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Does Economic Policy Uncertainty Affect Firms' Digital Transformation?

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Abstract

Economic policies in different regions in China vary greatly. This study examines the impact of Chinese provincial economic policy uncertainty (EPU) on firms' digital transformation using panel data of A-share listed Chinese firms over the 2007–2021 period using a high-dimensional fixed effects model. Notably, we use provincial-level EPU data to explore this impact and explore the moderating effect of leadership characteristics. Results reveal a U-shaped relationship between provincial EPU and firms' digital transformation. We also find that leaders' average age and gender influence the effect of EPU on digital transformation. The findings highlight the importance of economic policy consistency across China and encourage firms to improve board diversity to cope with EPU.

Keywords: Economic policy uncertainty, digital transformation, listed firms, leadership characteristics

JEL Classification: D22, O32, E60

1. Introduction

As digital technology continues to advance rapidly, digital transformation has become a crucial driver of economic development, particularly for developing countries. The Chinese government has promulgated many policies to promote China's digital development. For example, the 2022 14th Five-year Plan for Digital Economy Development unveiled was implemented to accelerate enterprises' digital transformation and upgrade. In addition, the process of companies' digital transformation in China has been developing rapidly in recent years. According to Accenture's 2018 and 2022 reports, the proportion of firms with

remarkable digital transformation in China increased from 7% in 2018 to 17% in 2022.[1] Digital transformation has tremendous economic and social implications. It positively impacts innovation (Gaglio *et al*., 2022; Peng and Tao, 2022; Liu *et al*., 2023a), can solve enterprises' innovation dilemmas (Zhuo and Chen, 2023) and affects their competitive advantage (Blichfeldt and Faullant, 2021), ultimately determining firms' future position in the market.

Global economic policy uncertainty (EPU) has become more volatile since the 2008 global financial crisis. The Chinese government has released multiple regional economic policies to promote economic development such as the four-region strategy, large-scale development in the western region and revitalisation in the northeast. As China is a policy-oriented country, compared with the impact of the national-level EPU, Chinese enterprises are more affected by regional policy uncertainty. Therefore, it is essential to use the Chinese provincial EPU index to examine the relationship between EPU and enterprises' digital transformation from a regional perspective.

In this context, we examine the relationship between Chinese provincial EPU and digital transformation from 2007 to 2021 using data from Chinese A-share listed firms. This study examines how EPU influences firms' digital transformation, whether EPU's influence on digital transformation is heterogeneous across regions and what moderating effect leadership characteristics have on the relationship between EPU and digital transformation.

We contribute to literature in two ways. First, the regional economic policies in China vary considerably and have greater impacts on domestic enterprises, which are beyond the bound of the widely used national-level EPU indices for describing uncertainty of foreign economic policies. To explore the relationship between EPU and digital transformation, we extend the research scope of policy economics from the national level to the provincial level. Second, positing that leaders' average age and gender affect the influence of EPU on firms' digital transformation, we investigate the relevant mechanism of action and moderating effects of leadership characteristics.

The remainder of this paper is organised as follows. Section 2 provides a review of the relevant literature and theoretical analysis. Section 3 outlines the study's methodology. Section 4 presents the empirical findings. Section 5 includes additional analysis, and Section 6 offers concluding remarks.

1 More details are available at: https://www.accenture.cn/cn-zh/insights/digital/corporate-digital-transformation-index, and https://www.accenture.cn/cn-zh/insights/strategy/china-digital-transformation-index-2022

2. Literature Review and Theoretical Analysis

2.1 Literature review

This study is related to four streams in literature. The first stream is concerned with the impact of EPU on economic activities. From the micro level, the literature about the economic effects of EPU primarily focuses on mergers and acquisitions (Gregoriou *et al*., 2021; Li *et al*., 2021), firms' raised capital (Ashraf *et al*., 2022) and corporate investment (Liu *et al*., 2020; Hou *et al*., 2021). Most literature shows that EPU inhibits economic activities. Regarding EPU's influence on innovation, EPU raises enterprises' financing costs, which reduces corporate innovation, particularly for firms with financial constraints and those that rely on external financing (Xu, 2020). Regarding EPU's influence on enterprise strategy, EPU increases government fiscal pressure, which raises taxes and imposes a greater tax burden on firms (Dang *et al*., 2019). EPU also increases the costs of external financing and managerial conservatism with a negative impact on corporate risk-taking. The intensity of this effect is related to the inherent cultures of uncertainty avoidance and individualism, where the negative effect is stronger and weaker, respectively (Tran, 2019). Mirza and Ahsan (2020) verify this conclusion, demonstrating that Chinese enterprises tend to choose defensive strategies in response to high EPU due to the cultural attributes of China. At the macro level, Nguyen (2022) uses major European Union countries as samples, determining that EPU is positively correlated with the probability of economic recession and prolongs the duration of economic recession. This logically echoes with most results at the micro level indicating that EPU inhibits enterprise economic activities.

The second stream of literature relates to the influencing factors of firms' digital transformation. From the organisational perspective, competitive pressure, organisational mindfulness, strategic alignment and information technology (IT) readiness all contribute to firms' digital transformation (Singh *et al*., 2021). From the policy perspective, different types of economic policy have varying impacts. For example, China's innovative city pilot policies, business tax to value-added tax policy, tax incentives and special subsidies promote firms' digital transformation by advancing technological progress, reducing their tax burden and alleviating financial constraints (Chen *et al*., 2023; Liu *et al*., 2024; He *et al*., 2025). However, China's Green Credit Policy and the policy of tax enforcement digitalisation are found to negatively affect digital transformation by reducing technological innovation, tightening financing constraints and increasing the tax burden (Zhang *et al*., 2024; Xu *et al*., 2025). This indicates that different economic policies may have opposite effect on digital transformation.

The third stream is about EPU's effects on firms' digital transformation. Some recent studies explore the relationship between EPU and digital transformation. For example, using country-level EPU data in China, Zhuo and Tajul (2022) examine the effect of EPU on enterprises' digital transformation. The authors find that EPU promotes enterprise digital transformation, and the economic channel is the competitive nature of the market. Because large-scale, state-owned and strong corporate governance companies have stronger viability, they lack the motivation for digital transformation under EPU.

The fourth stream of literature relates to the impact of leadership characteristics on firm risk-taking behaviour. According to upper echelons theory, top managers' backgrounds and values influence organisations' strategic choices and performance levels (Hambrick and Mason, 1984). Specifically, well-educated leadership is more receptive to innovative business ideas and has a clearer grasp of the external environment (Farag and Mallin, 2016). Educated leaders have superior decision-making skills, which influences their risk preferences, particularly those who received financial education (Alzayed *et al*., 2024; Vu *et al*., 2025). Fryt *et al*. (2022) indicate that the relationship between age and positive risk-taking follows an inverted U-shape, which is strongest in middle adulthood. Leadership's academic background provides academically grounded perspectives that enhance board diversity, improve leadership's ability to enhance decision-making quality and track industry trends and ultimately influences firm risk-taking (He and Zou, 2025). An overseas background enables leadership to think globally and promotes corporate risk-taking, particularly when leadership gains foreign experience from advanced economy countries (Guo and Li, 2025; Sun *et al*., 2023).

