1).

| 变量 | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | *Cash* | *Cash* | *rCash* | *Cash* | *Cash* | *Cash* |
| *DEDI* | −0.0797*** | | −0.3238*** | | −0.0330*** | −0.0387*** |
| | (0.0143) | | (0.0367) | | (0.0091) | (0.0095) |
| *L.DEDI* | | −0.0586*** | | | | |
| | | (0.0136) | | | | |
| *rDEDI* | | | | −0.8870*** | | |
| | | | | (0.1712) | | |
| Control | Yes | Yes | Yes | Yes | Yes | Yes |
| Enterprise FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Industry FE | No | No | No | No | Yes | No |
| Time FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Obs. | 30,208 | 26,578 | 30,208 | 30,208 | 30,208 | 30,208 |
| $R^2$ | 0.2511 | 0.1888 | 0.2372 | 0.2506 | 0.2371 | – |

## 5. Indirect impact test

### 5.1. Indirect effects of debt-financing capacity

Using debt-financing capacity (*Dfc*) as the intermediary variable, Equations (2)–(4) were estimated, resulting in columns (1)–(3) of Panel A in Table 7. It can be seen that there is a mediating effect. Taking together the symbol and significance of DEDI development level (*DEDI*) and debt-financing capacity (*Dfc*), we conclude that DEDI enhances enterprises' debt-financing capacity, which reduces corporate cash holdings; thus, hypothesis H2 is confirmed.

When estimating Equation (3), the DEDI development level (*DEDI*) may be endogenous due to measurement errors or factors that are difficult to be observed. Therefore, Equation (3) is re-estimated using *ivDEDI* as an instrumental variable, resulting in column (4) of

**Table 7**
Estimated results of indirect effects of debt financing capacity.

| Panel A | | | | | |
|---|---|---|---|---|---|
| Variables | (1) | (2) | (3) | (4) | (5) |
| | Cash | Dfc | Cash | Dfc | Cash |
| DEDI | −0.0830*** | 0.0803*** | −0.0631*** | 0.0784*** | −0.0608*** |
| | (0.0131) | (0.0150) | (0.0124) | (0.0162) | (0.0136) |
| Dfc | | | −0.2680*** | | −0.2641*** |
| | | | (0.0064) | | (0.0077) |
| Enterprise FE | Yes | Yes | Yes | Yes | Yes |
| Time FE | Yes | Yes | Yes | Yes | Yes |
| Control | Yes | Yes | Yes | Yes | Yes |
| Obs. | 30,208 | 30,208 | 30,208 | 30,208 | 30,208 |
| $R^2$ | 0.2511 | 0.1612 | 0.3184 | 0.1693 | 0.3183 |
| **Panel B** | | | | | |
| Variables | (1) | (2) | (3) | (4) | (5) |
| | Cash | Dfc | Cash | Dfc | Cash |
| rDEDI | −0.8870*** | 1.0370*** | −0.5751*** | 1.7442*** | −1.3518*** |
| | (0.1712) | (0.2021) | (0.1631) | (0.3604) | (0.3033) |
| Dfc | | | −0.2681*** | | −0.2636*** |
| | | | (0.0064) | | (0.0076) |
| Enterprise FE | Yes | Yes | Yes | Yes | Yes |
| Time FE | Yes | Yes | Yes | Yes | Yes |
| Control | Yes | Yes | Yes | Yes | Yes |
| Obs. | 30,208 | 30,208 | 30,208 | 30,208 | 30,208 |
| $R^2$ | 0.2506 | 0.1692 | 0.3180 | 0.1687 | 0.3174 |
| **Panel C** | | | | | |
| Variables | (1) | (2) | (3) | (4) | (5) |
| | rCash | Dfc | rCash | Dfc | rCash |
| DEDI | −0.3238*** | 0.0825*** | −0.2804*** | 0.0784*** | −0.2736*** |
| | (0.0367) | (0.0149) | (0.0354) | (0.0162) | (0.0383) |
| Dfc | | | −0.5840*** | | −0.5833*** |
| | | | (0.0177) | | (0.0234) |
| Enterprise FE | Yes | Yes | Yes | Yes | Yes |
| Time FE | Yes | Yes | Yes | Yes | Yes |
| Control | Yes | Yes | Yes | Yes | Yes |
| Obs. | 30,208 | 30,208 | 30,208 | 30,208 | 30,208 |
| $R^2$ | 0.2372 | 0.1693 | 0.2826 | 0.1693 | 0.2826 |
| **Panel D** | | | | | |
| | (1) | (2) | (3) | (4) | (5) |
| Variables | rCash | Dfc | rCash | Dfc | rCash |
| rDEDI | −4.0280*** | 1.0370*** | −3.3489*** | 1.7442*** | −6.0802*** |
| | (0.4750) | (0.2021) | (0.4584) | (0.3604) | (0.8522) |
| Dfc | | | −0.5839*** | | −0.5814*** |
| | | | (0.0177) | | (0.0234) |
| Enterprise FE | Yes | Yes | Yes | Yes | Yes |
| Time FE | Yes | Yes | Yes | Yes | Yes |
| Control | Yes | Yes | Yes | Yes | Yes |
| Obs. | 30,208 | 30,208 | 30,208 | 30,208 | 30,208 |
| $R^2$ | 0.2368 | 0.1692 | 0.2822 | 0.1687 | 0.2812 |

