Received: 23 May 2018 | Revised: 12 August 2023 | Accepted: 18 August 2023

DOI: 10.1002/smj.3551

RESEARCH ARTICLE

SMS | Strategic Management Journal

WILEY

When firms may benefit from sticking with an old technology

Xu Li

London School of Economics and Political Science, London, UK

Correspondence
Xu Li, London School of Economics and Political Science, Houghton Street, London WC2A 2AE, UK.
Email: x.li33@lse.ac.uk

Abstract

Research Summary: How should firms respond to technological discontinuities in order to achieve greater performance? In contrast to most studies that advocate a timely transition from the old to the new technology, this paper posits that in markets where a discontinuous technology exposes customers' latent preference heterogeneity for certain old technology attributes, firms may ultimately experience a performance surge by adhering to the old technology during technological change. Explicitly, I theorize a U-shaped relationship within such a market between competitors' increasing adoption of the new technology and the performance of firms that stick with the old technology. This prediction is thoroughly examined using comprehensive data from the traditional Chinese medicine industry in China during the 1990s and receives robust empirical support.

Managerial Summary: In some markets, the rise of a discontinuous technology, besides posing a substitute threat to the old technology, further exposes niche segments where customers continue to favor the old technology. This paper predicts that within such a market, as competitors increasingly adopt the new technology for varied motives, firms sticking with the old technology may see their performance declining before rebounding and potentially reaching new heights. Analyses using archival data from the traditional Chinese medicine industry in China during the 1990s provide robust support for this prediction. The arguments and findings of this paper offer an "existence proof" that when confronted with a technological discontinuity, adhering to the old technology may also represent an effective strategy that ultimately improves firm performance.

KEYWORDS

demand heterogeneity, firm performance, old technology, technological discontinuity

1 | INTRODUCTION

Decades of innovation research has widely acknowledged that discontinuous technological changes impact the rise and fall of firms across industries (Anderson & Tushman, 1990; Astley, 1985; Christensen, 1997; R. M. Henderson & Clark, 1990). A central question explored in this literature is how incumbents may remain competitive when confronted with a technological discontinuity (Adner & Snow, 2010; Sosa, 2011). Addressing this, most studies suggest, explicitly or implicitly, that the "correct" response is to simply "embrace its inevitability" (Adner & Snow, 2010, p. 1656). From the US tire industry to the global typesetter industry, the prevalent image put forward by research on technological change is one of winning firms that successfully transitioned from the old to the new technology, and of losing firms that fell behind (Adner & Snow, 2010, p. 1656; Cooper & Smith, 1992; Foster, 1986; Rosenbloom, 2000; Sull, 1999; Tripsas, 1997). Underlying these studies is the critical assumption of demand substitution, where the old technology, often of inferior functionality, is to be completely displaced as market demand shifts toward the new technology (Klepper, 1996; Tushman & Anderson, 1986; Utterback, 1996).

This process of "technology displacement," although observed in many different industries, has been increasingly questioned by recent research on the "retreat" and "reemergence" of old technologies (e.g., Adner & Snow, 2010; Raffaelli, 2019). Focusing on the demand context where multiple technologies compete, these studies pointed out that despite a new technology's being functionally superior, variations in customers' evaluation criteria, such as budget constraints, preferences for distinct attribute bundles, or emotional and nostalgic attachments, may still preserve substantial market space for the old technology (Adner, 2002; Adner & Levinthal, 2001; Raffaelli, 2019). For instance, decades after the emergence of quartz technology in watchmaking, mechanical watches were still appreciated by abundant customers for reasons having little to do with accurate timekeeping (Priem et al., 2012; Raffaelli, 2019). Nevertheless, although recognizing possible niches for old technologies, these studies insist that firms' "retrenching" into such niches during technological change is merely an option for "survival and contraction" rather than an opportunity for "growth and expansion" (Adner & Snow, 2010, p. 1657).

Building on these nonlinear perspectives on technology evolution, this paper offers an "existence proof" that firms may experience a performance boost by sticking with an old technology while facing the threat of a technological discontinuity. Specifically, I focus on markets where the rise of a discontinuous technology, besides posing a substitute threat, further exposes some customers' *latent preference* for *attributes of the old technology* (hence for the old technology) that are *discarded by the new technology*. Within such a market, I predict that the performance of old-technology firms will follow a U-shaped curve as their competitors increasingly pursue the new technology. I first argue that as early innovators quickly steal substantial market from the old technology, most firms will be left to battle in a severely contracted market for the old technology; this leads to *excess supply*, and thus heightened competition, in the old-technology market, causing old-technology firms to suffer in their performance early on. However, as more firms keep adopting the new technology for varied motives (see Abrahamson & Rosenkopf, 1993), market size for the old technology will decrease slower and eventually reach a plateau that comprises the "revealed niches" where customers persistently favor the old technology (Adner & Snow, 2010). As this takes place, the continued transition and possible over-entry into the new technology by competitors, a move that is difficult to reverse (see Eggers, 2012), will steadily *lessen* the excess supply, and hence the competitive intensity, in the smaller old-technology market. This will then allow the performance of firms adhering to the old technology to not only begin recovering but also likely reach new heights, especially if a collusive oligopoly or a monopoly ultimately emerges among the few remaining to serve the old-technology niches.

I empirically test my prediction using data on the entire population of firms in the traditional Chinese medicine (TCM) industry in China in the 1990s. During the study period, up to 63% of TCM producers per province (i.e., submarket) began launching so-called hybrid TCM in dosage designs adopted from Western medicine, a technological discontinuity that generated order-of-magnitude improvements in the stability, dose efficiency, and intake convenience of the traditional products (Dong, 2001). Yet, despite offering improved functionality at similar prices,[1] the new hybrid TCM, which scrapped the ancient TCM dosage designs (e.g., honey bolus, decoction), was not uniformly appreciated across all customer segments. According to industry experts, many customers, especially rural residents, continuously valued the old dosage formats and remain loyal to classic TCM today, over three decades after the invention of hybrid TCM (Recorded Interview).

Through careful analyses, I first verified that at the province level, as more firms introduced hybrid TCM, the per capita sales of classic TCM products in a province dropped rapidly before reaching a plateau, clearly indicating the existence of market niches for the old technology. More important, at the firm level, I found that with competitors increasingly adopting hybrid TCM, the profitability (and output) of TCM firms that stood by industry conventions declined drastically before steadily climbing to record highs. Results remained consistent and supportive of my theoretical arguments across various additional tests. Contrary to extant technological change studies, this paper highlights boundary conditions on when sticking with an old technology, despite the rise of a technological discontinuity, may also represent an effective strategic choice that elevates firm performance.

2 | TECHNOLOGICAL DISCONTINUITY AND REVEALED NICHE FOR THE OLD TECHNOLOGY

Innovation scholars have long noted that across industries, technologies evolve through periods of incremental changes punctuated by discontinuous breakthroughs (Anderson & Tushman, 1990;

[1]To prevent price inflation, the Chinese government closely monitored and curbed the price of hybrid TCM products based on existing TCM formulae during the study period (State Administration of Commodity Prices & National Administration of TCM, 1990; State Development Planning Commission, 1996).

Schumpeter, 1942; Tushman & Anderson, 1986). These breakthroughs offer significant price-performance improvements over existing technologies and could destroy or enhance the competence of firms within an industry (Abernathy & Clark, 1985; Tushman & Anderson, 1986). Although technological discontinuities may concern either underlying processes or the products themselves, this paper focuses on *product discontinuities* that are "fundamentally different product forms that command a decisive cost, performance, or quality advantage over prior product forms" (Anderson & Tushman, 1990, p. 607). Examples of such discontinuities include diesel (vs. steam) locomotives, CT scanners (vs. x-rays), and quartz (vs. mechanical) watches (Anderson & Tushman, 1990, p. 607; Tushman & Anderson, 1986).

In studying firms' reactions to discontinuous technological changes, most prior research implied a pro-innovation bias (Gopalakrishnan & Damanpour, 1997; Raffaelli, 2019; Rogers, 2003). On one hand, scholars argued that new technologies generate new market opportunities, and that by adopting them, firms are often able to attract customers outside of their home markets, ultimately enlarging their market spaces (Bond III & Houston, 2003; Christensen & Raynor, 2003; Rothaermel & Hill, 2005). For instance, during the early 1980s, the disruptive change to a 5.25-in. architecture from the previous 8-in. architecture made disk drives smaller, lighter, and cheaper, enabling innovators to appeal to the emerging market segment of desktop personal computers (Christensen & Bower, 1996; King & Tucci, 2002). On the other hand, and more critically, the literature asserted that within the home market, the rise of a discontinuous technology poses a substitute threat to the old technology and "forces the dismantling" of its applications, subsequently leaving firms no option but to retire the old technology (Raffaelli, 2019, p. 577; Foster, 1986; Schumpeter, 1934; Utterback & Abernathy, 1975). This process of "technology displacement" has been witnessed in the demise of numerous legacy technologies including bias tires, VHS tapes, and dial-up modems, where the old technology is "swept away" as customer demand shifts toward the new technology (Cusumano et al., 1992; Raffaelli, 2019, p. 578; Sull, 1999; Utterback & Suarez, 1993).

Nevertheless, calling on the concept of demand heterogeneity, research on technology "retreat" and "reemergence" posited that despite a new technology's superiority, complete displacement of the old technology in the home market is not inevitable (Adner & Snow, 2010; Raffaelli, 2019). For example, some customers may continue to favor the old technology over the new due to their budget constraints or emotional attachments to the old technology (Adner, 2002; Adner & Levinthal, 2001). More important, scholars contend that sustainable niches for the old technology are likely to form within the home market if the onset of a new technology concurrently reveals the *previously hidden differences* in customers' preferences toward *attributes of the old technology* that the new technology *neglects to address* (Adner & Snow, 2010, p. 1662). Unlike the old technology, a new technology uses novel approaches to deliver performance, often leading to new couplings and de-couplings of functional attributes presented to customers (Adner & Snow, 2010). This not only expands customers' choice set but also uncovers new dimensions along which preference heterogeneity may subsequently surface (Adner & Snow, 2010, p. 1661). For instance, the "mechanicalness" of a watch, once taken for granted by all, only became a choice following the advance of quartz technology in watchmaking; for customers who simply treasure the mechanical movement, a quartz watch, despite its improved accuracy in timekeeping and lowered price, failed to meet their needs (Adner & Snow, 2010; Raffaelli, 2019). Therefore, when a discontinuous technology exposes such latent preference dissimilarities among customers over certain old-technology attributes, besides presenting a substitute threat, it further unveils market niches where the old technology is persistently favored; within these niches, firms sticking with the old technology can maintain advantages over others that have adopted the new one.

3 | HYBRID TCM AND REVELAED NICHE FOR CLASSIC TCM IN CHINA

This mechanism of niche revelation for the old technology was evident in the context of TCM. As a complete healing system, TCM emerged in China over 3000 years ago and is considered one of the oldest continuously surviving traditions and a vital aspect of Chinese civilization (Yu et al., 2006; Zhu & Woerdenbag, 1995). Guided by comprehensive historical documentation, most TCM products have been consistently manufactured and prescribed in China for centuries (Chen & Xu, 2003; Siow et al., 2005). Since the economic reform, the marketization of the TCM industry has been vigorously encouraged by the Chinese authorities (Schroeder, 2002). Especially in the 1990s, not only was an increasing degree of managerial autonomy delegated to state-owned enterprises, but also various forms of private ownership began to blossom. During this period, up to 40% of China's health care was estimated to rely on TCM (Hesketh & Zhu, 1997).