In summary, few studies examine the correlation between EPU and digital transformation from a provincial EPU perspective. Distinct regions within a country have different economic development levels and economic policies and are inevitably affected by EPU differently. Therefore, it is necessary to examine these effects from a provincial perspective. However, existing literature primarily uses national-level EPU, which cannot measure regional EPU. To fill this gap, we examine the effect of EPU on Chinese firms' digital transformation using provincial-level EPU data. We also examine whether leadership characteristics will have an impact on firm digital transformation when facing EPU.

2.2 Theoretical analysis and research hypotheses

EPU brings great challenges to enterprises' operating environment and has a significant impact on strategic change decisions (Jin and Wu, 2021). Based on the existing literature, this study contends that three different possibilities exist for the impact of EPU on enterprises' digital transformation.

According to real options theory (Myers, 1977), future investment opportunities can be considered call options. When EPU increases, particularly when a project uses irreversible capital, the potential return of continuing to wait for the right time to invest is greater (Ebina *et al*., 2022; Yuan *et al*., 2025), and enterprises will choose to postpone digital transformation. Because investment projects are affected by technical, financial, market and social risks and other factors, and multiple risk factors are volatile, resulting in fluctuating investment project value, and investment projects have option value. EPU makes it difficult for enterprises to judge new technologies' expected return on investment, and enterprises will take a 'wait-and-see' strategy to determine whether to invest in new technologies when the situation is stable. Therefore, enterprises' digital transformation in China will be negatively affected by EPU. Based on the above analysis, we propose the following hypothesis:

Hypothesis 1 (H_1): *EPU has a restraining effect on enterprises' digital transformation.*

EPU not only introduces greater risks but also more opportunities. According to strategic growth option theory, uncertainty is an opportunity for enterprises to gain the first-mover advantage and have a huge market share in the future; therefore, uncertainty can encourage investment, particularly for firms in more competitive industries (Wen *et al*., 2021). Strategic investment not only reduces the production cost but also reduces the exercise price of future expansion options (Kulatilaka and Perotti, 1998). This is because strategic investment also has an impact on competitors' output decisions, prompting them to reduce aggressiveness, which increases investors' market share and raises the value of expanded options. When digital transformation has a significant pre-emptive effect, transformed enterprises will occupy a higher market share in the future, and compared with enterprises that do not engage in digital transformation, the profits of transformed enterprises are relatively more convex in the later stage. Based on the above analysis, we propose the following hypothesis:

Hypothesis 2 (H_2): *EPU promotes enterprises' digital transformation.*

Based on real options, strategic growth option and threat rigidity mechanisms, EPU's impact on corporate digital transformation may not be a simple linear relationship. In the early stages of rising EPU, due to the strategic importance and high sunk costs associated with digital transformation, increased EPU elevates the uncertainty of future returns, enhancing firms' real options value to defer investments and maintain decision-making flexibility. However, when EPU continues to intensify and surpasses a critical threshold, the effect is expected to shift to forced transformation wherein survival pressure becomes the dominant logic, as firms recognise that the adverse environment is no longer temporary and passive observation is inadequate to address challenges. At this stage, companies proactively seek to enhance operational efficiency and explore new market opportunities through digital

means to survive the crisis and capitalise on potential opportunities arising from uncertainty. Consequently, corporate strategy will transition from initial risk avoidance to subsequent proactive survival. Therefore, we propose the final hypothesis:

> **Hypothesis 3 (H_3):** *A U-shaped relationship exists between EPU and enterprises' digital transformation.*

3. Methodology

3.1 Data and variables

Our dataset covers 31 provinces and autonomous regions in China.[2] Enterprise data are sourced from the China Stock Market & Accounting Research (CSMAR, 2023), DRCNET (2023), and CNRDS (2023) databases. All the firms in this study strictly come from the 31 provinces. We start with the CSMAR database, select China's A-share listed firms and exclude financial firms and special treatment firms. We also drop firms with missing data for the main variables. Our final sample includes 4,196 firms with 34,281 firm–year observations across the 2007–2021 period.

3.1.1 Digital transformation

(1) Digital transformation measurement

Most researchers propose that digital transformation is based on digital technologies and enables major business improvements (Fitzgerald *et al*., 2014; Vial, 2019; Gong and Ribiere, 2021). Because digital transformation and digital technologies are inseparable, many researchers use the frequency of keywords linked to digital technology in companies' annual reports to assess the enterprises digital transformation (Zhai, *et al*., 2022; Zhu *et al*., 2022). The digital transformation data we use are obtained from CSMAR. First, we reference the digital transformation keywords specified by Wu *et al*. (2021), exclude negative words such as 'no', 'none' and 'not' before the keywords and conduct a full-text search of listed companies' annual financial reports. Finally, we measure enterprises' digital transformation with the sum of keywords' frequency.

2 China has 34 province-level divisions, including 23 provinces, 5 autonomous regions, 4 municipalities directly under the Central Government and 2 special administrative regions. Hong Kong Special Administrative Region and Macao Special Administrative Region adopt One country, two systems policy, meaning that these regions have different social systems and policies from those on the mainland. The island province Taiwan adopts different policies from the mainland as well. Therefore, we use the remaining 31 mainland provinces and autonomous regions in this study, encompassing Beijing, Tianjin, Hebei, Shanxi, Inner Mongolia, Liaoning, Jilin, Heilongjiang, Shanghai, Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, Shandong, Henan, Hubei, Hunan, Guangdong, Guangxi, Hainan, Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia and Xinjiang.

(2) Digital transformation measurement validation

We conduct a validation test to confirm that digital transformation measured by keyword frequency in annual reports captures actual digital adoption. Enterprises' expenditure on IT outsourcing services covers the core content of enterprise digital transformation and can reflect actual digital adoption. If an enterprise purchases IT services in a certain year and does not add other services, it is possible that no IT expenditure will occur in subsequent years. Therefore, we use *ITS* to denote the number of enterprises that have purchased IT outsourcing service, and *EDT* represents the number of enterprises that have keywords related to digital transformation in the annual report each year. We apply a Pearson correlation analysis between *ITS* and *EDT*, yielding a correlation coefficient of 0.9625 at a 1% significance level, confirming that the two variables are highly correlated. This result indicates that the digital transformation keyword frequency in annual reports can reflect enterprises' actual digital adoption and confirms the validity of our keyword frequency measure.

We obtain data on firms' IT outsourcing services expenditure (excluding costs paid to post and telecommunications enterprises) from the National Enterprise Tax Survey Database. These data have been collected since 2012, and survey data until 2016 can be obtained. Therefore, we use the *ITS* from 2012 to 2016 to test validity, not as a variable for measuring digital transformation.

3.1.2 *EPU* measurement

Baker *et al*. (2016) develop a monthly *EPU* index based on the frequency of *EPU*-related keywords in newspapers using a text research method, measuring China's country-level *EPU* index using the South China Morning Post. Unlike the existing studies constructing *EPU* indices with newspapers, Lee *et al*. (2023) construct daily and monthly frequency Chinese *EPU* indices based on posts on X. In contrast to the above studies that build national *EPU* indices, Yu *et al*. (2021) expand the keywords and construct a provincial monthly *EPU* index using the daily newspapers of 31 Chinese provinces. Distinct from Baker's China *EPU* dividing the target articles by all the articles, Yu *et al*. (2021) exclude non-economic news, quantifying *EPU* by dividing target articles by economy-related articles.