Note: The validity of the instrumental variables is tested.

Panel A in Table 7. Moreover, cash, as a liquid asset, increases debt capacity [55]. Cash holdings play a signaling role in characterizing debt capacity [56]. When estimating Equation (4), corporate cash holdings affect debt-financing capacity. Thus, a bidirectional causal relationship exists between corporate cash holdings and debt-financing capacity. Thus, debt-financing capacity ($Dfc$) is endogenous. Here, we draw on Section 4.2 and use the mean value of debt-financing capacity of other enterprises in the same year ($ivDfc$) as the instrumental variable. Then we use the instrumental variable method (IV), together with $ivDEDI$, to re-estimate Equation (4), resulting in column (5) of Panel A in Table 7. So, we conclude that the DEDI increases debt-financing capacity and thereby reduces corporate cash holdings based on columns (4) and (5). Therefore, H2 holds when endogeneity is excluded.

Replacing the explanatory variable with *rDEDI*, we re-estimate Equations (2)–(4) using the same method and procedure as when the explanatory variable is *DEDI*, resulting in Panel B of Table 7. Replacing the explained variable with *rCash*, we re-estimate Equations (2)–(4), following the approach when the explained variable is *Cash*, resulting in Panels C and D in Table 7. Panels B, C, and D of

**Table 8**
Estimated results of indirect effects of external credit supply capacity.

Panel A

| Variables | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| | Cash | Bcrt | Cash | Bcrt | Cash |
| DEDI | −0.0808*** | 0.0505*** | −0.0689*** | 0.0516*** | −0.0666*** |
| | (0.0130) | (0.0089) | (0.0128) | (0.0097) | (0.0141) |
| Bcrt | | | −0.2530*** | | −0.2253*** |
| | | | (0.0109) | | (0.0212) |
| Enterprise FE | Yes | Yes | Yes | Yes | Yes |
| Time FE | Yes | Yes | Yes | Yes | Yes |
| Control | Yes | Yes | Yes | Yes | Yes |
| Obs. | 30,081 | 30,081 | 30,081 | 30,081 | 30,081 |
| R² | 0.2581 | 0.0410 | 0.2780 | 0.0410 | 0.2777 |

Panel B

| Variables | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| | Cash | Bcrt | Cash | Bcrt | Cash |
| rDEDI | −0.8704*** | 0.4524*** | −0.7937*** | 1.1435*** | −1.4758*** |
| | (0.1706) | (0.1220) | (0.1681) | (0.2150) | (0.3116) |
| Bcrt | | | −0.2541*** | | −0.2263*** |
| | | | (0.0109) | | (0.0209) |
| Enterprise FE | Yes | Yes | Yes | Yes | Yes |
| Time FE | Yes | Yes | Yes | Yes | Yes |
| Control | Yes | Yes | Yes | Yes | Yes |
| Obs. | 30,081 | 30,081 | 30,081 | 30,081 | 30,081 |
| R² | 0.2577 | 0.0404 | 0.2777 | 0.0391 | 0.2771 |