In striving to remain competitive in a society undergoing rapid modernization, the integration of Western medicine compounding and preparation techniques became a prominent innovation approach among TCM producers in the early 1990s. This hybrid approach used methods including supercritical fluid extraction, membrane separation, and solid dispersion, turning TCM formulae from their ancient formats, such as decoction and honey bolus, into a variety of contemporary styles (e.g., tablet, capsule) previously seen only in Western medicine (Dong, 2001). As a clear indication of this trend, only 18 of 207 (8.7%) TCM products recorded in the 1985 edition of the Chinese Pharmacopoeia were in Western dosage designs; their number jumped to 40 of 275 (14.5%) by the 1990 edition, and then rose swiftly to 101 of 398 (25.4%) by the 1995 edition (Lin, 2008). By 1996, up to 63% of TCM producers per province had begun launching such hybrid TCM. The invention of hybrid TCM radically transformed the centuries-old TCM products, generating order-of-magnitude improvements in drug stability, dose efficiency, and intake convenience (Dong, 2001). It was widely regarded as a major product discontinuity among industry insiders.

Despite quickly gaining market popularity, the novel hybrid TCM had not been uniformly appreciated by all customers since its rise, even today—over three decades after its invention (AskCI.com, 2022). Besides its improved functionality, hybrid TCM brought about a new distinction between TCM products based on the style of their dosage formats—that is, traditional Chinese versus modern Western. This distinction allowed a subset of TCM customers, especially those residing in rural regions, to demonstrate their *once hidden, yet continued, preference* for the classic TCM dosage designs—an attribute discarded by the otherwise superior hybrid technology—revealing viable niche opportunities in the home market for the classic TCM technology. When asked how customers received TCM with contrasting dosage formats in the 1990s, the CEO of a major TCM firm commented:

> When it [hybrid TCM] first emerged in the market, lots of customers were enthusiastic about it … Many considered the new dosage designs to better suit the fast pace of modern life … But not everyone accepted it, as some considered the traditional dosage designs, such as honey boluses or herbal tea, a key essence of TCM … Notably, for people living in rural regions, their preference towards TCM in traditional dosage designs remained almost unchanged over the years.
>
> (Recorded Interview)

4 | THE PERFORMANCE CONSEQUENCE OF STICKING WITH AN OLD TECHNOLOGY

4.1 | The initial decline in the performance of old-technology firms

In markets where a technological discontinuity exposes customers' latent preference heterogeneity for certain old-technology attributes, such as that of TCM, the revelation of sustainable niches for the old technology has critical performance implications for firms sticking with the old technology during technological change. As Figure 1 illustrates, before any competitor launches the new technology, the home market is entirely dominated by the old technology. At this stage, all firms in the market continue to compete based on the old technology; therefore, the competitive dynamics within the market, and thus firm performance, are expected to stay largely unchanged as they have been prior to the emergence of any technological discontinuity.

As a small number of firms begin introducing the new technology, as shown in Figure 1, the process of "demand substitution" manifests (see Raffaelli, 2019) and *market size* for the old technology *declines sharply*. These early innovators, as prior research suggests (Kerin et al., 1992; Lieberman & Montgomery, 1988, 1998; VanderWerf & Mahon, 1997), tend to conquer significantly larger shares of the home market from the old technology than late adopters of the new technology. This is because unlike firms that commonly face substantial organizational inertia and switching costs that impede their transition to a discontinuous technology (Christensen, 1993; Eggers, 2014; Gilbert, 2005; R. Henderson, 1993), customers act much faster at adopting the new technology once its performance meets their needs (see Christensen, 1997; Christensen & Bower, 1996). In particular, studies showed that early innovators greatly influence how attributes of a new technology and their ideal combination are valued by customers (Carpenter & Nakamoto, 1989; Lieberman & Montgomery, 1998); they thus encounter less resistance and are able to "skim off" abundant customers, who view their inventions as the

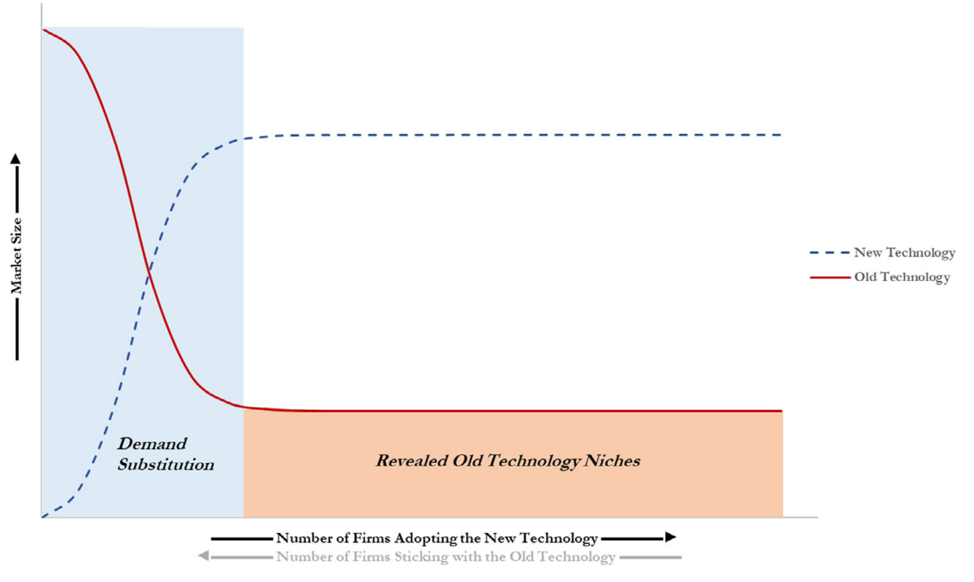

FIGURE 1 The relationship between competitors' new technology adoption and market size for the old technology.

"prototype," in comparison with firms late to the new technology that are mostly left with customers less predisposed to pursuing novelty (Carpenter & Nakamoto, 1989; Kerin et al., 1992, p. 35). Besides, while accumulating superior resources and capabilities, early innovators may preempt various resources, such as patents or prime physical locations, hence further raising the entry barriers to the new-technology market for other competitors (Lieberman & Montgomery, 1988, 1998); this deters followers' transition into the new technology, enabling the pioneering firms to retain and expand their market share by capturing more old-technology customers (Kerin et al., 1992).

As a result, the prompt launch of the new technology and acquisition of customers by early innovators are likely to leave the majority of firms, who stayed behind with the old technology, to battle in a severely contracted market for the old technology. This leads to *excess supply* in a smaller market for the old technology, subsequently causing intense price competition among firms adhering to the old technology. In addition, the reduced demand (and price) for the old technology may further depress the production of the old-technology firms, which would raise the per-unit cost of these firms in contexts where scale-economies are present (Chandler Jr., 1990; Silberston, 1972; Kogut, 1985). Hence, following the initial introduction of the discontinuous technology by a few competitors, I anticipate firms sticking with the old technology to *suffer* in their performance. For example, one TCM manager recalled:

> Initially, [there's] lots of competition on prices, as most firms were producing the same honey boluses … a few firms started introducing the new [hybrid] TCM … They might find themselves as one of the few that produced the new TCM … It significantly enhanced their chances [in market competition]. They certainly generated lots of profits and advantages by doing so … For our firm, over 80% of our traditional honey boluses were overtaken by the new TCM in the market.
>
> (Recorded Interview)

4.2 | The subsequent rise in the performance of old-technology firms

The worsening performance of old-technology firms, upon the rise of a discontinuous technology, may force some to exit the market entirely,[2] which mitigates the excess supply in the old-technology market. More important, prior research indicates that as their performance falls below social or historical aspiration levels, firms become more motivated to overcome various barriers and seek market position changes (see Greve, 1996, 1998). Especially in the earlier stage of diffusion, firms often adopt innovations, thus moving into the new technology themselves, to solve organizational problems and yield better returns (Abrahamson & Rosenkopf, 1993, p. 491; DiMaggio & Powell, 1983; Tolbert & Zucker, 1983). Indeed, many TCM managers I interviewed mentioned how after the launch of hybrid TCM by industry pioneers, the performance drop "stimulated lots of other firms to do the same thing" (Recorded Interview).

Crucially, as Figure 1 depicts, as a larger number of firms follow the early innovators and further adopt the discontinuous technology, *market size* for the old technology, in contrast to its steeper decline earlier on, will *diminish marginally and eventually plateau*. This plateau comprises the revealed niches in the home market where the old technology is persistently favored despite the boom of the new technology (Adner & Snow, 2010). Given such a relatively stable,

[2]For instance, during the study period, 158 of the 917 firms that stuck with classic TCM technology in my sample were eventually driven out of business following the rise of hybrid TCM.

albeit smaller, market for the old technology, the degree of excess supply for the old technology within, as discussed earlier, will growingly lessen as more competitors, who aspire to better performance (Fligstein, 1985; Greve, 1998; Tolbert & Zucker, 1983), continue to transition into the new technology to serve a bigger and less crowded market and exit the old-technology niches. Hence, rather than capturing additional market from the old technology, the increasing adoption of the new technology by firms after the early innovators will gradually *alleviate the competitive intensity* in the contracted market for old technology, allowing the performance of firms sticking with the old technology to begin *recovering*.

Despite this uptick in their performance, more old-technology firms are expected to keep adopting the new technology, further reducing competition in the old technology niches, even after supply is no longer excessive in such niches following the exits of prior adopters. This may occur because the new technology, as extant research suggested (Bond III & Houston, 2003; Christensen & Raynor, 2003; Rothaermel & Hill, 2005), expands its market by capturing not only customers in the home market but also ample new customers outside the home market who previously disregarded the old technology. Under such circumstances, as supply matches demand in the old technology niches after many competitors' exits, the new-technology market, due to its enlarged size, is likely to remain in a state of *shortage*; the excess demand in a bigger market for the new technology incentivizes more firms to embrace it and further abandon the old technology. For instance, industry experts remarked that, over time, more TCM firms launched hybrid TCM once realizing that doing so would allow them to attract substantial urban and youth customers who previously dismissed the classic TCM products (Recorded Interview).

Furthermore, irrespective of the new technology acquiring extra customers, more firms may still actively pursue it and subsequently *over-enter* the new-technology market. Scholars pointed out that in the later stage of diffusion, firms often adopt innovations for reasons other than their thorough assessments of the innovations' efficiency or returns (Abrahamson & Rosenkopf, 1993, p. 491). In particular, when facing a technological discontinuity, managers often overestimate the new technology's market potential, which prompts its wider adoption among firms (see Khessina et al., 2018; Li & Vermeulen, 2021). Such biases are likely prevalent when return of the new technology is highly risky, leading managers to disproportionally focus on successful innovators and undersample failures in vicarious learning (Denrell, 2003), or when a "bullwhip effect" manifests due to lack of coordination among supply chain members, causing managers to be misguided by the amplified demand information for the new technology passed upstream by retailers (Lee et al., 1997). In addition, firms may also adopt a new technology due to the institutional or competitive bandwagon pressures caused by the sheer number of competitors that have done so (Abrahamson & Rosenkopf, 1993). These pressures occur because firms fear either losing legitimacy by appearing different from the vast adopters (Meyer & Rowan, 1977; Selznick, 1957), especially if non-adoption is stigmatized and viewed by stakeholders as signs of organizational inattention or incompetence (see Adner & Snow, 2010), or falling below average in performance if most competitors profit from adoption (Abrahamson & Rosenkopf, 1990, 1993). Echoing these arguments, several TCM managers I interviewed simply attributed their firms' eventual launch of hybrid TCM in the 1990s to the "same move" by other competitors, particularly the successful ones (Recorded Interview).

