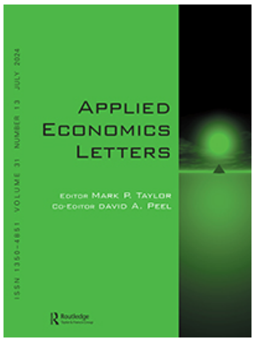

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The role of customers on digital technology innovation commercialization

Jinyue Tang and Shougui Luo

Antai College of Economics and Management, Shanghai Jiao Tong University, Shanghai, China

ABSTRACT
The rapid evolution of digital technology has sparked a profound transformation in economic dynamics. Based on firm-level data from China spanning 2008–2022, this study employs text analysis to construct a Digital Technology Innovation Commercialization (DTIC) index. By investigating the relationship between customers and DTIC, our analysis uncovers a significant positive impact of firms' customers, particularly in innovation systems with less governmental support, less intermediary service supply, and more high-tech market demand.

KEYWORDS
digital innovation; customer; innovation commercialization; text analysis

JEL CLASSIFICATION
D22; L86; O32

I. Introduction

In the preceding decade, digital technology has undergone rapid evolution, sparking a profound transformation in economic growth and firm dynamics (Shapiro and Mandelman 2021). Firms proficient in navigating this digital landscape stand to reap benefits such as enhanced customer experiences, streamlined operations, and the exploration of novel business avenues (Liu et al. 2023; Yang 2022). Conversely, inadequacies in managing digital technology pose a substantial threat to firms' competitive viability and overall survival (Fitzgerald et al. 2014). Hence, driving digital technology development assumes paramount significance.

To effectively leverage the role of a technology innovation in the economic landscape, commercialization becomes pivotal. However, barriers and challenges to commercialization exist, especially in developing countries, thus the frequency of successful commercialization is relatively low. Stevens and Burley (1997) highlighted that out of 3,000 raw innovative ideas, only 100 progressed to small research and development (R&D) projects, with just 8 leading to significant development projects, 1.7 to product launches, and ultimately only 1 achieving success. Data from China indicate that the commercialization rate of invention patents in China stands at 36.7%.[1] In the case of radical innovations like digital technology innovation (DTI), the rate is even lower due to their novelty, uniqueness, and divergence from previous products and services (Dahlin and Behrens 2005). Consequently, understanding and scrutinizing the commercialization of digital technology innovation (DTIC) emerges as a matter of significant importance.

While previous studies have delved into the determinants of DTI and its impact on value creation (Acemoglu and Restrepo 2020; Graetz and Michaels 2018; Igna and Venturini 2023), this paper underscores the pivotal role of commercialization in fully realizing the economic potential of DTI, deserving dedicated attention. While some qualitative research suggests that fostering interactive engagements with customers can facilitate commercialization (Chiesa and Frattini 2011), empirical evidence within this specific literature stream remains scarce. Moreover, the varying role of customers across different innovation systems warrants further investigation. Customers may play a more significant role in encouraging DTIC in innovation systems characterized by different government support, intermediary service provision, and high-tech market demand. Utilizing firm-level data from China spanning the period 2008 to 2022, we examine the relationship between customers and DTIC, as well as how external resources within innovation systems influence this relationship.

CONTACT Jinyue Tang tangjinyue@126.com Antai College of Economics and Management, Shanghai Jiao Tong University, 1954, Huashan Road, Xuhui District, Shanghai 200030, China

[1]Data sourced from 2022 China Patent Survey Report.

The rest of the paper is structured as follows. Section II presents hypothesis of this paper. Section III describes the empirical strategy and quantitative findings. Section IV concludes.