To examine the influence of *EPU* on digital transformation more accurately, we primarily reference Yu *et al*. (2021) to construct the *EPU* index for 31 Chinese provinces from 2007 to 2021. Our *EPU* construction method divides the number of articles in the full text of provincial and municipal daily newspapers containing relevant economy, policy and uncertainty keywords by the number of articles in the full text of provincial and municipal daily newspapers containing relevant economy-related keywords using the keyword criteria from Yu

et al. (2021). Dividing the target articles by economy-related articles makes *EPU* comparable across provinces, regardless of the media intensity and coverage across provinces.

3.1.3 Other variables

Following previous related studies (Tran, 2019; Guan *et al*., 2021; Lou *et al*., 2022), we control for a set of firm-level variables. Firms' leverage ratio (*Leverage*), as higher leverage diminishes firms' risk-taking capacity and managers' risk appetite, hindering firms' digital transformation; *Size*, because large firms have more resource reserves and risk management advantages, and tend to make aggressive decisions (Tian *et al*., 2024); income growth rate (*Growth*), as firms with strong past performance are more likely to exhibit risk-taking behaviour (Tsai and Luan, 2016); and profitability (*ROA*), according to prospect theory (Kahneman and Tversky, 1979) since people are risk-averse in the domain of gains and risk-seeking in the domain of losses, which will influence firms' decision-making about digital transformation; tangible asset ratio (*Tangibility*), as firms' asset structures impact their value and financial stability, so firms that depend on tangible and intangible assets have different risk-taking behaviours (Duho, 2021); cashflow asset ratio (*Cashflow*) because the level of cash flow will affect company insiders' private benefits and then influence their decision on risky projects (John *et al*., 2008); and ownership type (*SOE*), as state-owned enterprises face institutional pressure to serve government objectives and are able to secure greater access to scarce resources in the market (Yi *et al*., 2017), which will drive their digital transformation process.

In addition to these control variables, we use China's economic climate indicator (*Macroeco*) to test robustness, and firm leaders' average education (*Edu*), age (*Age*), gender (*Male*), academic background (*Acad*) and overseas background (*Ovs*) to examine the moderating effect of leadership characteristics between *EPU* and digital transformation.

Variable definitions are presented in Appendix Table A.1, and all data analysed in this study are publicly available in the Figshare repository at https://doi.org/10.6084/m9.figshare.30304738.v1

3.2 Baseline regression specification

To test the effects of *EPU* on firm digital transformation, we construct the following regression models:

$$DT_{i,t} = \alpha + \beta EPU_{i,t} + \gamma' Control_{i,t} + Firm_i + Province_i + Year_t + \varepsilon_{i,t} \quad (1)$$

$$DT_{i,t} = \alpha + \beta_1 EPU_{i,t} + \beta_2 EPU_{i,t}^2 + \gamma' Control_{i,t} + Firm_i + Province_i + Year_t + \varepsilon_{i,t} \quad (2)$$

where *i* denotes firm, *t* denotes time and ε is the residual term. The dependent variable *DT* refers to a firm's digital transformation, and *EPU* denotes economic policy uncertainty. *Firm* is a firm dummy variable, *Province* is a region dummy variable and *Year* is a year dummy variable. *Control* represents the previously described set of firm-specific control variables that affect digital transformation.

4. Results

4.1 Descriptive statistics

Table 1 presents a descriptive statistical analysis of the variables used in our analysis, revealing that the median of firm digital transformation is 0.693, and its minimum and maximum are zero and 6.301, respectively.

Table 1: Descriptive statistics

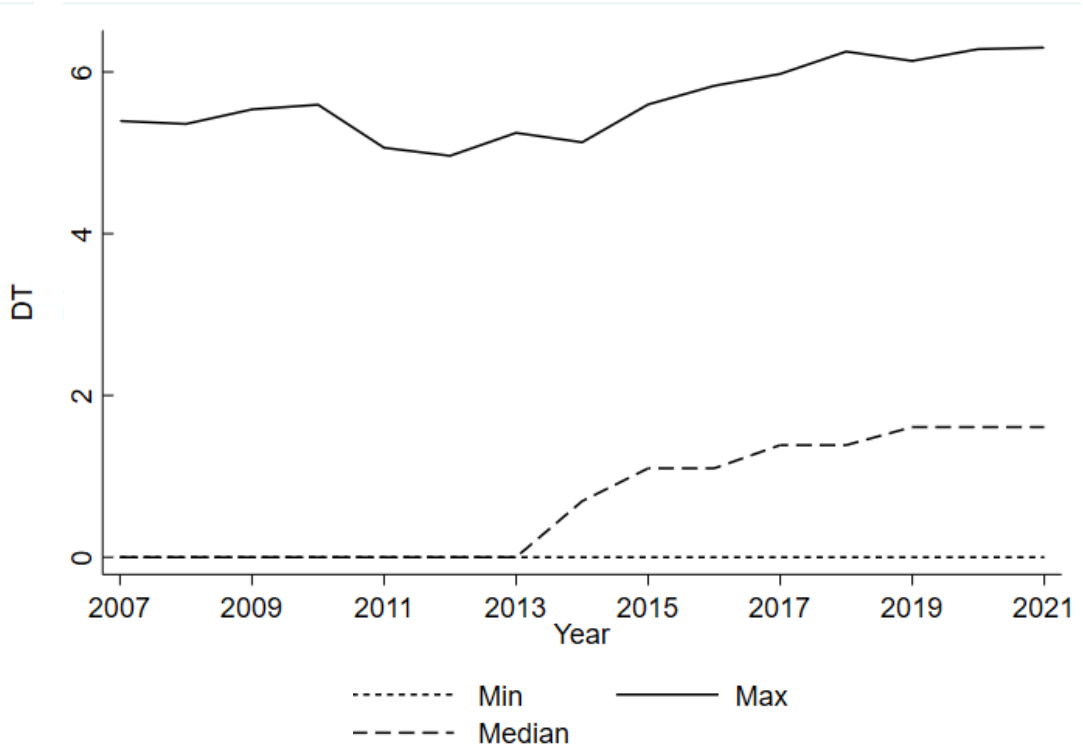
Variables	*N*	Mean	Median	SD	Min.	Max.
DT	34,281	1.238	0.693	1.382	0	6.301
EPU	34,281	0.528	0.523	0.119	0.187	0.834
Leverage	34,281	0.412	0.403	0.224	0.007	9.429
Size	34,281	22.08	21.87	1.323	17.88	28.64
Growth	34,263	0.342	0.125	11.86	−1.309	1,878
ROA	34,281	0.0420	0.0420	0.104	−4.946	7.446
Tangibility	34,281	0.929	0.958	0.0910	0.125	1
Cashflow	34,280	−0.0170	−0.007	0.113	−1.915	2.872
SOE	34,281	0.355	0	0.479	0	1
Macroeco	34,281	99.17	99.77	5.404	91.34	110.4
Edu	33,584	1.502	1.5	0.737	0	3
Age	33,567	51.13	51	5.758	25	81
Male	33,581	0.943	1	0.182	0	1
Acad	33,584	0.075	0	0.225	0	1
Ovs	33,584	0.07	0	0.215	0	1

Note: All variable definitions are presented in Appendix Table A.1.