Despite their motives, as more and more firms move into the new technology and exit the old-technology niches, competition within market for the old technology will inevitably become increasingly less severe. With fewer and fewer competitors left to serve customers in the old-technology niches, the bargaining power of these remaining firms over customers strengthens (Casciaro & Piskorski, 2005; Emerson, 1962; Porter, 1979), allowing them to possibly raise prices for the old technology. This would be especially salient if a collusive oligopoly or a monopoly ultimately emerges among the handful of firms that adhere to the old technology throughout. In addition, facing a stable niche market and a decreasing number of direct competitors, old-technology firms are likely to see their output rebounding from the early declines due to "demand substitution," which, in contexts where scale economies exist, would lower their per-unit cost (Chandler, 1990; Kogut, 1985; Silberston, 1972). As these gradually take place, the performance of firms sticking with the old technology, despite losing the mainstream market to the discontinuous technology, will *not only keep on recovering but also potentially reach new heights*. As one TCM manager elegantly put it:

> They [market segments of traditional TCM and hybrid TCM] were like two different battlefields. If everybody moved to the new battlefield, and I stayed where I was, I might get even better here … I remember at some point everybody shifted to adopt Western dosage designs … We kept manufacturing our drug ** in honey boluses … Later we became the only firm producing this drug ** in the old way … [We] never changed it, [the drug was] still the same … We ended up making over 700 million RMB, in contrast to the 200 million beforehand.
>
> (Recorded Interview)

It is important to note that after adopting a new technology, returning to the old technology, although possible, is challenging for firms. When transitioning to a discontinuous technology, old-technology firms need to overcome significant organizational inertia and invest substantially in creating new structures, processes, and capabilities (Gilbert, 2005; R. M. Henderson & Clark, 1990; Leonard-Barton, 1992). For example, in the 1990s, it cost TCM firms over 12 million RMB to build standard production facilities suitable for hybrid TCM (Tang & Zeng, 1992, p. 43), and 2–6 million RMB annually up to a decade for its R&D (Liu, 1999, p. 20). More important, once deciding to pursue a new technology, even if the technology ultimately fails, firms tend to persist in their R&D activities, causing prolonged investment (Eggers, 2012, p. 51; Griliches, 1990; Helfat, 1994; Van Oorschot et al., 2013). This escalation of commitment not only generates new inertia that prevents firms from easily reverting to the old technology but also decreases the resources available for reinvesting in the old technology and for competing effectively with others that have been fully committed to it (Eggers, 2012, 2014; Guler, 2007). Besides, given the performance decline that most old-technology firms suffered upon the rise of the discontinuous technology, a "once bitten, twice shy" effect likely occurs (Eggers, 2012, p. 51), whereby the early failure diminishes the appeal of the old technology to firms, lowering their willingness to jump back into it despite its profitable niche applications (Denrell & March, 2001; Eggers, 2012).

Finally, it is also possible that in the end, due to the high market concentration within the old-technology niches, the few remaining competitors that stick with the old technology collude to thwart the (re)entry of not only incumbents that previously left for the new technology, but also de novo firms pursing the old technology (Asch & Seneca, 1975; Caves & Porter, 1978; Orr, 1974). The barriers for entry and subsequent success in the old-technology niches will be particularly high for de novo entrants, who, in comparison to firms adhering to the old technology before and throughout the technological change, lack critical resources such as established brands, history, and authenticity associated with the old technology (see Lehman et al., 2019; Verhaal et al., 2022), which likely hinders their appeal to the niche customers.

To sum up, building on all the arguments above, I hypothesize the following:

Hypothesis. In markets where a discontinuous technology exposes customers' latent preference heterogeneity for certain old-technology attributes, as more competitors adopt the new technology, the performance of firms sticking with the old technology will initially decline before rising again (i.e., a U-shaped curve).

5 | METHOD

5.1 | Data sources and sample

My main analyses utilize data on the TCM industry in China between 1991 and 1996, a prime period acknowledged by industry experts and reports (e.g., Qing, 1993; Wu & Ding, 1994; Yan, 1996) for the rise of hybrid TCM. Quantitative data come from three sources. First, the Chinese State Economic and Trade Commission publishes an annual TCM industry report, known as the Firm Registration Yearbook, that covers detailed firm-level production information for all domestic TCM manufacturers in China. Through industry insiders, I gained access to the 1991 through 1996 editions of these otherwise confidential yearbooks. I gathered similar yearbooks for the Western medicine industry in China to assist the analyses. Unfortunately, yearbooks from 1996 onwards are still considered "top secret" and not available to the public. Nevertheless, using secondary sources, I was able to collect additional but incomplete production information for TCM firms between 1997 and 2000, extending the data for 4 more years. Since firm-level controls (see below) are missing for these later years, I report analyses using the extended sample, which produced consistent results, as robustness checks in the Appendix 2.

Second, to identify firms that incorporated Western medicine techniques in R&D and began launching hybrid TCM during the study period, I relied on the new-drug registration database compiled by the Chinese SFDA. With the help of three industry experts, I tracked records for all drug innovations by domestic TCM firms from 1985[3] through 1996 and carefully identified those integrating Western dosage designs. Third, I obtained province-level macro data, including average disposable income, foreign direct investment, and rural population, from the 1991 through 1996 editions of the Statistical Yearbook of China and the China Population Statistics Yearbook issued by the Chinese Statistics Bureau. Moreover, to deepen my understanding of the empirical context, I reviewed over 40 TCM firm and industry reports published in the 1990s, visited multiple TCM headquarters and research labs across China, and conducted 33 in-depth interviews with industry experts, many of whom have been actively involved in TCM R&D and sales since the late 1980s.

Because the current study investigates the performance of firms sticking with the old technology, the final merged sample includes 917 (of a total 1453) TCM producers operating across 29 provinces in China between 1991 and 1996 that remained traditional and shunned the introduction of hybrid TCM themselves.

[3]This SFDA database is subscription based and contains the complete archives of all drug innovations ever approved for manufacture in the Chinese market since the 1985 Provisions for New Drug Approval.

5.2 | Dependent variable

To capture *firm performance*, I followed prior research (e.g., Cool & Dierckx, 1993; Palepu, 1985) and simply employed a firm's annual return on sales (ROS), measured as the ratio of firm profits to product sales in the same year.

5.3 | Independent variable

According to industry experts, most TCM firms, being small to medium-sized, compete primarily within their own provinces in the early 1990s. Given that sufficient administrative and cultural boundaries exist between Chinese provinces (Deng & Kaitin, 2004; Hesketh & Zhu, 1997; Zhou et al., 2017), I followed prior research (e.g., Li & Vermeulen, 2021) and treated each province as a unique submarket[4] and divided all TCM producers into 29 submarkets using geographic information recorded in the yearbooks.

For each TCM firm adhering to industry conventions, I identified a distinct submarket based on its geographic location. Of all firms in my sample, none changed location during the study period. Subsequently, for every submarket in a given year, I calculated the percentage of all TCM producers within that began introducing hybrid TCM in Western dosage form by the end of the previous year. I labeled this measure *competitors' new technology adoption* and used it to indicate the amount of competitors in a market that had already adopted the discontinuous technology.[5] The *squared term* of this measure was also entered in the regressions to capture the predicted second-order effects. Table 1 outlines the descriptive statistics of this measure and the annual per-capita sales of classic TCM products across all 29 provinces, indicating the overall shifts in both supply and demand for the ancient TCM technology in China during the study period.

5.4 | Control variables

I included a series of control variables across all models. At the province (i.e., submarket) level, to capture customers' familiarity with hybrid TCM, for each year, I controlled for both *local hybrid TCM density*, measured as the count of hybrid TCMs introduced by all TCM producers within a focal province by the end of the previous year, and *foreign hybrid TCM density*, measured as the count of hybrid TCMs launched by TCM producers from all provinces other than the focal province by the end of the previous year. Next, I calculated per-capita sales of the Western medicine industry in each province in the previous year based on data from the Western medicine yearbooks and used it to indicate the *competition from Western medicine* within a province. Moreover, given that urban and rural residents seemed to differ in their preferences for classic TCM according to industry experts, for each province, besides controlling for the

[4]As a robustness check, I repeated the main analysis using a subsample of small firms with total employees less than 263.35, the mean of the full sample. I assume, based on consultations with industry experts, that these smaller firms were especially more likely to solely focus on their local markets. Results are entirely consistent and reported in Appendix 2.

[5]Although possibly correlated with the "time" since the local emergence of hybrid TCM, this measure allows me to better capture the possible re-entry into the old-technology niches by firms that previously adopted hybrid TCM and the heterogeneous speeds that the new technology diffused among TCM firms across different provinces.

TABLE 1 Descriptive statistics of key variables for each province (i.e., submarket).

	Market size (i.e., annual per capita sales in hundred RMB) for classic TCM				Percentage of firms adopting hybrid TCM			
Variable	**Mean**	**SD**	**Min.**	**Max.**	**Mean**	**SD**	**Min.**	**Max.**
1. Shanghai	0.78	0.45	0.25	1.19	0.04	0.10	0.00	0.22
2. Yunnan	0.06	0.01	0.05	0.08	0.03	0.02	0.00	0.05
3. Inner Mongolia	0.02	0.00	0.02	0.03	0.15	0.06	0.08	0.23
4. Beijing	0.08	0.04	0.03	0.12	0.33	0.18	0.18	0.58
5. Jilin	0.34	0.04	0.29	0.40	0.12	0.04	0.07	0.16
6. Sichuan	0.09	0.05	0.04	0.17	0.01	0.02	0.00	0.03
7. Tianjin	0.13	0.07	0.04	0.19	0.54	0.07	0.44	0.63
8. Ningxia	0.04	0.02	0.02	0.07	0.09	0.12	0.00	0.25
9. Anhui	0.06	0.02	0.03	0.08	0.11	0.04	0.05	0.14
10. Shandong	0.03	0.02	0.02	0.06	0.33	0.05	0.24	0.37
11. Shanxi	0.04	0.01	0.03	0.05	0.03	0.03	0.00	0.06
12. Guangdong	0.28	0.05	0.22	0.33	0.08	0.06	0.02	0.15
13. Guangxi	0.19	0.05	0.11	0.24	0.02	0.01	0.00	0.02
14. Xinjiang	0.03	0.02	0.01	0.06	0.12	0.08	0.00	0.20
15. Jiangsu	0.03	0.01	0.02	0.06	0.16	0.06	0.07	0.22
16. Jiangxi	0.13	0.02	0.10	0.16	0.13	0.02	0.10	0.15
17. Hebei	0.04	0.00	0.04	0.05	0.04	0.03	0.00	0.09
18. Henan	0.03	0.01	0.03	0.05	0.12	0.02	0.10	0.15
19. Zhejiang	0.09	0.03	0.06	0.14	0.17	0.03	0.13	0.20
20. Hainan	0.16	0.27	0.01	0.47	0.33	0.29	0.00	0.50
21. Hubei	0.07	0.02	0.04	0.10	0.11	0.04	0.07	0.16
22. Hunan	0.04	0.01	0.03	0.06	0.16	0.03	0.14	0.21
23. Gansu	0.03	0.01	0.01	0.04	0.26	0.05	0.22	0.33
24. Fujian	0.12	0.03	0.09	0.16	0.02	0.02	0.00	0.05
25. Guizhou	0.08	0.05	0.03	0.14	0.06	0.05	0.00	0.13
26. Liaoning	0.05	0.01	0.04	0.06	0.20	0.05	0.14	0.26
27. Shaanxi	0.07	0.06	0.02	0.16	0.11	0.04	0.04	0.14
28. Qinghai	0.03	0.00	0.02	0.03	0.00	0.00	0.00	0.00
29. Heilongjiang	0.07	0.02	0.05	0.10	0.06	0.07	0.00	0.15