II. Hypothesis

Customer and DTIC

Firms benefit from customer involvement in DTIC for the following reasons. 1) Customers serve as external participants in firms' open innovation processes and may even act as contractors for R&D projects. Their engagement accelerates the exchange of knowledge, both inbound and outbound, thereby fostering internal innovation and expanding markets for the external utilization of innovation (Chesbrough and Crowther 2006). Involving customers in open innovation provides firms with clear and predictable objectives and directions for commercialization, consequently reducing the uncertainty associated with DTIC (Huizingh 2011). 2) Customers provide firms with valuable insights into the product market, competitors, and potential buyer demands and preferences, thereby alleviating information asymmetry between firms and buyers (Itani et al. 2020). This facilitates the identification of market opportunities, adjustments to innovation direction, and enhancements in DTIC (Fang 2008). 3) Acting as an external governance mechanism, customers incentivize managers to approach innovation with seriousness, thereby addressing the lack of innovation motivation stemming from principal-agent problems. Additionally, customers contribute to risk reduction in business operations, enabling firms to allocate more resources to innovation and achieve superior performance in DTIC. Based on the analysis, we propose the following hypothesis:

H1: Customers have a positive impact on DTIC.

Customer, innovation systems and DTIC

Firms derive heterogeneous benefits from customers in DTIC when situated in innovation systems with different external resources. 1) The Chinese government has instituted various policy instruments, including R&D subsidies, direct purchases, and tax incentives, to stimulate firms' DTIC activities (Kang and Park 2012). These policies alleviate financial constraints and risks for firms, thereby promoting DTIC. 2) Intermediary service institutions offer firms targeted products based on knowledge, information, and services, aiding in the establishment of cross-organization, cross-industry, and cross-region contact networks with other innovators. This, in turn, reduces the cost of knowledge integration and enhances DTIC (Howells 2006). 3) A larger high-tech market demand ensures that firms' innovation achievements can be sold at a faster pace and higher price, providing stronger incentives for firms to expedite DTIC and achieve higher returns in product markets. However, innovation systems that firms are located in differ greatly, and firms may struggle to obtain the resources needed for DTIC. Consequently, firms in these innovation systems benefit more from customer involvement, complementing their DTIC processes. Based on the analysis, we propose the second hypothesis as follows:

H2: The impact of customers on DTIC is greater for firms in innovation systems with less governmental support, fewer intermediary service supplies, and higher high-tech market demand.

III. Methodology and results

Model specification

Data source

This analysis draws on annual statistical data from technology firms in Shanghai (STFD) spanning the period from 2008 to 2022, collected by the Shanghai Science and Technology Committee and the Shanghai Bureau of Statistics. STFD boasts a significantly larger scale, covering a total of 56,085 firms and 166,207 observations, enhancing the comprehensiveness of the dataset.

Variables

We use the ratio of digital production (*Product*) to the number of digital patents applied in the past 5 years (*Patent5*) to measure DTIC (*DTIC*), based on text analysis methods (see Appendix A).

We derive the number of firms' major customers (*Customer*) from self-reported data.

Following existing literature, we control total employees (*Labor*), total assets (*Asset*), firms' age (*Age*), total debt (*Debt*), and return on assets (*ROA*).

We calculate average governmental R&D subsidy (*IS_GovRD*), intermediary consulting or services (*IS_Service*), and sales of high-tech products (*IS_Market*) cross firms of the region a firm locate in.[2] If the average surpasses the mean count across regions, we set dummy variables (*DGovRD*, *DService*, and *DMarket*) equal to 1, otherwise 0.

Table A1 presents the descriptive statistics of the variables (see Appendix B).

Methodology

We use a fixed-effect model to analyse the impact of customers on DTIC:

$$DTIC_{i,j,t} = \alpha + \beta Customer_{i,t} + X_{i,t}\gamma + \mu_j \times v_t + \varepsilon_{i,j,t}$$

where subscripts i, j and t indicate firm, industry and year; $DTIC_{i,j,t}$ represents firms' DTIC intensity; $Customer_{i,t}$ represents the number of firms' main customers; $X_{i,t}$ is the vector of control variables; $\mu_j \times v_t$ is the industry-year FE, to account for time-specific shocks on different industries; $\varepsilon_{i,j,t}$ is error term.