Source: Authors' own calculations

Figure 1 shows that the minimum values from 2007 to 2021 are all zero, and the medians are also almost zero. This indicates that most firms have not yet undergone digital transformation or are at lower digitalisation levels, and firms' digital transformation process considerably varies.

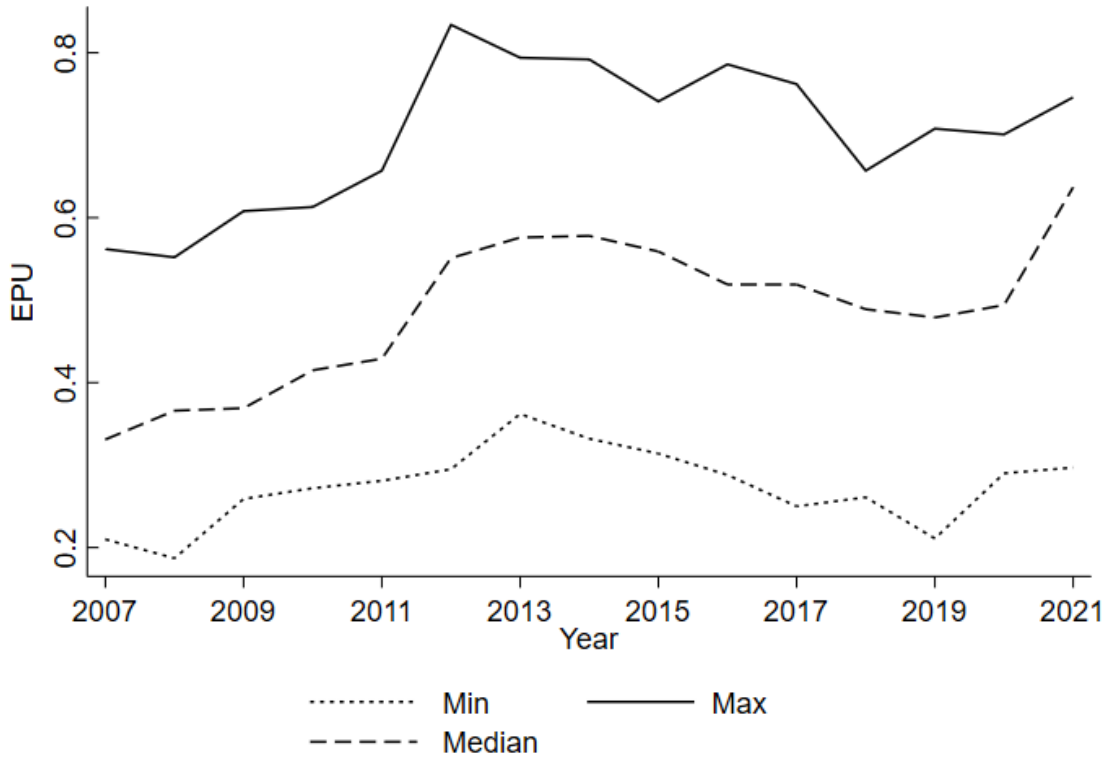
Figure 1: Digital transformation distribution by year



Source: Authors' own elaboration

Figure 2 shows that the range of *EPU* is very large every year of the sample, indicating enormous disparity in *EPU* among China's 31 provinces. The *EPU* suffered by firms in different provinces is decidedly heterogeneous. In addition, the maximum and minimum of *EPU* show a trend of initial rapid increase, which decreases slowly, and the median of *EPU* also shows a similar trend. However, the trend of median *EPU* gradually approaches the maximum over time. This demonstrates that China's provinces are undergoing heterogeneous structural changes in relation to *EPU*, and the proportion of provinces with larger *EPU* is rising. Therefore, it is necessary to use the provincial *EPU* index to examine the impact of *EPU*.

Figure 2: EPU distribution per year



Source: Authors' own elaboration

4.2 Baseline results

We compared fixed and random effects models using the Hausman test, and the results provide evidence against the null hypothesis, confirming the fixed effects model for regression analysis.

Table 2: Baseline regression

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	DT	*DT*	*DT*	*DT*	*DT*	*DT*
EPU	−0.448*** (0.066)	−2.085*** (0.293)	−2.096*** (0.545)	−0.394*** (0.065)	−2.195*** (0.29)	−2.207*** (0.54)
EPU²	–	1.535*** (0.269)	1.553*** (0.486)	–	1.689*** (0.265)	1.708*** (0.483)
Leverage	–	–	–	−0.009 (0.035)	−0.01 (0.035)	−0.008 (0.057)
Size	–	–	–	0.255*** (0.012)	0.256*** (0.012)	0.256*** (0.031)
Growth	–	–	–	0.0004*** (0.0001)	0.0004*** (0.0001)	0.0004*** (0.0001)
ROA	–	–	–	−0.115** (0.053)	−0.116** (0.054)	−0.113* (0.065)
Tangibility	–	–	–	−0.864*** (0.079)	−0.866*** (0.079)	−0.866*** (0.195)
Cashflow	–	–	–	0.001 (0.039)	0.001 (0.039)	−0.01 (0.054)
SOE	–	–	–	−0.029 (0.033)	−0.03 (0.033)	−0.029 (0.075)
Constant	1.469*** (0.035)	1.884*** (0.08)	1.887*** (0.152)	−3.364*** (0.28)	−2.927*** (0.285)	−2.93*** (0.653)
Model specifications						
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Cluster SE	No	No	Yes	No	No	Yes
Observations	33,806	33,806	33,673	33,790	33,790	33,657
Adjusted R^2	0.7486	0.7489	0.7496	0.7570	0.7573	0.7581
Wald test (H_0: $\beta^2 = 0$), *F*-value	–	32.68	10.20	–	32.68	10.20
***p*-value**	–	0.0000	0.0017	–	0.0000	0.0017

Notes: We clustered standard errors at the fourth level industry classification when indicated. Robust standard errors are in parentheses. ***, ** and * denote statistical significance at 1%, 5% and 10% levels, respectively.

Source: Authors' own calculations

Table 2 presents the models (1) and (2) regression results, revealing that the coefficients of *EPU* in the linear regressions and those of EPU^2 in the nonlinear regressions are statistically significant. Moreover, the adjusted R-squared (R^2) of the nonlinear regression is higher than that of the linear model, and the Wald test results reject the null hypothesis, indicating that the quadratic model provides a better fit than the linear model. In the nonlinear regressions, the coefficients of EPU^2 are significantly positive at the 1% level, and the coefficients of *EPU* are significantly negative at the 1% level. The turning point of the U-shaped relationship is calculated at an *EPU* value of 0.65 and is statistically meaningful as it lies within the observed range of *EPU*. Therefore, the relationship between *EPU* and digital transformation follows a U-shaped pattern. When we cluster standard errors in column (3) and introduce control variables in columns (5) and (6), the results remain significant. This indicates that the impact of *EPU* on digital transformation is initially negative but subsequently becomes positive as *EPU* rises. These results support H_3, indicating that a prevalent wait-and-see mentality dominates at low *EPU* levels, while the imperative for survival drives firms to embrace digital transformation as a strategic pathway once *EPU* exceeds a critical threshold. This is inconsistent with previous research conclusions using national EPU indices (Zhu *et al*., 2023; Xu and Liu, 2023; Yang *et al*., 2023). The main reason is that the *EPU* index used in previous literature is national, and primarily measures the EPU from countries outside China, while the provincial *EPU* used in this study describes the EPU related to the internal economic policy changes of the country and provinces.