Note: All numbers are based on 6 years of data.
Abbreviation: TCM, traditional Chinese medicine.

yearly percentage of its *rural population*[6] (mean-centered), I separately controlled for the per-capita *annual disposable income* of both its rural and urban households. Finally, I also controlled for the per-capita *foreign direct investment* of each province in a given year to capture the

[6]During the study period, consistent with the household registration system (i.e., Hukou) in China, a rural population is defined in the China Population Statistics Yearbook as all individuals whose livelihood depends on agriculture, hunting, fishing, or forestry.

possible Western influence in a province, which might shape people's preference for traditional products in general.

At the firm level,[7] I controlled for *firm size*, measured as the total number of employees at the beginning of a year. *Firm status* was indicated using a binary variable equal to 1 if a firm's sales value reached the top 10 within its province in the previous year.[8] The *R&D investment* of a firm was proxied using the percentage of its technical employees among all employees during the previous year. I adopted another binary variable to capture a *firm's ownership*, equal to 1 if a firm was owned by the state. A firm's *research alliance* was measured as the total number of its R&D collaborators in the previous year. Whether a firm *manufactured Western medicine* in a given year was also demonstrated through a binary variable coded 1 if that was the case. Additionally, whether a firm owned any *exclusive classic TCM formula*—a unique and often newly uncovered ancient formula that was granted 3–8 years of market exclusivity by the Chinese State Food and Drug Administration Bureau (SFDA) in a given year—was also controlled for. Finally, I included *year dummies* to capture any remaining unobserved factors affecting the performance of TCM firms but varying by year. Table 2 displays the descriptive statistics and correlations of all variables.

5.5 | Modeling approach

With a panel of 917 firms across 6 years, I employed firm fixed effects to test the hypothesis (Greene, 2003). Note that because no firm changed geographic location during the study period, the firm fixed effects also absorbed the province fixed effects.

6 | RESULTS

A critical premise for the hypothesis, as Figure 1 illustrates, is that at the market level, as more firms adopt the discontinuous technology, market size for the old technology will decline sharply before reaching a plateau that represents the revealed niches for the old technology. Appendix 1 summarizes analyses at the province level, validating that in the TCM context, despite decreasing initially, *market size for classic TCM*—measured by the annual per capita sales of classic TCM products in a province (see Martin & Mitchell, 1998; Nerkar & Roberts, 2004)—indeed plateaued and remained stable once more than 20.4% of firms (on average) in a province had begun launching hybrid TCM in Western dosage form.

At the firm level, my hypothesis postulates a U-shaped relationship between competitors' growing adoption of the discontinuous technology and the performance of firms adhering to the old technology. Table 3 summarizes results of the regression analyses testing this

[7]Information on firms' founding years is unavailable from current data sources. Hence, to control for firm age, I manually searched, using google.com or baidu.com, and gathered information on the founding years for 826 of the 917 firms in my sample. Despite the further loss of 327 (11.2%) observations, results were highly consistent after controlling for firm age in the regressions. Specifically, the estimated effect of *competitors' new technology adoption* on *firm performance* is negative ($\beta = -1.829$, $p = .037$), and that of its *squared term* is positive ($\beta = 5.922$, $p = .007$). To avoid further sample-selection bias, I hereby report the analyses without firm age as a control.

[8]This coding method is derived from the institutionalized tradition in China whereby most provinces commend the top 10 firms (e.g., commonly based on sales or tax contribution) within each industry on a yearly basis. These firms often receive media exposure for making the list and are generally considered to be of higher status in the industry.

TABLE 2 Descriptive statistics and correlations (sample for firm-level analyses).

Variable	Mean	SD	Min.	Max.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. Firm performance	−0.08	2.19	−100	3.16																	
2. Competitors' new technology adoption	0.10	0.08	0	0.63	−.01																
3. Competitors' new technology adoption squared	0.02	0.03	0	0.39	.00	.88															
4. Firm size	263.35	298.03	6	4651	.03	−.06	−.04														
5. Firm status	0.30	0.46	0	1	.07	.01	.07	.39													
6. State ownership	0.84	0.36	0	1	−.02	−.05	−.10	−.04	−.10												
7. R&D investment	0.11	0.08	0	0.76	.02	−.03	−.03	−.10	.03	−.10											
8. Research alliance	0.00	0.03	0	1	.00	−.01	−.01	.04	.01	.01	−.03										
9. Operation in Western medicine	0.01	0.09	0	1	−.01	−.05	−.04	.01	.01	.02	−.01	−.00									
10. Exclusive classic TCM formulae	0.02	0.13	0	1	.01	−.01	.01	.12	.08	.01	−.04	.09	−.01								
11. Firm output scale	6.27	1.43	0	11.92	.21	−.07	−.01	.59	.51	−.16	−.01	.04	.03	.11							
12. Rural population	0	0.12	−0.46	0.13	.01	−.33	−.28	−.09	.02	.03	.09	−.02	.03	−.00	.03						
13. Local hybrid TCM density	6.17	6.55	0	30	−.04	.69	.50	−.05	−.24	−.05	−.02	.00	−.04	.01	−.13	−.47					
14. Foreign hybrid TCM density	124.79	34.22	66	179	−.06	.03	.00	−.02	−.01	−.35	.13	−.01	−.03	−.02	.01	.05	.07				
15. Western medicine competition	0.37	0.34	0.05	4.11	−.01	.23	.23	.19	.03	−.16	−.03	.02	−.02	−.01	.14	−.60	.25	.16			
16. Rural disposable income	15.36	9.38	4.89	50.33	−.09	−.03	.03	.07	−.06	−.23	.06	.00	.00	.00	.10	−.09	.05	.52	.33		
17. Urban disposable income	32.10	14.84	7.32	81.59	−.03	.20	.14	.06	.00	−.33	.10	.02	−.06	−.01	.12	−.13	.17	.60	.59	.32	
18. FDI	0.28	0.44	0	3.62	−.03	.10	.14	.14	.02	−.21	.01	.03	−.04	.02	.14	−.38	.10	.18	.76	.44	.69

Note: All numbers are based on $n = 2908$ (6 years of data).
Abbreviation: TCM, traditional Chinese medicine.

hypothesis. Model 1 is the baseline firm fixed effects regression, including only control variables. In Model 2, I entered both the linear and the squared terms of the independent variable *competitors' new technology adoption*. Estimates from Model 2 support the hypothesis. In detail, the estimated effect of *competitors' new technology adoption* on *firm performance* is negative ($\beta = -1.570$, $p = .043$), while that for its *squared term* is positive ($\beta = 5.564$, $p = .007$).

To further verify this U-shaped relationship, I next followed Lind and Mehlum (2010) and Haans et al. (2016) and calculated the slopes of the curve at both ends of my data range. At the lower bound (0) of *competitors' new technology adoption*, the slope of the curve is negative (−1.570, $p = .042$), where a 1% increase in *competitors' new technology adoption* decreases the ROS of classic TCM producers by 0.015 on average; at its upper bound (0.625), the slope is positive (5.385, $p = .009$), where a 1% increase in *competitors' new technology adoption* improves the ROS of classic TCM firms by 0.054. These results indicate that the relationship estimated is a full rather than half U-shape (Haans et al., 2016). Moreover, to determine whether the minimum of the curve falls within my data range,[9] I derived the confidence interval of the turning point using the Fieller method (Fieller, 1954; Haans et al., 2016). The estimated extremes of Fieller's (1954) confidence interval are 0.012 and 0.273, well within the range of *competitors' new technology adoption* (0–0.625). Together, these tests strongly support the hypothesis.

Figure 2 depicts the estimates of Model 2. As predicted, a TCM firm that stuck with the old technology saw its ROS initially fall as a small percentage of competitors in its province began launching hybrid TCM in Western dosage design. Its ROS reached minimum (−0.127) when 14.1% of TCM producers in the province had adopted the new technology. However, following that, the ROS of the focal firm resurged and gradually climbed above its previous height before the local emergence of hybrid TCM. Overall, findings at both the province and firm levels from the TCM industry validate my theory that in markets where the rise of a technological discontinuity simultaneously reveals sustainable niches for the old technology, as competitors increasingly jump into the new technology, the performance of old-technology firms, despite the early setback, will eventually rebound and potentially achieve new heights.

6.1 | Rural population and niche size for the old technology

My in-depth interviews with industry experts revealed that in the TCM context, rural customers were the majority among those who persistently favored classic TCM products and their ancient dosage designs, despite the rise of hybrid TCM in the 1990s; their preference endures today (Recorded Interview). This implies that in provinces with a more rural population, the upsurge of hybrid TCM likely exposed bigger niches for classic TCM than it did in less rural provinces. Indeed, as Appendix 1 shows, analyses at the province level confirmed that during the study period, as TCM producers increasingly launched hybrid TCM, in provinces with a larger rural population, *market size for classic TCM* decreased slower (i.e., with less negative slopes) and ultimately settled into a higher plateau than in provinces with a smaller rural population.

Based on this finding and my theory, I anticipate that as competitors continued to adopt hybrid TCM after niches for classic TCM were established, in provinces that were more rural, firms sticking with classic TCM would see their performance recover faster and subsequently outperform their counterparts in less rural provinces. In other words, the U-shaped curve posited by the

[9]Of the total 2908 firm-year observations, 867 (29.8%) lie to the right of the minimum point (i.e., *competitors' new technology adoption* = 0.141) of the U-shaped performance curve estimated.

TABLE 3 Regressions predicting the performance of classic TCM firms.