Panel C

| Variables | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| | rCash | Bcrt | rCash | Bcrt | rCash |
| DEDI | −0.3224*** | 0.0505*** | −0.2896*** | 0.0516*** | −0.2839*** |
| | (0.0367) | (0.0089) | (0.0359) | (0.0097) | (0.0388) |
| Bcrt | | | −0.6982*** | | −0.6136*** |
| | | | (0.0302) | | (0.0630) |
| Enterprise FE | Yes | Yes | Yes | Yes | Yes |
| Time FE | Yes | Yes | Yes | Yes | Yes |
| Control | Yes | Yes | Yes | Yes | Yes |
| Obs. | 30,081 | 30,081 | 30,081 | 30,081 | 30,081 |
| R² | 0.2439 | 0.0410 | 0.2654 | 0.0410 | 0.2651 |

Panel D

| Variables | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| | rCash | Bcrt | rCash | Bcrt | rCash |
| rDEDI | −3.9989*** | 0.4524*** | −3.7872*** | 1.1435*** | −6.2927*** |
| | (0.4731) | (0.1220) | (0.4649) | (0.2150) | (0.8611) |
| Bcrt | | | −0.7023*** | | −0.6177*** |
| | | | (0.0302) | | (0.0618) |
| Enterprise FE | Yes | Yes | Yes | Yes | Yes |
| Time FE | Yes | Yes | Yes | Yes | Yes |
| Control | Yes | Yes | Yes | Yes | Yes |
| Obs. | 30,081 | 30,081 | 30,081 | 30,081 | 30,081 |
| R² | 0.2436 | 0.0404 | 0.2653 | 0.0391 | 0.2641 |

Note: All instrumental variables pass validity tests. Given the missing data variable, *Bcrt* has only 30,081 observations.

Table 7 similarly show that the DEDI can improve enterprises' debt-financing capacity, thereby reducing corporate cash holdings. Thus, hypothesis H2 is still supported when endogeneity is excluded.

## 5.2. Indirect effects of external credit supply capacity

Using external credit supply capacity (*Bcrt*) as the intermediary variable, we carry out the estimation of Equations (2)–(4), resulting in columns (1)–(3) of Panel A in Table 8, which indicating that there is a mediating effect. Overall, considering the signs and significance of DEDI development level (*DEDI*) and external credit supply capacity (*Bcrt*), the DEDI can increase enterprises' external credit supply capacity, which reduces their cash holdings. Therefore, H3 is valid.

When estimating Equation (3), the development level of DEDI (*DEDI*) is endogenous due to errors of measurement or unobservables. Therefore, using *ivDEDI* as the instrumental variable, Equation (3) is re-estimated using IV method. Column (4) of Panel A in Table 8 displays the results. Additionally, the more cash an enterprise holds, the more it can afford to externally supply credit. Therefore, there is a bidirectional causality between corporate cash holdings and external credit supply capacity when estimating Equation (4). Thus, the external credit supply capacity (*Bcrt*) is endogenous. Here, referring to Section 4.2, we use the average of the external credit supply capacity of other enterprises in the same year (*ivBcrt*) as the instrumental variable, together with *ivDEDI*, to re-estimate Equation (4) using the IV method. Column (5) of Panel A in Table 8 shows the results. The results in the mentioned columns (4) and (5) indicating that the DEDI can increase enterprises' external credit supply capacity and then reduce corporate cash holdings. Thus, H3 is supported when endogeneity is excluded.

Replacing the explanatory variable with *rDEDI*, Equations (2)–(4) were re-estimated using the same method and procedure as when the explanatory variable is *DEDI*, resulting in Panel B of Table 8. Then we replace the explained variable with *rCash*, following the approach when the explained variable is *Cash*; we re-estimate Equations (2)–(4), resulting in Panels C and D of Table 8. Panels B, C, and D of Table 8 similarly show that the DEDI increase enterprises' external credit supply capacity, which subsequently reduce corporate cash holdings. Therefore, even after excluding endogeneity, H3 holds.