The estimated coefficients for control variables are generally as expected. Consistent with Chemmanur *et al*. (2019), the coefficient of *Size* is positive and significant at the 1% level, indicating that larger firms are more capable, have more capital and are more inclined towards digital transformation. The coefficient of *Growth* is significantly positive at the 1% level. This implies that greater operating income growth is associated with higher-level digital transformation. The coefficient of *ROA* is significantly negative, indicating that firms with higher profitability are less likely to engage in digital transformation. The coefficient of *Tangibility* is significantly negative at the 1% level in regressions. This finding indicates that firms with higher tangible assets shares are less likely to engage in digital transformation. This result aligns with the finding of the current literature (Pang and Wang, 2020).

4.3 Heterogeneity analysis

4.3.1 Firm ownership heterogeneity

To explore whether heterogeneity is evident in the influence of *EPU* on digital transformation based on firm ownership, we divide the sample into SOEs and non-SOEs based on listed firms' ownership structure. As shown in columns (1) and (2) of Table 3, the regression coefficient of EPU^2 to enterprise digital transformation in non-SOEs is 0.84, which is significant at the 5% level. The regression coefficient of EPU^2 on digital transformation in SOEs is 2.29 and significant at the 1% level. The heterogeneity analysis reveals that the U-shaped relationship is steeper for SOEs, whose strategic turning point emerges at a lower *EPU* level than that of non-SOEs. This indicates that SOEs are more sensitive to shifts in the economic policy environment and can swiftly mobilise large-scale digital transformation once a moderate uncertainty threshold is crossed. In contrast, non-SOEs demonstrate a more tempered and lagged response, consistent with a reactive adaptation posture.

Table 3: Results of heterogeneity analysis

Variables	(1)	(2)	(3)	(4)
	Non-SOEs	SOEs	High LI	Low LI
	DT	*DT*	*DT*	*DT*
EPU	−1.423*** (0.446)	−2.54*** (0.372)	−2.007*** (0.409)	−2.227*** (0.442)
EPU²	0.84** (0.405)	2.29*** (0.348)	1.525*** (0.375)	1.809*** (0.407)
Leverage	−0.039 (0.041)	−0.202*** (0.075)	−0.059 (0.063)	−0.022 (0.047)
Size	0.272*** (0.016)	0.194*** (0.019)	0.232*** (0.018)	0.293*** (0.018)
Growth	0.0004 (0.001)	0.0005*** (0.0001)	0.0005*** (0.0002)	0.002 (0.002)
ROA	−0.117** (0.056)	0.072 (0.206)	−0.359*** (0.101)	−0.043 (0.046)
Tangibility	−0.842*** (0.094)	−0.314* (0.163)	−0.792*** (0.112)	−1.003*** (0.129)
Cashflow	0.058 (0.046)	−0.263*** (0.072)	0.012 (0.057)	0.001 (0.057)
SOE	–	–	−0.016 (0.048)	−0.01 (0.05)
Constant	−3.204*** (0.383)	−2.436*** (0.457)	−2.524*** (0.431)	−3.642*** (0.449)
Model specifications				
Firm FE	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	21,657	12,075	16,324	16,428
Adjusted R^2	0.7711	0.7243	0.7897	0.7435

Notes: Robust standard errors are in parentheses. ***, ** and * denote statistical significance at 1%, 5% and 10% levels, respectively.

Source: Authors' own calculations

4.3.2 Market competition heterogeneity

To examine the effect of *EPU* on digital transformation under different degrees of market competition, we divide the sample into two groups according to median market competition each year, using the industry Lerner index (LI) to measure industrial competitiveness (Aghion *et al*., 2015). Those above market competition median are classified as the high market competition group (high LI), and the remainder as the low market competition group (low LI). We then regress digital transformation on *EPU* and other control variables for each group using model (2), presenting the results in columns (3) and (4) of Table 3.

The results demonstrate heterogeneity in the impact of *EPU* on digital transformation at different market competition levels. The estimated coefficient for EPU^2 is 1.525 for firms in the high market competition in column (3), and 1.809 for firms in the low market competition in column (4), which are both significant at the 1% level. This result demonstrates that the U-shaped curve is steeper for firms in low competitive markets than for firms in high competitive markets. This indicates that in the initial stages of *EPU*, firms in low competitive markets experience a stronger inhibitory effect on their digital transformation. Such markets may provide a comfort zone for firms, which makes them more inclined to postpone investments and adopt a wait-and-see approach when *EPU* arises. Once *EPU* reaches a level that pushes firms out of their comfort zones, their lack of experience and capability to survive in harsh environments translates into intense survival anxiety, which subsequently drives a more radical transformation response. In contrast, firms in high competitive markets, already accustomed to a sense of crisis, demonstrate consistent vigilance and adaptability, resulting in a relatively more gradual and measured response in their transformation decisions. These heterogeneity analyses confirm our baseline results.

4.4 Robustness tests

4.4.1 Residual uncertainty

EPU may be affected by economic uncertainty, capturing uncertainty related to the economy but not to policy, which could introduce error-in-measurement bias into our regression results. To address this concern, we reference Kaviani *et al*. (2020) and Schwarz and Dalmácio (2021) by regressing the *EPU* on the macroeconomic variables and using the regression residuals as an alternative *EPU* measure. The regression specification is as follows:

$$EPU_{i,t} = \alpha + \beta Macroeco_t + \varepsilon_t \quad (3)$$

where $Macroeco_t$ is the economic climate indicator, using the residual ε as the new policy uncertainty index named (*REPU*) and replacing *EPU* with *REPU* in model (2) as follows:

$$DT_{i,t} = \alpha + \beta_1 REPU_{i,t} + \beta_2 REPU_{i,t}^2 + \gamma' Control_{i,t} + Firm_i + Province_i + Year_t + \varepsilon_{i,t} \quad (4)$$

Table 4 presents the results, revealing that *REPU* has a U-shaped effect on *DT*, which shows that our results remain robust to error-in-measurement bias.