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Competitors' new technology adoption		−1.570	−2.155	−1.649	−1.352	−1.723	−1.069
		(0.910)	(0.987)	(0.928)	(0.687)	(0.765)	(0.783)
Competitors' new technology adoption squared		5.564	8.774	5.766	2.980	4.942	4.476
		(2.250)	(2.996)	(2.316)	(1.375)	(2.145)	(2.533)
Competitors' new technology adoption × Rural population			−3.857			−2.657	
			(4.123)			(3.545)	
Competitors' new technology adoption squared × Rural population			18.209			11.362	
			(7.852)			(7.413)	
Competitors' new technology adoption × Exclusive classic TCM formulae				3.857			
				(2.075)			
Competitors' new technology adoption squared × Exclusive classic TCM formulae				−9.145			
				(5.327)			
Firm size	0.000	0.000	0.000	0.000	0.001	0.001	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Firm status	0.045	0.048	0.047	0.047	0.170	0.170	0.028
	(0.045)	(0.045)	(0.045)	(0.045)	(0.056)	(0.057)	(0.041)
State ownership	−0.072	−0.078	−0.083	−0.077	−0.110	−0.113	−0.173
	(0.112)	(0.113)	(0.113)	(0.113)	(0.075)	(0.076)	(0.072)
R&D investment	0.049	0.041	0.039	0.036	−0.222	−0.223	−0.557
	(0.463)	(0.463)	(0.463)	(0.463)	(0.278)	(0.278)	(0.730)
Research alliance	−0.035	−0.031	−0.024	0.004	0.244	0.247	−0.175
	(0.087)	(0.094)	(0.093)	(0.075)	(0.053)	(0.055)	(0.082)
Operation in Western medicine	−0.211	−0.227	−0.243	−0.228	0.051	0.040	−0.244
	(0.141)	(0.126)	(0.125)	(0.126)	(0.190)	(0.189)	(0.116)
Exclusive classic TCM formulae	0.103	0.088	0.084	−0.136	0.367	0.365	0.097
	(0.198)	(0.202)	(0.203)	(0.193)	(0.249)	(0.248)	(0.208)
Rural population	−4.960	−4.619	−4.095	−4.698	0.098	0.439	−1.737
	(3.938)	(3.629)	(3.687)	(3.639)	(2.557)	(2.638)	(2.999)
Local hybrid TCM density	−0.033	−0.034	−0.035	−0.034	−0.032	−0.033	−0.036
	(0.021)	(0.024)	(0.025)	(0.024)	(0.009)	(0.009)	(0.020)
Foreign hybrid TCM density	0.015	0.014	0.014	0.014	0.001	0.001	−0.007
	(0.015)	(0.015)	(0.016)	(0.015)	(0.003)	(0.003)	(0.005)
Western medicine competition	−0.149	−0.167	−0.159	−0.170	0.205	0.211	−0.037
	(0.374)	(0.376)	(0.377)	(0.377)	(0.209)	(0.208)	(0.347)
Rural disposable income	−0.015	−0.014	−0.013	−0.014	0.001	0.001	−0.001
	(0.013)	(0.013)	(0.014)	(0.013)	(0.007)	(0.007)	(0.008)

TABLE 3 (Continued)

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Urban disposable income	−0.008	−0.006	−0.006	−0.006	0.003	0.003	0.014
	(0.018)	(0.018)	(0.018)	(0.018)	(0.007)	(0.007)	(0.009)
FDI	−0.044	−0.015	−0.019	−0.013	−0.206	−0.207	−0.277
	(0.378)	(0.375)	(0.371)	(0.375)	(0.158)	(0.161)	(0.289)
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	−1.632	−1.578	−1.581	−1.574	6.160	6.163	0.999
	(1.838)	(1.854)	(1.891)	(1.855)	(0.358)	(0.359)	(0.763)
Number of observations	2908	2908	2908	2908	2908	2908	1847
Number of provinces/ firms	917	917	917	917	917	917	409
Goodness of fit	$F = 3.68$	$F = 3.45$	$F = 3.20$	$F = 3.16$	$F = 20.02$	$F = 17.12$	$F = 6.37$

Note: Robust standard errors, clustered at the firm level, are reported in parentheses.
Abbreviation: TCM, traditional Chinese medicine.

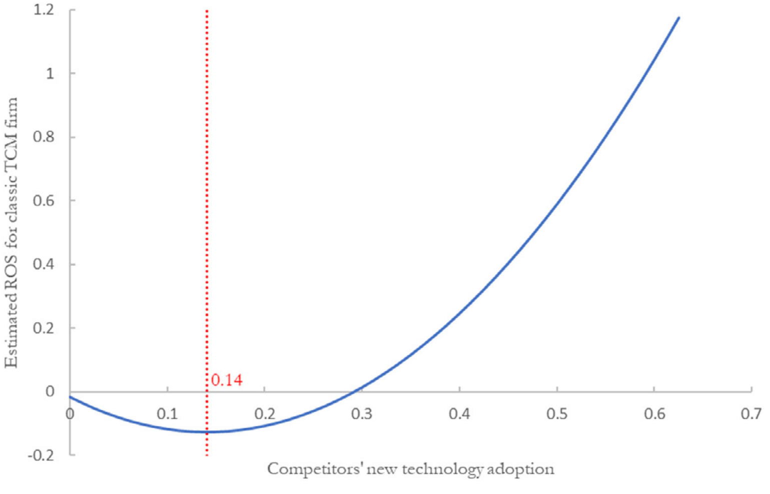

FIGURE 2 Estimated ROS for TCM firms sticking with classic TCM (Model 2). To generate the graph above, I used coefficient estimates from Model 2, with mean values for all control variables. ROS, return on sales; TCM, traditional Chinese medicine.

hypothesis, specifically the right half of it, would be steeper for classic TCM producers operating in more rural provinces. This is because with few firms left to serve the classic TCM niches after most competitors' exits, when such niches were bigger (e.g., in more rural provinces), the further transition into hybrid TCM by some would free up more niche customers for the remaining classic TCM producers to capture than if the niches were smaller (e.g., in less rural provinces). Among the remaining classic TCM firms, competition would also be less intense in larger niches with more available customers than in smaller ones with fewer customers.

I examined this by creating two interaction terms between the *percentage of rural population* (mean-centered) in a province and *competitors' new technology adoption* and its *squared term* and entered both into the firm fixed effects regression. Results are displayed in Model 3. The estimated interaction effect between *rural population* and *competitors' new technology adoption squared* on *firm performance*, as shown in Model 3, is positive ($\beta = 18.209$, $p = .011$). This supports my prediction (see Haans et al., 2016). This additional analysis further validates the role of customers' exposed preference heterogeneity over the old technology during technological change that underlies my hypothesis.

6.2 | Exclusive classic TCM formula and competition intensity within niches

Whereas most classic TCM producers compete on "generic products," thereby facing ample direct competition from others, very few own exclusive formulae that others cannot legally produce. These are often unique, secretive, or historic formulae newly uncovered by a firm, for which the Chinese SFDA typically grants 3 to 8 years of market exclusivity. According to the SFDA's new drug registration database, between 1991 and 1996, only 19 of the 917 firms (2.1%) in my sample had at times owned 1 exclusive drug in their product portfolio, and 3 firms (0.3%) had at times owned 2.

Building on my theory, I expect that compared with those merely selling generic products, classic TCM firms who owned exclusive formulae would see their performance less affected by the changing competitive intensity in the old-technology market as others increasingly adopted hybrid TCM. Specifically, because the SFDA prevented others from replicating exclusive formulae, classic TCM firms with such formulae in their portfolio would suffer less from the "excess supply," and thus heightened rivalry, expected in the contracted classic TCM market after early innovators' launch of hybrid TCM, and therefore experience smaller initial declines in their performance. Furthermore, as competitors continued to move into hybrid TCM, firms with exclusive formulae would also benefit less from reduced "direct competition" within the classic TCM niches, which they had less to begin with, and hence recover more marginally in their performance later on. Put differently, I anticipate the U-shaped curve predicted by my hypothesis to be flatter for classic TCM producers who owned exclusive formulae than for others that solely produced generic products.

To test this, I created two interaction terms between a firm's *exclusive classic TCM formulae* and *competitors' new technology adoption* and its *squared term*, and included both in the firm fixed effects regression. Model 4 summarizes the results. As shown in Model 4, the estimated interaction effect between a firm's *exclusive classic TCM formulae* and *competitors' new technology adoption squared* on firm performance is negative ($\beta = -9.145$, $p = .043$). This is consistent with my expectation, further verifying my theoretical argument on the changing competitive intensity in the old-technology niches that drives the U-shaped performance curve predicted for old-technology firms during technological change.

6.3 | Better profitability but smaller scale?

One concern following the prior analyses is that despite the eventual recovery in their profitability, due to the limited size of the old-technology niches, firms sticking with the old technology might end up operating with higher margins but at *smaller scales* than before the onset of the technological discontinuity. Within the TCM context, I checked this empirically by regressing[10] *firm output scale*, measured using the logarithm of a firm's annual sales (see Hitt et al., 1997), on the linear and squared terms of my independent variable *competitors' new technology adoption* and all other control variables. I anticipate a U-shaped relationship here because, as theorized earlier, although depressed by the reduced demand (and price) for classic TCM early on, the output of classic TCM producers would later rebound as more competitors further jumped into hybrid TCM, leaving fewer to serve the stable, albeit smaller, classic TCM niches. Especially in more rural provinces with bigger niches for classic TCM, I expect the output of classic TCM firms to recover to higher levels after most competitors' adoption of hybrid TCM, than in less rural provinces.

Models 5 and 6 summarize the regression results. As predicted, in Model 5, the estimated effect of *competitors' new technology adoption* on *firm output scale* is negative ($\beta = -1.352$, $p = .025$), whereas that for its *squared term* is positive ($\beta = 2.980$, $p = .015$); these indicate a U-shaped relationship between competitors' growing pursuit of hybrid TCM and the output of classic TCM firms. Next, I created two interaction terms between the *percentage of rural population* in a firm's province and *competitors' new technology adoption* and its *squared term* within the province, and included both in Model 6. According to Model 6, the estimated interaction effect between a province's *rural population* and *competitors' new technology adoption squared* on *firm output scale* is positive ($\beta = 11.362$, $p = .063$). This effect is plotted in Figure 3.

Figure 3 shows that for an average classic TCM producer (i.e., *rural population* and all control variables kept at mean levels), although diminishing initially, its total output later *resurged* and gradually *surpassed* its level prior to the emergence of hybrid TCM as competitors in its province increasingly adopted hybrid TCM. This suggests that in the TCM context, despite losing substantial market to the discontinuous technology, on average, firms sticking with the old technology ultimately enjoyed not only higher profitability but also at a relatively large scale. While encouraging, a critical boundary condition here, based on my field interviews and review of industry reports from the 1990s, is that the size of classic TCM niches, instead of being tiny, remained relatively moderate over the years. For instance, from 1991 to 1996, the average *ratio* between *the lowest* and *highest* annual per capita sales for classic TCM products across all 29 provinces in my sample is 43.9%. This implies that despite the rise of hybrid TCM, classic TCM held on to an average of 44% of the market that it once fully occupied. Given that most TCM firms were small to medium-sized, such a moderate niche size for classic TCM allowed those sticking with the old technology to eventually recover to reasonably high levels of output after most competitors had transitioned to hybrid TCM.