## 6. Heterogeneity analysis

### 6.1. Heterogeneity analysis of CEO duality

CEO duality means one person serving as both the CEO and board chair. The CEO of a CEO duality enterprise has greater control and decision-making power [17], stronger responsibility, and executive power over the enterprise. This can improve the decision-making system and avoid disruptive delays in corporate decisions [57]. Executors with greater power are active in implementing corporate strategies. They can effectively avoid confusion and disengagement between decision-making and execution caused by the presence of multiple senior managers in the enterprise. Therefore, enterprises with CEO duality are able to respond quickly to external changes [58].

Based on this, the data advantages and market opportunities brought about by the rapid DEDI development can be captured by managers in CEO duality enterprises, who are more aware of what decisions are needed to improve enterprise performance [59]. The DEDI development puts enterprises in a dynamic business environment. CEO duality enterprises give managers more discretionary power, which enhances their ability to respond more flexibly in a dynamic business environment, improving management efficiency of enterprises [57,58]. It also enables them to more efficiently allocate resources. Therefore, the DEDI's effect in improving information environment, accuracy of corporate decision-making and forecasting, and asset turnover is greater in enterprises with CEO duality. Moreover, managers of CEO duality enterprises are more sensitive and direct in effectively allocating resources and stabilizing customer relationships by improving debt-financing and external trade credit supply capacities, thereby reducing cash holdings. This implies that, for CEO duality enterprises, the DEDI plays a greater role in reducing corporate cash holdings.

**Table 9**
Estimated results of CEO duality heterogeneity.

| Variables | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | *Cash* | *rCash* | *Cash* | *rCash* |
| *DEDI* (CEO non-duality) | −0.0551*** | −0.2503*** | | |
| | (0.0131) | (0.0364) | | |
| *DEDI* (CEO duality) | −0.1790*** | −0.5765*** | | |
| | (0.0175) | (0.0515) | | |
| *rDEDI* (CEO non-duality) | | | −0.7507*** | −3.6765*** |
| | | | (0.1718) | (0.4738) |
| *rDEDI* (CEO duality) | | | −1.3177*** | −5.1392*** |
| | | | (0.1920) | (0.5471) |
| Enterprise FE | Yes | Yes | Yes | Yes |
| Time FE | Yes | Yes | Yes | Yes |
| Control | Yes | Yes | Yes | Yes |
| Obs. | 30,208 | 30,208 | 30,208 | 30,208 |
| $R^2$ | 0.2536 | 0.2397 | 0.2515 | 0.2377 |

To test this conjecture, we classify enterprises into CEO duality and non-duality based on whether the same individual serves as CEO and board chair. The varying-coefficient individual fixed-effects model was used to estimate Equation (1) with *Cash* and *rCash* as explained variables respectively, and *DEDI* as the explanatory variable; the results are shown in columns (1) and (2) of Table 9. Replacing the explanatory variable with *rDEDI* and using *Cash* and *rCash* as explained variables results in columns (3) and (4) of Table 9. From Table 9, we derive the several conclusions. First, the coefficients of DEDI are significantly negative at the 1 % significance level for both CEO duality and non-duality enterprises, indicating that the DEDI can reduce corporate cash holdings. Second, the absolute value of the coefficient of CEO duality enterprises' explanatory variable is larger than that of CEO non-duality enterprises, indicating that the impact of DEDI in decreasing corporate cash holdings is larger for CEO duality enterprises.

### 6.2. Heterogeneity analysis of enterprises size

SMEs significantly differ from large enterprises in terms of behavioral flexibility and the information asymmetry problems they face. First, the characteristics of SMEs, such as their small size, few management levels, and high flexibility, contribute to better transmission of market information, rapid response to market information [60], and timely adjustments of business behavior. SMEs are highly adaptable and can quickly adapt to changes in business operation models [10]. Conversely, large enterprises often have multiple levels of bureaucracy and complex organizational structures. It is usually necessary for them to plan in advance to implement changes. Thus, large enterprises adjust their business behavior with long cycles and slow actions.