Table 4: Results of robustness test

Variables	(1)	(2)	Variables	(1)	(2)
	DT	***DT***		***DT***	***DT***
REPU	−0.42*** (0.065)	−0.411*** (0.118)	**ROA**	−0.114** (0.053)	−0.111* (0.065)
REPU²	1.68*** (0.276)	1.705*** (0.49)	**Tangibility**	−0.866*** (0.079)	−0.866*** (0.195)
Leverage	−0.009 (0.035)	−0.007 (0.057)	**Cashflow**	−0.000004 (0.039)	−0.011 (0.054)
Size	0.256*** (0.012)	0.256*** (0.031)	**SOE**	−0.029 (0.033)	−0.029 (0.075)
Growth	0.0004*** (0.0001)	0.0004*** (0.0001)	**Constant**	−3.611*** (0.278)	−3.615*** (0.669)
Model specifications		**(1)**		**(2)**	
		DT		***DT***	
Firm FE		Yes		Yes	
Province FE		Yes		Yes	
Year FE		Yes		Yes	
Cluster SE		No		Yes	
Observations		33,790		33,657	
Adjusted R^2		0.7573		0.7581	

Notes: Robust standard errors are in parentheses. ***, ** and * denote statistical significance at 1%, 5% and 10% levels, respectively.

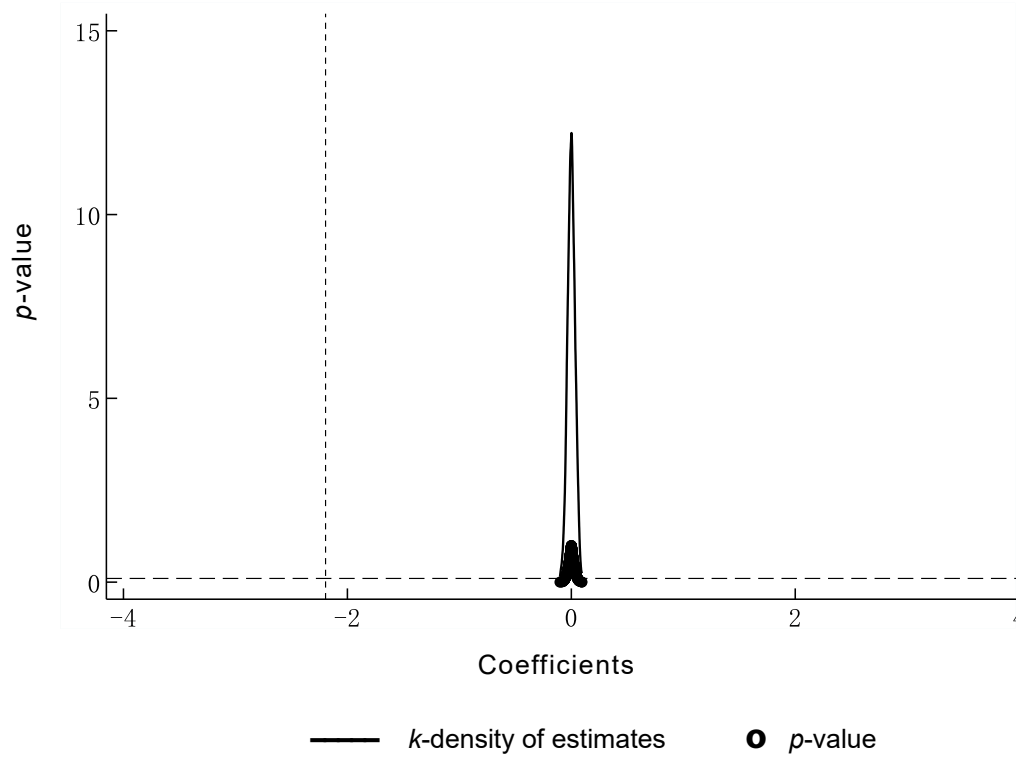
Source: Authors' calculations

4.4.2 Placebo tests

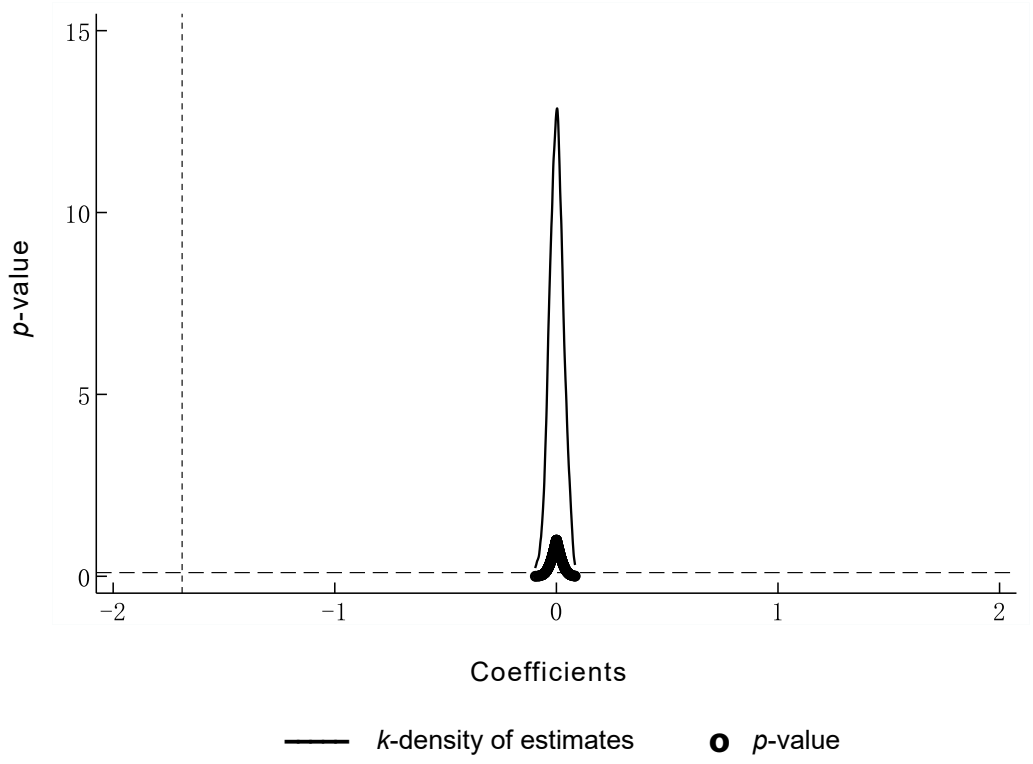
Referencing Berger *et al*. (2022), we replace *EPU* with EPU_{random}, which is randomly drawn from the *EPU* distribution. We estimate regression coefficients with 500 random samples of EPU_{random} and illustrate the distribution of estimated coefficients of EPU_{random} and EPU_{random}^2 in Figure 3. In the random sampling results, the estimation coefficients of EPU_{random} and EPU_{random}^2 are largely concentrated around 0, and most of the estimated values have *p*-values greater than 0.1 and insignificant at the 10% level, and the baseline regression coefficients of *EPU* (−2.195) and EPU^2 (1.689) are small probability events. This confirms that our benchmark findings are unlikely to be erroneously obtained, providing further confirmation of our baseline regression results' robustness.

Figure 3: Distribution of EPU_{random} and EPU_{random}^2 coefficients in placebo tests

(a) Coefficients of EPU_{random}



(b) Coefficients of EPU_{random}^2



Notes: This figure illustrates the distribution of 500 EPU_{random} and EPU_{random}^2 estimation coefficients and their *p*-values. The *x*-axes in figures (a) and (b) represents the estimation coefficients of EPU_{random} and EPU_{random}^2, respectively. The *y*-axes display the density value and *p*-value. Curves represent the kernel density distributions of the estimation coefficients, and circles represent the corresponding *p*-values. Vertical dashed lines in figures (a) and (b) are the true estimated values of *EPU* (–2.195) and EPU^2 (1.689) in the baseline regression, respectively. The horizontal dashed lines indicate a 0.1 significance level.