Baseline regression

Table 1 , Column (1) presents the benchmark regression results. Utilizing *DTIC* as the dependent variable, the coefficient on *Customer* exhibits a positive sign and attains statistical significance at the 1% level. Specifically, an additional major customer results in an average increase of 3.2% in DTIC, and H1 is confirmed.

The results in benchmark regression are supported by a series of robustness checks, shown in Columns (2) - (6). First, we use different dependent variables, including the ratio of *Product* to the number of digital patent applications for the past 3 years (*DTIC3*) and 7 years (*DTIC7*). Second, the sample used in the baseline is a sub-sample of firms with digital patent applications, so we regress *Product* on *Patent5* to avoid sample selection bias. Third, we use instrument variable (IV) method by employing the average number of customers in each industry, firm size, and year (*Customer_IV*) as an IV. Results in robustness checks are consistent with the baseline.

Mechanism analysis

Table 2 shows the results of mediating effects of governmental support, intermediary service supply and high-tech market demand. We re-estimate Equation (1) using sub-samples of firms in

Table 1. Benchmark regression and robustness checks.

Variables	(1) *DTIC*	(2) *DTIC3*	(3) *DTIC7*	(4) *Product*	(5) *Customer*	(6) *DTIC*
Customer	0.032***	0.034***	0.032***	0.009***		0.091***
	(0.006)	(0.006)	(0.005)	(0.001)		(0.027)
Patent5				0.009***		
				(0.001)		
Customer × Patent5				0.002***		
				(0.001)		
Customer_IV					0.919***	
					(0.010)	
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Industry-Year FE	Yes	Yes	Yes	Yes		
Industry FE					Yes	Yes
Year FE					Yes	Yes
LM statistic					170.484	
Wald F statistic					176.456	
Obs.	4,013	3,652	4,174	155,968	155,982	4,038
R2	0.104	0.109	0.104	0.115	0.327	0.012

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. Robust standard errors are in parentheses. Same as follows.

[2]We consider the district in which a firm is located as the innovation system to which it belongs.

Table 2. Mechanism analysis.

	(1)	(2)	(3)	(4)	(5)	(6)
	Governmental support		Intermediary service supply		High-tech market demand	
Variables: *DTIC*	High	Low	High	Low	High	Low
Customer	0.018**	0.044***	0.023***	0.043***	0.039***	0.028***
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.007)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Industry-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Region FE	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	1,741	2,066	1,790	2,020	1,633	2,178
R2	0.127	0.114	0.111	0.122	0.110	0.118

innovation systems with high or low level for three types of resources, respectively. We find that customers make a larger impact on firms in innovation systems with lower governmental support or lower intermediary service supply. Besides, the effect is higher on firms in innovation systems with larger high-tech market demand, confirming H2.

IV. Conclusion

Using firm-level data from China spanning 2008 to 2022, this study employs text analysis to construct a DTIC index, investigating the relationship between customers and DTIC. Our analysis unveils a significant positive impact of customers on firms' DTIC, and further test heterogeneity between different innovation systems.

Theoretical implication

This paper holds several theoretical implications: 1) While previous studies have primarily focused on the determinants of DTI and its impact on value creation (Acemoglu and Restrepo 2020; Graetz and Michaels 2018; Igna and Venturini 2023), this paper underscores the critical role of commercialization in fully maximizing the economic output of DTI. Thus, it emphasizes the necessity of dedicating attention to the commercialization process. 2) This paper contributes to open innovation theory by offering empirical evidence of the impact of customers on innovation, specifically within the context of digital innovation commercialization. By highlighting the role of customers in this process, it enhances our understanding of open innovation dynamics. 3) Additionally, this paper contributes to innovation system theory by examining methods for successful innovation, particularly for firms operating in less developed innovation systems. By investigating the challenges and opportunities faced by such firms, it enriches our understanding of commercialization processes within diverse socio-economic contexts.