Second, SMEs face more severe information asymmetry problems; therefore, they are more sensitive to DEDI development. SMEs have limited access to traditional data sources, face more severe information asymmetry, and, consequently hold higher levels of cash [28]. Thus, DEDI development has had an even greater impact on the behavior of SMEs after dramatically improving their information environment. Specifically, in terms of debt-financing capacity, SMEs face greater financing constraints because of information asymmetry [20]. When the information environment improves, SMEs' debt-financing capacity generally increases to a greater extent than that of large enterprises; moreover, the motives to hoard cash are reduced. In terms of external credit supply capacity, SMEs face greater competition and depend more on upstream and downstream enterprises for their daily operations. Thus, when information asymmetry significantly improves, they have more incentives and improved ability to use cash to provide external trade credit to maintain competitiveness and customer relationships. This finding implies that the DEDI's role in decreasing corporate cash holdings is greater for SMEs.

To test this speculation, we categorize enterprises with a size above the annual median as large enterprises and those below as SMEs, following Florackis and Sainani [19]. Next, using *Cash* and *rCash* as explained variables and *DEDI* as an explanatory variable, Equation (1) is estimated using the varying-coefficient individual fixed-effects. The results are displayed in columns (1) and (2) of Table 10. We replace the explanatory variable with *rDEDI* and use *Cash* and *rCash* as explained variables, resulting in columns (3) and (4) of Table 10, respectively. From Table 10, we draw several conclusions. First, the coefficients of the DEDI are significantly negative at 1 % or 10 % significance level for both large enterprises and SMEs, indicating that the DEDI reduce enterprise' cash holdings. Second, the absolute values of the coefficients of the explanatory variables of SMEs are larger than those of large enterprises, indicating that the effect of DEDI on reducing corporate cash holdings is greater for SMEs.

### 6.3. Heterogeneity analysis of industry

We believe that the impact of the DEDI on an enterprise's cash holdings is related to whether the enterprise belongs to the DEDI. The industry classification of Chinese listed companies has not yet formed a direct correspondence with the division of DEDI by the NBS. Moreover, the information technology industry is closest to the DEDI category. Accordingly, we conduct industry heterogeneity analysis based on whether enterprises belong to the information technology industry. The business operation modes of enterprises in the information technology industry, especially those in the DEDI, differ from those of enterprises in other industries. The enterprises

**Table 10**
Estimated results of enterprise size heterogeneity.

| Variables | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | *Cash* | *rCash* | *Cash* | *rCash* |
| *DEDI* (small and medium) | −0.2132*** | −0.7092*** | | |
| | (0.0177) | (0.0520) | | |
| *DEDI* (large) | −0.0248* | −0.1515*** | | |
| | (0.0132) | (0.0360) | | |
| *rDEDI* (small and medium) | | | −1.7009*** | −6.6688*** |
| | | | (0.1938) | (0.5550) |
| *rDEDI* (large) | | | −0.4518*** | −2.6161*** |
| | | | (0.1725) | (0.4691) |
| Enterprise FE | Yes | Yes | Yes | Yes |
| Time FE | Yes | Yes | Yes | Yes |
| Control | Yes | Yes | Yes | Yes |
| Obs. | 30,208 | 30,208 | 30,208 | 30,208 |
| $R^2$ | 0.2566 | 0.2441 | 0.2541 | 0.2420 |

in the information technology industry are highly dependent on Internet infrastructure, Internet platforms, and data elements, and their operations continuously generate data. They also have greater technological and platform advantages, enabling them to better utilize the beneficial effects of DEDI development. Compared to non-information technology enterprises, information technology enterprises can more proactively take advantage of the opportunities brought about by digitalization [61], and are more able to extract value from data elements. So, the impact of data elements on information technology enterprises is greater than that of other enterprises [62].

First, data elements are an advantage for information technology enterprises. Such enterprises can fully utilize data elements and effectively enhance the accuracy of enterprise decision-making and predictions based on DEDI development, thereby enhancing their ability to cope with information asymmetry and uncertainty. Second, considering the characteristics of data-sharing, the industry to which information technology enterprises belong can have a synergistic effect with other DEDI sub-industries, which can greatly improve the information environment of the information technology enterprises. Therefore, this reduces the motive to hold cash as a precautionary measure to a greater extent. In terms of transmission channels, given DEDI development, information technology enterprises have a greater degree of information symmetry. Therefore, the transmission channels of debt-financing capacity and external credit supply are more effective. This finding implies that the DEDI's role in reducing corporate cash holdings is stronger for information technology enterprises.