Consistent with my prediction, Figure 3 further illustrates that following most competitors' adoption of hybrid TCM, the output of classic TCM firms rebounded to the highest level when they operated in more rural Chinese provinces; in contrast, in less rural provinces with smaller niches for classic TCM, classic TCM producers hardly managed to regain their previous output level before the emergence of hybrid TCM. Together, these findings suggest that in the end, whether firms adhering to the old technology would enjoy higher margins at reasonable scales depends critically on the *size of the old technology niches* that were exposed by the rise of the discontinuous technology.

6.4 | Subsample of surviving firms

Some may suspect that as competitors in a market increasingly embrace a new technology, among firms that stick with the old technology, those with low performance will be the first to

[10]Consistent with my main firm-level analyses, firm fixed effects is adopted as the modeling approach.

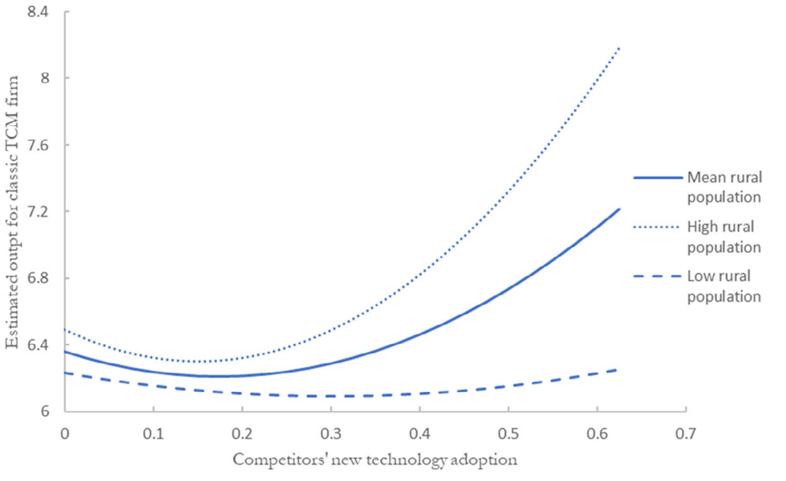

FIGURE 3 Estimated output for classic TCM firms conditioned on provincial rural population (Model 6). To generate the graph above, I used coefficient estimates from Model 6, with *rural population* separately at its mean, two standard deviations above and below the mean, and mean values for all other control variables. TCM, traditional Chinese medicine.

be driven out of the market, leaving only the high-performing ones to survive. Hence, at the firm level, each half of the U-shaped curve discovered could also be driven by the performance of two different subsamples of TCM firms. To rule out this possibility, I repeated my analysis on a subsample of TCM producers that adhered to industry conventions and that survived the entire study period. Model 7 summarizes the result. Once again, the estimated coefficient for *competitors' new technology adoption* is negative ($\beta = -1.069$, $p = .087$), while that for its squared term is positive ($\beta = 4.476$, $p = .039$), supporting the hypothesis. Here, the estimated U-shaped curve reached its turning point when 11.9% of competitors in a province began producing hybrid TCM. Accordingly, even for the surviving classic TCM firms, a U-shaped relationship manifested between their competitors' growing launch of hybrid TCM and their performance. This result sufficiently eliminates the alternative explanation outlined earlier.

7 | DISCUSSION

When confronted with a technological discontinuity, how should firms react to achieve higher performance? In answering this question, a pro-innovation bias seemingly arises in the literature on technological change, which advocates for firms to timely transition from the old to the new technology (Adner & Snow, 2010; Raffaelli, 2019). In contrast to this view, in this paper I show, paradoxically, that in markets where the rise of a discontinuous technology concurrently exposes customers' latent preference heterogeneity over certain old technology attributes, firms might enhance their performance by adhering to the old technology during technological change. Specifically, I hypothesized a U-shaped relationship between competitors' rate of adopting a new technology and the profitability of firms sticking with the old technology. Using archival data from the Chinese TCM industry in the 1990s, I found robust empirical support for my prediction.

A few boundary conditions are essential for generalizing the present arguments and findings. First, while my theory acknowledges that the formation of old-technology niches requires some customers' latent preference for the old technology to be revealed during technological change, for the niches to be truly sustainable, such customer preferences should *persist* and *not fade* over time. Among other things, scholars pointed out that especially in markets with highly institutionalized norms about products or practices, such as TCM, gas lighting (Hargadon & Douglas, 2001), and winemaking (Negro et al., 2011), more customers are likely to continuously favor the old technology and its conventional attributes for a longer period, and to reject radical changes as illegitimate norm violations (Ody-Brasier & Vermeulen, 2020; Rao et al., 2005). When it comes to TCM, it is encouraging to see that even in 2022, over three decades since the invention of hybrid TCM, classic TCM still generated about 30% of the total operating revenue of the TCM industry in China, and abundant customers remained committed to the ancient technology throughout the country (AskCI.com, 2022; Yuanhengxiang Group, 2023). More interestingly, as the younger generation in China lately expressed growing interest in herbal and organic products, the market for classic TCM not only persisted but also showed signs of resurgence (China Youth Daily, 2021). Future research should explore how such revived interests in an old technology from a new customer segment might further impact firms' technology strategy and performance.

Second, as theorized, for the performance of old-technology firms to rebound from its initial decline following early innovators' launch of a discontinuous technology, more competitors must be incentivized to keep moving into, and potentially *over-entering*, the new-technology market. According to prior research, such incentives, especially in the later stage of diffusion, often arise from sources other than firms' thorough assessment of an innovation's efficiency or returns (Abrahamson & Rosenkopf, 1993). In particular, firms may adopt a new technology due to managers' biased beliefs about its market potential, which likely prevail when return of the new technology is highly risky, leading managers to undersample failures in vicarious learning (Denrell, 2003; Li & Vermeulen, 2021), or when there is a lack of coordination among supply chain members, causing distorted demand information for the new technology to be passed upstream to managers from retailers (i.e., the bullwhip effect; Lee et al., 1997). Moreover, the presence of institutional or competitive bandwagon pressures, thanks to the vast adoption of the new technology among competitors, may also prompt more firms to pursue it, especially if non-adopters are stigmatized or discounted by stakeholders (Abrahamson & Rosenkopf, 1993; Meyer & Rowan, 1977; Tolbert & Zucker, 1983). While out of the scope of this study, future research should further investigate possible motives for firms' over-entry into a new-technology market during technological change.

Third, once achieving superior performance in the revealed old-technology niches after most competitors' exits, for old-technology firms to maintain such performance, certain *costs* or *barriers* are needed to deter both incumbents that previously adopted the new technology and de novo firms from easily (re)entering and competing in such niches. Research suggests that for incumbents, switching technologies is often highly challenging as it requires significant resource and time commitments and the overcoming of ample organizational inertia (Eggers, 2012, 2014; R. M. Henderson & Clark, 1990; Van Oorschot et al., 2013). For de novo entrants, their appeal to niche customers is likely limited by their lack of established brands, history, and authenticity associated with the old technology (see Lehman et al., 2019; Verhaal et al., 2022). Although rarely the case, if barriers for (re)entering and competing in the old-technology niches were negligible in an industry, the higher performance that I predicted for old-technology firms following most competitors' pursuit of a new technology would soon be diluted as many de novo or incumbent firms, particularly those who had "over-entered" the new-technology market, quickly (re)enter to serve the old-technology niches after witnessing the performance boost of firms who had never left the niches. Finally, as discussed extensively in the additional analyses, for firms sticking with the old technology to ultimately enjoy higher margins at reasonably output scales, the *size* of the revealed old-technology niches is a critical determinant.

This study contributes to literature at the intersection of technology discontinuities and firm performance. First, echoing growing research on the "retreat" and "reemergence" of old technologies (e.g., Adner & Snow, 2010; Raffaelli, 2019), this paper further emphasizes the importance of attending to the inherent heterogeneity of a demand context in analyzing the dynamics of technological change and its performance implications at both the market and firm levels. Such demand heterogeneity, due to varied sources, may preserve niche opportunities in a market for an old technology, preventing it from complete displacement by the new technology (cf. Klepper, 1996; Tushman & Anderson, 1986; Utterback, 1996). This subsequently makes it possible for firms sticking with the old technology to thrive for an unexpectedly long period despite the rise of a new technology with superior functionality.

More important, although acknowledging the possible existence of sustainable niches for old technologies during technological change, prior technology "retreat" studies insist that given the limited size of these niches, the expectation of firms "retrenching" into such niches is "not for growth and expansion, but rather for survival and contraction" (Adner & Snow, 2010, p. 1657). While the size of old-technology niches certainly is critical, this claim ignored that the performance of firms serving these niches also depends on the competitive intensity within the niches. By taking account of competitors' adoption rate of the new technology in a market, the present study addresses this limitation and highlights a series of boundary conditions under which firms may experience profitability (and output) growth by sticking with the old technology, despite losing the mainstream market to a discontinuous technology. Together, arguments and findings of this paper imply that within certain markets, besides transitioning to the new technology, firms' decision to stay with an old technology during technological change may also constitute a proactive strategic choice that ultimately enhances their performance and does not necessarily equate to organizational inertia or incompetence (cf. Adner & Snow, 2010).

ACKNOWLEDGMENTS

The author is grateful for the thoughtful guidance of Associate Editor J. P. Eggers during the revisions. The paper benefited from helpful comments from Joao Albino-Pimentel, Julia Bodner, Linus Dahlander, Kristina Dahlin, Kamini Gupta, Johannes Luger, Louise Mors, Vera Rocha, Lourdes Sosa, Kamil Stronski, Thomaz Teodorovicz, and Caroline Witte. Special thanks go to Jan-Hendrik Berndt, Victoria Sevcenko, and Freek Vermeulen for the countless discussions and their continued support of this project over the years.

DATA AVAILABILITY STATEMENT

The non-restricted parts of the data for this study are available from the author upon reasonable request.

ORCID

Xu Li https://orcid.org/0000-0003-3888-3235

REFERENCES

Abernathy, W. J., & Clark, K. B. (1985). Innovation: Mapping the winds of creative destruction. *Research Policy*, *14*(1), 3–22.

Abrahamson, E., & Rosenkopf, L. (1990). When do bandwagon diffusions roll? How far do they go? And when do they roll backwards?: A computer simulation. *Academy of Management Proceedings*, *1990*(1), 155–159.

Abrahamson, E., & Rosenkopf, L. (1993). Institutional and competitive bandwagons: Using mathematical modeling as a tool to explore innovation diffusion. *Academy of Management Review*, *18*(3), 487–517.

Adner, R. (2002). When are technologies disruptive: A demand-based perspective on the evolution of competition. *Strategic Management Journal*, *23*, 667–688.

Adner, R., & Levinthal, D. (2001). Demand heterogeneity and technology evolution: Implications for product and process innovation. *Management Science*, *47*, 611–628.

Adner, R., & Snow, D. (2010). Old technology responses to new technology threats: Demand heterogeneity and technology retreats. *Industrial & Corporate Change*, *19*, 1655–1675.

Anderson, P., & Tushman, M. L. (1990). Technological discontinuities and dominant designs: A cyclical model of technological change. *Administrative Science Quarterly*, *35*(4), 604–633.

Asch, P., & Seneca, J. J. (1975). Characteristics of collusive firms. *The Journal of Industrial Economics*, *23*(3), 223–237.