Source: Authors' own elaboration

4.4.3 Manufacturing sample

Different industries have different demands for digital transformation, and digital technology is being widely adopted in the manufacturing industry. China has always placed a strong emphasis on encouraging digital transformation in the manufacturing sector. Under the impetus of this policy, we examine whether manufacturing enterprises' digital transformation is affected by *EPU* in a U-shaped pattern. To do so, we conduct regression (2) using manufacturing enterprise data, obtaining similar results for the U-shaped effect of *EPU* on digital transformation (Table 5). This result shows that our conclusion remains robust after reducing the sample to manufacturing enterprises.

Table 5: Manufacturing sample robustness test

Variables	Reduced sample		Variables	Reduced sample	
	DT	***DT***		***DT***	***DT***
EPU	–2.828*** (0.373)	–2.827*** (0.572)	***ROA***	–0.079 (0.084)	–0.076 (0.104)
EPU²	2.12*** (0.343)	2.12*** (0.512)	***Tangibility***	–0.754*** (0.111)	–.0749*** (0.226)
Leverage	0.053 (0.05)	0.054 (0.087)	***Cashflow***	0.012 (0.047)	0.005 (0.065)
Size	0.229*** (0.015)	0.229*** (0.037)	***SOE***	–0.102** (0.044)	–0.102 (0.109)
Growth	0.0004 (0.001)	0.0004 (0.001)	***Constant***	–2.355*** (0.382)	–2.363*** (0.797)

Model specifications	Reduced sample	
	DT	***DT***
Firm FE	Yes	Yes
Province FE	Yes	Yes
Year FE	Yes	Yes
Cluster SE	No	Yes
Observations	22,238	22,155
Adjusted R^2	0.7175	0.7180

Note: Robust standard errors are in parentheses. ***, ** and * denote statistical significance at 1%, 5% and 10% levels, respectively.

Source: Authors' own calculations

4.4.4 Lag effect of EPU on digital transformation

To test the lag effect of EPU, we add a 1-period lag EPU and EPU^2 to model (2) to construct model (5).

$$DT_{i,t} = \alpha + \beta_1 EPU_{i,t} + \beta_2 EPU_{i,t}^2 + \beta_3 EPU_{i,t-1} + \beta_4 EPU_{i,t-1}^2 + \gamma' Control_{i,t} + Firm_i + \\ + Province_i + Year_t + \varepsilon_{i,t} \quad (5)$$

Table 6 presents the regression results of model (5), revealing that the regression coefficients of *EPU* and EPU_{t-1} are significantly negative at the 1% level and those of EPU^2 and $(EPU_{t-1})^2$ are significantly positive at the 1% level. This shows that current *EPU* has a U-shaped influence on enterprises' digital transformation, and the lagged *EPU* also has a U-shaped influence, indicating a time lag in the U-shaped impact of *EPU*.

Table 6: Results of lag effect robustness test

Variables	*DT*	Variables	*DT*
EPU	−1.182*** (0.363)	***Growth***	0.0004*** (0.0001)
EPU^2	0.926*** (0.329)	***ROA***	−0.114** (0.054)
EPU_{t-1}	−1.175*** (0.348)	***Tangibility***	−0.717*** (0.085)
$(EPU_{t-1})^2$	0.855*** (0.322)	***Cashflow***	−0.074* (0.043)
Leverage	−0.035 (0.039)	***SOE***	−0.044 (0.034)
Size	0.261*** (0.013)	***Constant***	−3.107*** (0.32)
Model specifications		***DT***	
Firm FE		Yes	
Province FE		Yes	
Year FE		Yes	
Observations		29,571	
Adjusted R^2		0.7660	

Note: Robust standard errors are in parentheses. ***, ** and * denote statistical significance at 1%, 5% and 10% levels, respectively.

Source: Authors' calculations

5. Additional Analysis: Moderating Effect of Leaders' Characteristics

Existing studies demonstrate that leadership characteristics affect enterprises' digital transformation in many ways (Porfírio *et al*., 2021; Liu *et al*., 2023b; Zhu *et al*., 2022). To explore whether leadership characteristics affect the impact of *EPU* on firms' digital transformation, we conduct an additional analysis on the moderating effect of characteristics of the chairman and managing director between *EPU* and digital transformation. We add the interaction terms of $EPU_{i,t}$ and $EPU_{i,t}^2$ with the moderating variables ($X_{i,t}$) in model (2). *X* represents the chairman and managing director's personal characteristic variables, which are average education level (*Edu*), age (*Age*), gender (*Male*), academic background (*Acad*) and overseas experience (*Ovs*). The remaining control variables are the same as those in the benchmark model. The following model is applied:

$$DT_{i,t} = \alpha\beta_1 EPU_{i,t} + \beta_2 EPU_{i,t}^2 + \beta_3 EPU_{i,t} \times X_{i,t} + \beta_4 EPU_{i,t}^2 \times X_{i,t} + \beta_5 X_{i,t} + \quad (6)$$
$$+ \gamma' Control_{i,t} + Firm_i + Province_i + Year_t + \varepsilon_{i,t}$$

As shown in column (2) of Table 7, the coefficient of $EPU^2 \times Age$ is significantly negative and that of $EPU \times Age$ is significantly positive at the 1% level. This indicates that the average age of leadership significantly flattens the U-shaped relationship between *EPU* and digital transformation, making corporate digital transformation decisions less sensitive to *EPU*. This indicates that older managers' inherent risk aversion attenuates the firm's strategic sensitivity to external environmental shocks. Consequently, digital decision-making becomes more conservative overall, and the magnitude of *EPU*'s impact – whether inhibitory or promotive – is diminished.

In column (3) of Table 7, the coefficient of $EPU^2 \times Male$ is significantly positive and the coefficient of $EPU \times Male$ is significantly negative at the 5% level. This indicates that a higher proportion of male leaders steepens the U-shaped curve between *EPU* and digital transformation, amplifying the inhibitory effect at lower *EPU* levels and the promotional effect at higher levels. Male managers, potentially due to greater confidence or risk-taking propensity, exacerbate the volatility of digital transformation strategies in response to *EPU*. The interaction terms in columns (1), (4) and (5) of Table 7 are insignificant. These findings imply that the average age and proportion of male chairmen and managing directors moderate the effects of *EPU* on digital transformation, substantiating and extending the upper echelons theory (Hambrick and Mason, 1984).