To test this hypothesis, we divide listed companies into information technology and non-information technology enterprises. Next, using *Cash* and *rCash* as explained variables and *DEDI* as an explanatory variable, we estimate Equation (1) using the varying-coefficient individual fixed-effects model. The results are shown in columns (1) and (2) of Table 11. We replace the explanatory variable with *rDEDI,* and use *Cash* and *rCash* as explained variables, resulting in columns (3) and (4) of Table 11. It shows that, first, whether it is information technology or non-information technology enterprises, *DEDI*'s coefficient is significantly negative. This finding indicates that the DEDI can reduce an enterprise's cash holdings. Second, the absolute value of the explanatory variable's coefficient for information technology enterprises is greater than that of non-information technology enterprises, indicating that DEDI plays a greater role in reducing cash holdings for information technology enterprises.

## 7. Discussion

Our findings suggest that the DEDI reduces corporate cash holdings. DEDI reduces enterprises' precautionary and transactional motives for holding cash by improving the information environment, enhancing the accuracy of enterprises' decisions and forecasts, and improving asset turnover. This coincides with results from Sun et al. [30], who find that the digital transformation of enterprises reduces cash holdings by mitigating transactional and precautionary motives.

Our study shows that DEDI increases enterprises' debt-financing capacity. DEDI improves enterprises' debt-financing capacity by reducing information asymmetry between banks and enterprises and other effects. This is consistent with the findings Li et al. [4], who argue that the digital economy can realize the rapid matching of information between the supply and demand sides of funds, reduce information asymmetry, and enhance creditors' prediction of the enterprise's cash flow, thus reducing enterprises' financing constraints and unclogging their external financing channels.

Our study suggests that DEDI increases the external trade credit supply capacity of enterprises. DEDI improves external credit supply capacity mainly by reducing the information asymmetry among enterprises in the supply chain, and by reducing the default risk faced by enterprises. This coincides with results from Wu et al. [50], who conclude that, when the default risk faced by enterprises is reduced because of trust, enterprises provide more trade credit to their customers. This is consistent with the findings of Liu and Wang [44], who show that digital transformation contributes to an increase in trade credit supply.

## 8. Conclusion, implications, and outlook

### 8.1. Conclusion

This study investigates the impact of the DEDI on corporate cash holdings. We conduct a theoretical analysis of the DEDI's impact on corporate cash holdings in terms of direct impact, indirect impact, and heterogeneity; we empirically test it using Chinese data from 2008 to 2020. For this, we use two-way fixed effects by time and individual. First, the DEDI reduces corporate cash holdings. As the development level of the DEDI in cities where enterprises are located increases, their cash holdings gradually decrease. Second, the DEDI indirectly affects corporate cash holdings by influencing debt-financing and external credit supply capacities. Specifically, in the upstream of funding sources, the DEDI increases enterprises' debt-financing capacity; in the downstream of funding sources, the DEDI increases enterprises' external credit supply capacity. Both of these effects reduce enterprises' cash holdings. Third, the impact of DEDI on corporate cash holdings is heterogeneous. For enterprises with CEO duality, SMEs, and technology industry enterprises, the effect is greater.

### 8.2. Implications

First, the government should provide multiple guarantees for the healthy development of DEDI. First, the construction of digital infrastructure should be further strengthened. The basic prerequisite for developing the DEDI is sound digital infrastructure, and the construction of digital infrastructure greatly varies from region to region. Therefore, the government should improve the digital infrastructure to provide basic protection for DEDI development. Second, the government should prevent the monopolization of the

**Table 11**

Estimated results of industry heterogeneity.

| Variables | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | Cash | rCash | Cash | rCash |
| DEDI(non-information technology) | −0.0439*** | −0.1832*** | | |
| | (0.0134) | (0.0367) | | |
| DEDI(information technology) | −0.3056*** | −1.1241*** | | |
| | (0.0260) | (0.0901) | | |
| rDEDI(non-information technology) | | | −0.5713*** | −2.7566*** |
| | | | (0.1725) | (0.4738) |
| rDEDI(information technology) | | | −3.2057*** | −13.3672*** |
| | | | (0.2880) | (0.9887) |
| Enterprise FE | Yes | Yes | Yes | Yes |
| Time FE | Yes | Yes | Yes | Yes |
| Control | Yes | Yes | Yes | Yes |
| Obs. | 30,208 | 30,208 | 30,208 | 30,208 |
| $R^2$ | 0.2553 | 0.2450 | 0.2555 | 0.2480 |

DEDI with reasonable regulations, allowing data elements to play a better role in enterprises, promoting enterprises to more effectively use cash, and enhancing the value of enterprises. Third, the government must promote the integrated development of the DEDI and data market, improve the data element trading mechanism. It should break barriers to circulate data elements among multiple subjects, such as among different platforms and enterprises, promote cross-industry integration and use of data. Thus, the government can provide a favorable data element environment for enterprises.