AskCI.com. (2022, March 31). Report on the market trajectory and investment in the traditional Chinese medicine industry in China in 2022. https://baijiahao.baidu.com/s?id=1728745096813954894&wfr=spider&for=pc

Astley, W. G. (1985). The two ecologies: Population and community perspectives on organizational evolution. *Administrative Science Quarterly*, *3*, 224–241.

Bond, E. U., III, & Houston, M. B. (2003). Barriers to matching new technologies and market opportunities in established firms. *Journal of Product Innovation Management*, *20*(2), 120–135.

Carpenter, G. S., & Nakamoto, K. (1989). Consumer preference formation and pioneering advantage. *Journal of Marketing Research*, *26*(3), 285–298.

Casciaro, T., & Piskorski, M. J. (2005). Power imbalance, mutual dependence, and constraint absorption: A closer look at resource dependence theory. *Administrative Science Quarterly*, *50*(2), 167–199.

Caves, R. E., & Porter, M. E. (1978). Market structure, oligopoly, and stability of market shares. *The Journal of Industrial Economics*, *26*(4), 289–313.

Chandler, A. D., Jr. (1990). *Scale and scope: The dynamics of industrial capitalism*. Belknap Press.

Chen, K. J., & Xu, H. (2003). The integration of traditional Chinese medicine and Western medicine. *European Review*, *11*, 225–235.

China Youth Daily. (2021, November 11). The increasing popularity of TCM products during "Double Eleven Day" and how it meets the health needs of the youth population.

Christensen, C. M. (1993). The rigid disk drive industry: A history of commercial and technological turbulence. *Business History Review*, *67*(4), 531–588.

Christensen, C. M. (1997). *The innovator's dilemma: When new technologies cause great firms to fail*. Harvard Business School Press.

Christensen, C. M., & Bower, J. L. (1996). Customer power, strategic investment, and the failure of leading firms. *Strategic Management Journal*, *17*(3), 197–218.

Christensen, C. M., & Raynor, M. (2003). *The innovator's solution*. Harvard Business School Press.

Cool, K., & Dierckx, I. (1993). Rivalry, strategic groups, and firm profitability. *Strategic Management Journal*, *14*, 47–59.

Cooper, A. C., & Smith, C. G. (1992). How established firms respond to threatening technologies. *Academy of Management Executive*, *6*, 55–70.

Cox, N. J., Warburton, J., Armstrong, A., & Holliday, V. J. (2008). Fitting concentration and load rating curves with generalized linear models. *Earth Surface Processes and Landforms*, *33*, 25–39.

Cusumano, M. A., Mylonadis, Y., & Rosenbloom, R. S. (1992). Strategic maneuvering and mass-market dynamics: The triumph of VHS overbeta. *Business History Review*, *66*, 51–94.

Deng, R., & Kaitin, K. I. (2004). The regulation and approval of new drugs in China. *Therapeutic Innovation and Regulatory Science*, *38*(1), 29–39.

Denrell, J. (2003). Vicarious learning, undersampling of failure, and the myths of management. *Organization Science*, *14*(3), 227–243.
Denrell, J., & March, J. G. (2001). Adaptation as information restriction: The hot stove effect. *Organization Science*, *12*(5), 523–538.
DiMaggio, P. J., & Powell, W. W. (1983). The iron cage revisited: Institutional isomorphism and collective rationality in organizational fields. *American Sociological Review*, *48*(2), 147–160.
Dong, F. Y. (2001). *Modern dosage form design techniques in TCM*. People's Health Publishing.
Eggers, J. P. (2012). Falling flat: Failed technologies and investment under uncertainty. *Administrative Science Quarterly*, *57*(1), 47–80.
Eggers, J. P. (2014). Competing technologies and industry evolution: The benefits of making mistakes in the flat panel display industry. *Strategic Management Journal*, *35*(2), 159–178.
Emerson, R. M. (1962). Power-dependence relations. *American Sociological Review*, *27*(1), 31–41.
Fieller, E. C. (1954). Some problems in interval estimation. *Journal of the Royal Statistical Society. Series B (Methodological)*, *16*, 175–185.
Fligstein, N. (1985). The spread of the multidivisional form among large firms, 1919–1979. *American Sociological Review*, *50*(3), 377–391.
Foster, R. N. (1986). *Innovation: The attacker's advantage*. Summit Books.
Gilbert, C. G. (2005). Unbundling the structure of inertia: Resource versus routine rigidity. *Academy of Management Journal*, *48*(5), 741–763.
Gopalakrishnan, S., & Damanpour, F. (1997). A review of innovation research in economics, sociology and technology management. *Omega*, *25*(1), 15–28.
Greene, W. H. (2003). *Econometric analysis* (5th ed.). Prentice Hall.
Greve, H. R. (1996). Patterns of competition: The diffusion of a market position in radio broadcasting. *Administrative Science Quarterly*, *41*, 29–60.
Greve, H. R. (1998). Performance, aspirations, and risky organizational change. *Administrative Science Quarterly*, *43*(1), 58–86.
Griliches, Z. (1990). Patent statistics as economic indicators: A survey. *Journal of Economic Literature*, *28*(4), 1661–1707.
Guler, I. (2007). Throwing good money after bad? Political and institutional influences on sequential decision making in the venture capital industry. *Administrative Science Quarterly*, *52*(2), 248–285.
Haans, R. F., Pieters, C., & He, Z. L. (2016). Thinking about U: Theorizing and testing U- and inverted U-shaped relationships in strategy research. *Strategic Management Journal*, *37*, 1177–1195.
Hargadon, A. B., & Douglas, Y. (2001). When innovations meet institutions: Edison and the design of the electric light. *Administrative Science Quarterly*, *46*(3), 476–501.
Helfat, C. E. (1994). Evolutionary trajectories in petroleum firm R&D. *Management Science*, *40*(12), 1720–1747.
Henderson, R. (1993). Underinvestment and incompetence as responses to radical innovation: Evidence from the photolithographic alignment equipment industry. *The RAND Journal of Economics*, *24*, 248–270.
Henderson, R. M., & Clark, K. B. (1990). Architectural innovation: The reconfiguration of existing product technologies and the failure of established firms. *Administrative Science Quarterly*, *35*(1), 9–30.
Hesketh, T., & Zhu, W. X. (1997). Health in China. Traditional Chinese medicine: One country, two systems. *British Medical Journal*, *315*(7100), 115–117.
Hitt, M. A., Hoskisson, R. E., & Kim, H. (1997). International diversification: Effects on innovation and firm performance in product-diversified firms. *Academy of Management Journal*, *40*, 767–798.
Kerin, R. A., Rajan Varadarajan, P., & Peterson, R. A. (1992). First-mover advantage: A synthesis, conceptual framework, and research propositions. *Journal of Marketing*, *56*, 33–52.
Khessina, O. M., Goncalo, J. A., & Krause, V. (2018). It's time to sober up: The direct costs, side effects and long-term consequences of creativity and innovation. *Research in Organizational Behavior*, *38*, 107–135.
King, A. A., & Tucci, C. L. (2002). Incumbent entry into new market niches: The role of experience and managerial choice in the creation of dynamic capabilities. *Management Science*, *48*(2), 171–186.
Klepper, S. (1996). Entry, exit, growth, and innovation over the product life cycle. *The American Economic Review*, *86*, 562–583.
Kogut, B. (1985). Designing global strategies: Profiting from operational flexibility. *Sloan Management Review*, *27*, 27–38.

Lee, H. L., Padmanabhan, V., & Whang, S. (1997). Information distortion in a supply chain: The bullwhip effect. *Management Science*, *43*(4), 546–558.

Lehman, D. W., O'Connor, K., Kovács, B., & Newman, G. E. (2019). Authenticity. *Academy of Management Annals*, *13*(1), 1–42.

Leonard-Barton, D. (1992). Core capabilities and core rigidities: A paradox in managing new product development. *Strategic Management Journal*, *13*(S1), 111–125.

Li, X., & Vermeulen, F. (2021). High risk, low return (and vice versa): The effect of product innovation on firm performance in a transition economy. *Academy of Management Journal*, *64*(5), 1383–1418.

Lieberman, M. B., & Montgomery, D. B. (1988). First-mover advantages. *Strategic Management Journal*, *9*, 41–58.

Lieberman, M. B., & Montgomery, D. B. (1998). First-mover (dis)advantages: Retrospective and link with the resource-based view. *Strategic Management Journal*, *19*, 1111–1125.

Lin, Y. (2008). Observing the changes of TCM dosage form designs from the Chinese pharmacopoeias. *Chinese Journal of Information on Traditional Chinese Medicine*, *15*(7), 6–7.

Lind, J. T., & Mehlum, H. (2010). With or without U? The appropriate test for a U-shaped relationship. *Oxford Bulletin of Economics and Statistics*, *72*, 109–118.

Liu, Z. (1999). Continued technological innovation, new looks of state-owned firms, and rebuilding firms to glory. *Traditional Chinese Medicine Research and Information*, *7*, 16–21.

Martin, X., & Mitchell, W. (1998). The influence of local search and performance heuristics on new design introduction in a new product market. *Research Policy*, *26*(7–8), 753–771.

Meyer, J. W., & Rowan, B. (1977). Institutionalized organizations: Formal structure as myth and ceremony. *American Journal of Sociology*, *83*(2), 340–363.

Negro, G., Hannan, M. T., & Rao, H. (2011). Category reinterpretation and defection: Modernism and tradition in Italian winemaking. *Organization Science*, *22*(6), 1449–1463.

Nerkar, A., & Roberts, P. W. (2004). Technological and product-market experience and the success of new product introductions in the pharmaceutical industry. *Strategic Management Journal*, *25*(8–9), 779–799.

Ody-Brasier, A., & Vermeulen, F. (2020). Who is punished most for challenging the status quo? *Academy of Management Journal*, *63*(5), 1621–1651.

Orr, D. (1974). The determinants of entry: A study of the Canadian manufacturing industries. *The Review of Economics and Statistics*, *56*(1), 58–66.

Palepu, K. (1985). Diversification strategy, profit performance, and the entropy measure. *Strategic Management Journal*, *6*, 239–255.

Porter, M. (1979). How competitive forces shape strategy. *Harvard Business Review*, *57*(2), 137–145.

Priem, R. L., Li, S., & Carr, J. (2012). Insights and new directions from demand-side approaches to technology innovation, entrepreneurship and strategic management research. *Journal of Management*, *38*, 346–374.

Qing, B. (1993). Five big trends in the traditional Chinese medicine market in China. *Journal of Medical Forum*, *1*, 38.

Raffaelli, R. (2019). Technology reemergence: Creating new value for old technologies in Swiss mechanical watchmaking, 1970–2008. *Administrative Science Quarterly*, *64*(3), 576–618.

Rao, H., Monin, P., & Durand, R. (2005). Border crossing: Bricolage and the erosion of categorical boundaries in French gastronomy. *American Sociological Review*, *70*(6), 968–991.

Rogers, E. M. (2003). *Diffusion of innovations* (5th ed.). Free Press.

Rosenbloom, R. S. (2000). Leadership, capabilities, and technological change: The transformation of NCR in the electronic era. *Strategic Management Journal*, *21*, 1083–1103.

Rothaermel, F. T., & Hill, C. W. (2005). Technological discontinuities and complementary assets: A longitudinal study of industry and firm performance. *Organization Science*, *16*(1), 52–70.