Table 7: Results of moderating effects

Variables	(1)	(2)	(3)	(4)	(5)
	DT	*DT*	*DT*	*DT*	*DT*
	X = Edu	*X = Age*	*X = Male*	*X = Acad*	*X = Ovs*
EPU	−2.096*** (0.62)	−8.589*** (2.341)	1.241 (1.418)	−2.27*** (0.306)	−2.169*** (0.302)
EPU²	1.49** (0.583)	7.384*** (2.195)	−0.837 (1.3)	1.753*** (0.281)	1.685*** (0.278)
X	0.027 (0.091)	−0.035*** (0.012)	1.046*** (0.385)	−0.391 (0.302)	0.236 (0.381)
EPU × X	−0.047 (0.35)	0.126*** (0.046)	−3.58** (1.45)	1.069 (1.146)	−0.377 (1.362)
EPU² × X	0.125 (0.33)	−0.112*** (0.043)	2.647** (1.331)	−0.692 (1.071)	0.265 (1.195)
Leverage	−0.007 (0.036)	−0.006 (0.036)	−0.008 (0.036)	−0.008 (0.036)	−0.008 (0.036)
Size	0.255*** (0.012)	0.258*** (0.012)	0.256*** (0.012)	0.256*** (0.012)	0.256*** (0.012)
Growth	0.0004*** (0.0001)	0.0004*** (0.0001)	0.0004*** (0.0001)	0.0004*** (0.0001)	0.0004*** (0.0001)
ROA	−0.105** (0.052)	−0.104** (0.052)	−0.105** (0.052)	−0.105** (0.052)	−0.105** (0.052)
Tangibility	−0.817*** (0.079)	−0.816*** (0.079)	−0.816*** (0.079)	−0.818*** (0.079)	−0.82*** (0.079)
Cashflow	−0.009 (0.039)	−0.007 (0.039)	−0.009 (0.039)	−0.009 (0.039)	−0.009 (0.039)
SOE	−0.038 (0.033)	−0.031 (0.033)	−0.032 (0.033)	−0.032 (0.033)	−0.03 (0.033)
Constant	−3.019*** (0.329)	−1.248* (0.672)	−3.995*** (0.47)	−2.961*** (0.293)	−3.004*** (0.293)
Model specifications					
Firm FE	Yes	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Observations	33,014	32,998	33,012	33,014	33,014
Adjusted R^2	0.7595	0.7596	0.7595	0.7594	0.7594

Notes: Robust standard errors are in parentheses. ***, ** and * denote statistical significance at 1%, 5% and 10% levels, respectively.

Source: Authors' own calculations

6. Conclusion

6.1 Theoretical contributions

This study addresses the gap in the research regarding the influence of provincial EPU on firms' digital transformation. Our empirical analysis is based on a panel of Chinese enterprises from 2007 to 2021. The findings reveal that EPU has a U-shaped effect on enterprises' digital transformation. The main reason is a fundamental shift in strategic logic from risk avoidance at low EPU to survival-driven necessity at high EPU. The heterogeneity analyses show that EPU's effect on digital transformation is stronger for SOEs and firms in low competitive industries. The main result still holds following a series of robustness tests. We also investigate the moderating effect of leadership characteristics, demonstrating that the average age and gender of chairmen and managing directors influence the effect of EPU on digital transformation.

This study breaks the national setting of EPU spatial scale in existing EPU and digital transformation research and empirically demonstrates that provincial EPU can accurately capture regional economic policy fluctuation and its impact on local enterprises' digital transformation. This provides a reference for spatial segmentation in subsequent EPU research and brings EPU-related research closer to regional policy. Furthermore, according to our knowledge, this is the first study to examine the role of leadership characteristics between EPU and digital transformation. We construct a theoretical transmission chain from provincial-level EPU to leadership characteristics, and subsequently to enterprise decision-making, providing theoretical coherence to the connection between macro-level policy and micro-level practices.

6.2 Policy implications

Based on our findings, we propose three policy recommendations. First, governments should maintain economic policy consistency. Economic policy is a crucial instrument for governments to stimulate economic growth and advance corporate digitalisation. However, frequent changes in economic policy can disrupt enterprises' strategic planning. Therefore, while adjusting economic policies to promote corporate digitalisation, governments must also consider the effects of EPU on businesses and strive to maintain long-term consistency in economic policy. Second, considering that different types of enterprises exhibit varying sensitivities to EPU, and SOEs and firms operating in low competitive sectors are more severely affected by its consequences, the government should strengthen policy guidance for these enterprises' digital transformation. Third, as leaders' age and gender can influence

the U-shaped effects of EPU on digital transformation, enterprises should proactively build their top management teams and boards with diverse ages and genders and foster a multi-faceted leadership structure.

6.3 Limitations

Several limitations in our research may provide directions for future research. First, the measurement of EPU we use is based on newspapers. Now that China's digital network has been developed, newspapers' audience is increasingly shrinking, and firms' EPU can be measured based on the social media more accurately. Therefore, future research can use keyword frequencies on the internet to measure EPU. Although Lee *et al*. (2023) construct Chinese EPU based on X, this social media platform is unavailable in China, and the information on X cannot influence firms' decision-making in China. Therefore, it is necessary to use social media in China to measure EPU.

Second, although we conducted validity tests, the DT measure still has several limitations. Our measure reflects managerial emphasis on digitalisation, which makes it susceptible to symbolic disclosure rather than actual resource input. Moreover, it captures the breadth but not the depth of digital transformation. This misses intangible and OPEX-driven change that characterise modern digitalisation such as competence development, organisational restructuring, flexible business process redesign and business model innovation. Future studies should employ case studies and surveys to validate and deepen these findings.

Third, potential endogeneity may exist in this research. Reverse causality may be evident, as prior digital transformation in developed regions may prompt underdeveloped regions to enact new digitalisation policies to catch up, increasing local EPU. Moreover, this study primarily considers the influencing factors at the firm level, and we neglect other external factors such as the facilitation of government policies on promoting the digital, networked and intelligent development of manufacturing industry, which could be explored in future research.

Finally, our research sample is listed companies in China, and the results may not be generalisable. On the one hand, unlike countries where interactions between enterprises and the government are more oriented towards market-based consultation, interactions in China tend to be managed through administrative guidance. Furthermore, China's cultural context causes enterprises to adopt more conservative strategies when facing EPU. Therefore, enterprises in other countries may not be affected by the EPU as strongly as those in China, and results of this study maybe limited beyond China. Further research should examine countries with different institutional environments and cultural backgrounds to compare and enrich the results.

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Appendix

Table A.1: Variable definitions

Variables	Definitions
DT	ln (Digital transformation index)
EPU	Economic policy uncertainty index
Leverage	Total liabilities / Total assets
Size	ln(Total assets)
Growth	(Current operating income – Last operating income) / Last operating income
ROA	Net profit / Total assets
Tangibility	Total tangible assets / Total assets
Cashflow	(Net operating cash flow + net investment cash flow) / total assets
SOE	Takes a value of 1 if the ultimate firm controller is state-owned and 0 otherwise
Macroeco	Economic Climate Indicator: Coincident Index (1996 = 100). Source: DRCNET Database
Edu	Average education of chairman and general manager. Education takes a value of 0 for education lower than a bachelor's degree, 1 for bachelor's degree, 2 for master's degree and 3 for doctoral degree
Age	Average age of chairman and general manager
Male	Average gender of chairman and general manager. When one is male, it takes a value of 1 and 0 otherwise
Acad	Average academic background of chairman and general manager. When one is employed by a university, research institution or professional association conducting research, *Acad* takes a value of 1 and 0 otherwise
Ovs	Average overseas background of chairman and general manager. When one has experience working or studying overseas, *Ovs* takes a value of 1 and 0 otherwise

Source: Authors' own elaboration