Practical implication

This paper yields several practical implications: 1) Firms are encouraged to enhance their relationships with customers by offerring a variety of interaction platforms to facilitate engagement. Strengthening these connections can lead to valuable insights and feedback from customers, ultimately enhancing the success of DTIC processes. 2) Governments play a crucial role in supporting regional innovation systems. They should consider subsidizing firms' DTIC processes and optimizing intermediary service supply to alleviate financial constraints and promote knowledge sharing and collaboration among firms. 3) Governments should prioritize the development of high-tech product markets to create a conducive environment for innovation. Thus, firms will be incentivized to expedite their DTIC efforts, leading to higher returns and greater motivation for innovation.

Limitation

This paper still has the following limitations, which also provide directions for future research. 1) Due to data constraints, this paper is unable to disaggregate characteristics such as customers' size, industry, innovation capability, and relationship with firms. Future research could supplement micro-level data and explore the relationship between customer heterogeneity and DTIC. 2) This paper examines digital patents, which is the most prevalent output of innovation. Enriching the DTIC measure and augmenting the conclusions drawn from this paper are feasible avenues for subsequent research.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Appendices

Appendix A. Measure of DTIC

The dependent variable measuring digital technology innovation commercialization (DTIC) in this study is derived from two components. The first pertains to digital technology output, serving as the intermediate stage of innovation and measured through digital patent applications (*Patent*). The second pertains to digital economic output, representing the innovation transformation stage and quantified by the production of digital products (*Product*). DTIC is gauged as the ratio of economic output to technology output, utilized as the dependent variable (*DTIC*).

To acquire information on digital production and digital patent applications for each firm annually, a text analysis method is employed. The statistical data employed in this study delineates the firms' yearly scope of business. The text data, complementing this, offers detailed insights into the nature and content of the products manufactured by the firms. Following the methodology outlined by Wu et al. (2021), digital-related dictionaries/feature words are compiled. These encompass terms such as artificial intelligence, big data, cloud computing, and block chain. Employing Python for text extraction from firms' annual business scope, the feature words are used to search, match, and tally word frequencies, ultimately forming the total word frequency. This, in turn, serves as the indicator for the firms' digital production output (*Product*).

Firms' annual patent applications are obtained from the Incopat database,[3] and text analysis of patent abstracts is conducted using the digital-related dictionaries/feature words. If a patent abstract incorporates digital-related feature words, it is classified as a technical application within the digitization domain. Consequently, firms' annual digital patent applications for the current year (*Patent1*) are determined through this process.

Figure A1 illustrates the trend of digital production (*Product*) and digital patent applications (*Patent1*), both of which exhibit substantial increases from 2008–2018.[4] To capture a more comprehensive view, we calculate the number of digital patent applications within three years (*Patent3*), five years (*Patent5*), and seven years (*Patent7*). Recognizing that the commercialization of innovation necessitates a prolonged period rather than being realized in the current year, this paper employs the ratio of digital patent applications within the past five years as the independent variable (*DTIC*). Furthermore, applications within the past three years (*DTIC3*) and past seven years (*DTIC7*) are included in robustness checks. Figure A2 portrays the trend

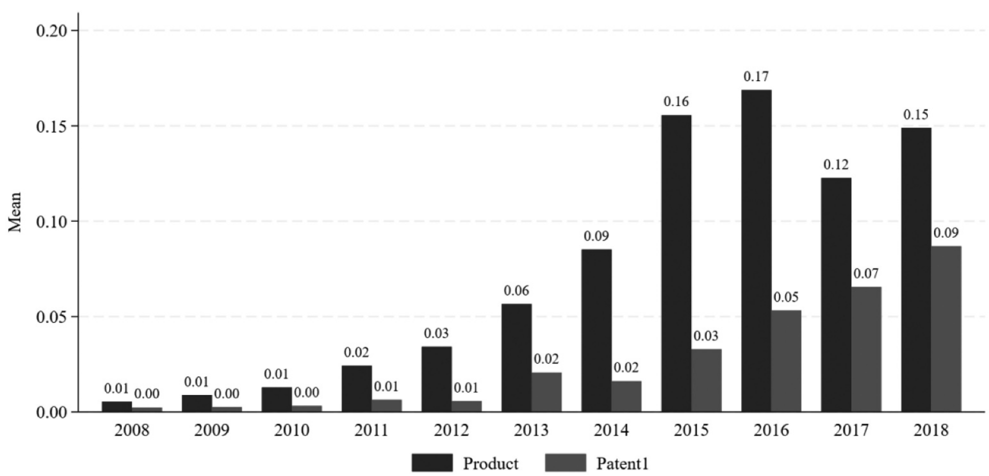

Figure A1. The trend of digital production and digital patent application.