Second, enterprises should actively embrace DEDI development. First, the roles brought about by DEDI development should be emphasized from the perspective of the strategic development of enterprises. Second, enterprises' ability to internalize the development advantages of the DEDI should be enhanced. This will effectively transform data into a resource to alleviate information asymmetry. Third, SMEs are numerous and form an essential foundation of a country's economy, but are relatively deficient in data capabilities. Therefore, it is important for SMEs to overcome these difficulties and focus on improving their data capabilities. The government should also provide SMEs with targeted protection and assistance to reduce the cost of internalizing and utilizing the advantages of DEDI development and enhance their ability to utilize data. Fourth, our research shows that CEO duality enterprises' cash holdings are more sensitive to DEDI development; therefore, enterprises should continuously improve managers' abilities and sensitivity of decision-making. Fifth, enterprises in the information technology industry can benefit from DEDI development. Therefore, they should actively utilize the effects brought by the DEDI development to promote their own development. Furthermore, enterprises should actively utilize the DEDI to effectively enhance their debt-financing and external credit supply capacities, thereby improving cash utilization efficiency and enterprise value, and ultimately contributing to macroeconomic growth.

Third, this study provides recommendations for China's policy-making and Chinese enterprise development and implications for other developing countries. Enterprises face information asymmetry, making it difficult to obtain external financing, and face default risks when providing trade credit, which are common problems in many developing countries. Therefore, in a rapidly developing digital economy, developing countries should promote the healthy development of DEDI, such as Internet platforms, Internet finance, and property rights trading, et cetera. By driving DEDI development, information asymmetry can be alleviated and enterprises' debt-financing and external credit supply capacities can be improved. This can alleviate problems like insufficient funds and high default risk, and encourage enterprises to effectively reduce cash holdings and efficiently allocate cash to enhance enterprise value.

Finally, this study provides several significant implications for global investors. China is the second-largest digital economy. In this context, the development of China's DEDI has attracted the attention of global investors. This study indicates that the DEDI reduces corporate cash holdings, and the influence paths are improvements in debt-financing and trade credit supply capacities. A decrease in enterprises' cash holdings can help them effectively utilize resources for development. Therefore, given the influence of DEDI development, global investors can reduce their concerns regarding the uncertainty of Chinese enterprises' development.

### 8.3. Outlook

Our study is based on a sample of Chinese enterprises. However, this study has some limitations. First, research conducted in China cannot accurately represent the situation in other developing countries. Moreover, China has a banking-led financial system; therefore, the transmission channels of the DEDI affecting corporate cash holdings may not be significant in countries with developed direct financing markets. Second, this study only examines the influence paths of debt-financing and external credit supply capacities; however, other influence paths have not yet been explored. Therefore, these aspects are worthy of further research.

First, national differences exist in the impact of DEDI on enterprises' cash holdings. China has a bank-dominated financial system and direct financing is not well-developed. In countries with well-developed direct financing systems, the effect remains uninvestigated.

Second, there may be other paths through which DEDI influences corporate cash holdings. We explore only two influencing paths, namely, debt-financing and external credit supply capacities. The influence paths of the DEDI may be broader, and there may be other influence paths that have not been studied in our research. This is a possible direction for future research.

## Funding statement

## Data availability statement

The data in the paper are available on request from the corresponding author.

## CRediT authorship contribution statement

**Yubing Xiang:** Writing – review & editing, Visualization, Validation, Supervision, Funding acquisition, Formal analysis, Writing – original draft. **Mei Xu:** Writing – original draft, Software, Resources, Methodology, Investigation, Data curation, Writing – review & editing.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Acknowledgements

None.

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