[3]Data sourced from: https://www.incopat.com/

[4]The annual statistical data of technology firms in Shanghai (STFD) were collected since 2008 and terminated in 2018. In order to ensure the timeliness of data, we searched the firms surveyed in STFD from the CSMAR database (https://data.csmar.com/) and downloaded their latest data during the period 2019–2022. However, the supplemented data do not cover all firms in STFD. As a result, to ensure the stationarity of the trend of digital production, patents, and DTIC, we only show the trend based on original STFD during 2008–2018 in Figure A1 and A2.

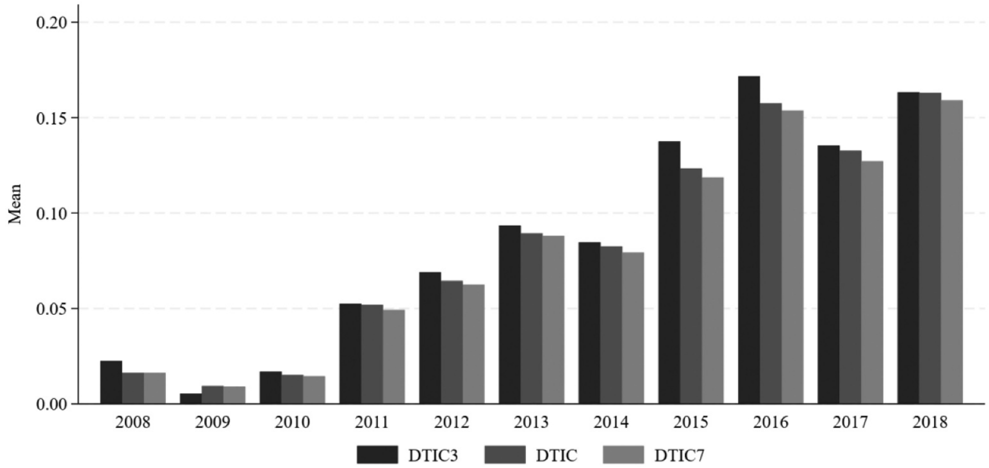

Figure A2. The trend of digital technology innovation commercialization.

of DTIC, revealing a consistent increase from 2008 to 2018. Notably, the trends of the three indicators—*DTIC*, *DTIC*3, and *DTIC*7—are relatively similar, affirming the reliability of the selected indicators in this study.

Appendix B. Summary statistics

Table A1 presents the descriptive statistics of the variables.

The number of digital patent applications for some observations is zero, leading to missing values in the dependent variable (*DTIC*). Considering this issue, the benchmark regression sample only includes observations with a digital patent application count greater than zero. In Table 1 Column (4), when using digital production (*Product*) as the dependent variable for a robustness check, regression is conducted using the full sample.

Table A1. Summary statistics.

Variable	Measure	Mean	Std. Dev.
Dependent variable			
DTIC	Ratio of digital production to digital patent application (for the past 5 years)	0.125	0.347
Independent variable			
Customer	Number of main customers	1.481	1.082
Control variables			
Labor	Total employee (tho personnel)	0.088	0.393
Asset	Total asset (billion yuan)	0.002	0.048
Debt	Total debt (billion yuan)	0.001	0.038
Age	Firm age (year)	8.057	5.987
ROA	Return on assets (revenue/asset)	0.021	0.787
Moderating variables			
DGovRD	Regional governmental support (0–1)	0.441	0.497
DService	Regional intermediate service (0–1)	0.434	0.496
DMarket	Regional high-tech product market (0–1)	0.321	0.467
Observations	**166,863**		