Santos Silva, J. M. C., & Tenreyro, S. (2006). The log of gravity. *Review of Economics and Statistics*, *88*, 641–658.

Schroeder, T. (2002). Chinese regulation of traditional Chinese medicine in the modern world: Can the Chinese effectively profit from one of their most valuable cultural resources? *Pacific Rim Law Policy Journal*, *11*(3), 687–716.

Schumpeter, J. A. (1934). *The theory of economic development*. Harvard University Press.

Schumpeter, J. A. (1942). *Capitalism, socialism, and democracy*. Harper & Brothers.

Selznick, P. (1957). *Leadership in administration*. Harper & Row.

Silberston, A. (1972). Economies of scale in theory and practice. *Economic Journal*, *82*(325), 369–391.

Siow, Y. L., Gong, Y., Au-Yueng, K. K., Woo, C. W., Choy, P. C., & Karmin, O. (2005). Emerging issues in traditional Chinese medicine. *Canadian Journal of Physiology and Pharmacology*, *83*, 321–334.

Sosa, M. L. (2011). From old competence destruction to new competence access: Evidence from the comparison of two discontinuities in anticancer drug discovery. *Organization Science*, *22*(6), 1500–1516.

State Administration of Commodity Prices & National Administration of TCM. (1990). Notice on the administration of traditional Chinese medicine prices. State Administration of Commodity Prices & National Administration of Traditional Chinese Medicine.

State Development Planning Commission. (1996). Interim measures for the administration of drug prices. State Development Planning Commission.

State Economic and Trade Commission. (1997). Proposals on the reform and development of state-owned enterprises. State Economic and Trade Commission.

Sull, D. N. (1999). The dynamics of standing still: Firestone Tire & Rubber and the radial revolution. *Business History Review*, *73*, 430–464.

Tang, L., & Zeng, L. (1992). The rise of Hengyang TCM factory through reformation. *Chinese Traditional Patent Medicine*, *14*(6), 43.

Tolbert, P. S., & Zucker, L. G. (1983). Institutional sources of change in the formal structure of organizations: The diffusion of civil service reform, 1880–1935. *Administrative Science Quarterly*, *28*(1), 22–39.

Tripsas, M. (1997). Unraveling the process of creative destruction: Complementary assets and incumbent survival in the typesetter industry. *Strategic Management Journal*, *18*, 119–142.

Tushman, M., & Anderson, P. (1986). Technological discontinuities and organizational environments. *Administrative Science Quarterly*, *31*, 439–465.

Utterback, J. M. (1996). *Mastering the dynamics of innovation*. Harvard Business Press.

Utterback, J. M., & Abernathy, W. J. (1975). A dynamic model of process and product innovation. *Omega*, *3*, 639–656.

Utterback, J. M., & Suarez, F. (1993). Innovation, competition, and industry structure. *Research Policy*, *22*, 1–21.

Van Oorschot, K. E., Akkermans, H., Sengupta, K., & Van Wassenhove, L. N. (2013). Anatomy of a decision trap in complex new product development projects. *Academy of Management Journal*, *56*(1), 285–307.

VanderWerf, P., & Mahon, J. (1997). Meta-analysis of the impact of research methods on findings of first-mover advantage. *Management Science*, *43*, 1510–1519.

Verhaal, J. C., Hahl, O., & Fandl, K. J. (2022). Authenticity-based connections as organizational constraints and the paradox of authenticity in the market for Cuban cigars. *Organization Science*. https://doi.org/10.1287/orsc.2022.1574

Wooldridge, J. (2002). *Econometric analysis of cross section and panel data*. MIT Press.

Wu, W., & Ding, Z. (1994). A few issues to note during new product development in TCM. *Shizhen Traditional Chinese Medicine Research*, *5*(2), 47–48.

Yan, C. (1996). Ten main changes in the market of Chinese Materia Medica in China. *Journal of China Pharmacy*, *7*(3), 104–106.

Yu, F., Takahashi, T., Moriya, J., Kawaura, K., Yamakawa, J., Kusaka, K., Itoh, T., Morimoto, S., Yamaguchi, N., & Kanda, T. (2006). Traditional Chinese medicine and Kampo: A review from the distant past for the future. *Journal of International Medical Research*, *34*, 231–239.

Yuanhengxiang Group. (2023, June 15). Analysis on the development of the Chinese herbal medicine industry. https://163.com/dy/article/179OE1UG055277EZ.html

Zhou, K. Z., Gao, G. Y., & Zhao, H. (2017). State ownership and firm innovation in China: An integrated view of institutional and efficiency logics. *Administrative Science Quarterly*, *62*, 375–404.

Zhu, Y. P., & Woerdenbag, H. J. (1995). Traditional Chinese herbal medicine. *Pharmacy World & Science*, *17*(4), 103–112.

How to cite this article: Li, X. (2023). When firms may benefit from sticking with an old technology. *Strategic Management Journal*, 1–30. https://doi.org/10.1002/smj.3551

APPENDIX 1: ANALYSES VERIFYING THE EVENTUAL PLATEAUING OF THE CLASSIC TCM MARKET

A critical premise for my hypothesis is that at the *market level*, as more firms adopt the discontinuous technology, market size for the old technology will first diminish before reaching a plateau that represents the revealed niches for the old technology (see Figure 1). To verify this in the TCM context, I followed prior research (Cox et al., 2008; Santos Silva & Tenreyro, 2006; Wooldridge, 2002) and estimated an exponential relationship between *competitors' new technology adoption* and *market size for the old technology* in a submarket using the generalized linear models (GLM) with logarithmic link[11] to a sample of 29 provinces over 6 years (1991–1996). Here, *market size for classic TCM* was measured by the annual per capita sales of classic TCM products in a province (see Martin & Mitchell, 1998; Nerkar & Roberts, 2004). Results are summarized in Table A1. Model 1 is the baseline province-level GLM regression, including only control variables. The independent variable *competitors' new technology adoption* was entered in Model 2. According to Model 2, the estimated coefficient for *competitors' new technology adoption* is negative ($\beta = -10.580$, $p = .022$), indicating an exponential curve as I predicted.

Furthermore, to show that market size for the old technology in a submarket indeed plateaued as firms increasingly launched the new technology, I calculated the slopes (i.e., conditional marginal effects) of the exponential curve estimated in Model 2 at every 10th percentile of the independent variable *competitors' new technology adoption*. Results show that once *competitors' new technology adoption* exceeds 0.204, the slopes of the estimated curve become indifferent from zero (i.e., $p \geq .159$), confirming the eventual plateauing of the curve. As a robustness check, I next split my sample using this turning point (i.e., *competitors' new technology adoption* = .204) and ran two simple OLS regressions using subsamples of province-level data on each side of the turning point. Results are displayed in Models 3 and 4. As shown in Model 3, when *competitors' new technology adoption* is less than 0.204, its estimated effect on the *market size for the old technology* within a submarket is negative ($\beta = -.723$, $p = .005$). By contrast, according to Model 4, when *competitors' new technology adoption* is greater than 0.204, its estimated impact becomes indifferent from zero ($\beta = -.013$, $p = .435$). These results together confirm that in the context of TCM, despite declining in the beginning, market size for classic TCM products remained stable once more than 20.4% of firms in a province had begun launching hybrid TCM in Western dosage form.

Finally, in Model 5, I created an interaction term between *competitors' new technology adoption* and the *percentage of rural population* in a province and included it in the province-level GLM regression. The estimated coefficient for the interaction term, according to Model 5, is positive ($\beta = 12.321$, $p = .019$); this suggests that as more competitors adopted the hybrid TCM, in provinces with a larger rural population, market size for classic TCM decreased more slowly (i.e., with a less negative slope) and settled into a higher plateau than in less rural provinces.

[11]As an alternative approach, I ran a province fixed-effects regression with both the independent variable *competitors' new technology adoption* and its *squared term* included in the regression. The estimated coefficient for *competitors' new technology adoption* is negative ($\beta = -.827$, $p = .003$), whereas that for its *squared term* is positive ($\beta = 1.128$, $p = .020$). I next followed Haans et al. (2016) and calculated the slopes of the estimated curve at every 10th percentile of my independent variable; calculations show that once competitors' new technology adoption exceeds 0.204, the slopes of the estimated curve change from being smaller than zero ($p \leq .004$) to being indifferent from zero ($p \geq .176$). These results suggest that the estimated relationship is merely the left half of a U-shape, which, according to Haans et al. (2016, p. 1182), is better fitted using an exponential function such as the GLM with log link.

TABLE A1 Regressions predicting market size for classic TCM.

Variable	Model 1	Model 2	Model 3	Model 4	Model 5
Competitors' new technology adoption		−10.580	−0.723	−0.013	−9.792
		(5.236)	(0.254)	(0.077)	(2.600)
Competitors' new technology adoption × Rural population					12.321
					(5.893)
Rural population	0.435	−1.508	0.025	−0.024	−2.508
	(0.875)	(0.964)	(0.177)	(0.053)	(0.915)
Local hybrid TCM density	−0.033	0.076	0.010	−0.001	0.083
	(0.024)	(0.053)	(0.006)	(0.001)	(0.030)
Foreign hybrid TCM density	−0.039	−0.015	0.000	−0.001	−0.011
	(0.013)	(0.009)	(0.000)	(0.000)	(0.007)
Western medicine competition	0.290	−0.255	0.190	0.116	−0.445
	(0.221)	(0.289)	(0.055)	(0.031)	(0.215)
Rural disposable income	0.043	0.031	0.001	−0.002	0.030
	(0.012)	(0.012)	(0.001)	(0.006)	(0.011)
Urban disposable income	0.007	0.017	−0.002	0.003	0.014
	(0.012)	(0.009)	(0.001)	(0.004)	(0.008)
FDI	0.328	0.268	0.119	−0.048	0.360
	(0.170)	(0.258)	(0.058)	(0.019)	(0.243)
Year dummies	Yes	Yes	Yes	Yes	Yes
Constant	2.231	−0.598	0.028	0.036	−0.931
	(1.655)	(1.160)	(0.032)	(0.049)	(0.931)
Number of observations	142	142	110	32	142
Number of provinces/firms	29	29	26	13	29
Goodness of fit	Log pseudolikelihood = 151.40	Log pseudolikelihood = 170.12	$F = 270.85$	$F = 104.77$	Log pseudolikelihood = 172.78

Note: Robust standard errors, clustered at the province level, are reported in parentheses.

APPENDIX 2: REGRESSIONS PREDICTING MARKET SIZE FOR CLASSIC TCM AND PERFORMANCE OF CLASSIC TCM FIRMS

	1991–2000 sample		1991–1996 sample of small firms
Variable	**Market level model 1**	**Firm level model 2**	**Firm level model 3**
Competitors' new technology adoption	−2.512 [0.000] (0.461)	−1.261 [0.019] (0.603)	−1.673 [0.038] (0.938)
Competitors' new technology adoption squared		2.531 [0.034] (1.383)	5.312 [0.029] (2.797)
Firm size			0.000 (0.003)
Firm status			0.040 (0.067)
State ownership			0.010 (0.162)
R&D investment			−0.336 (0.438)
Research alliance			0.000 (1.000)
Operation in Western medicine			−0.313 (0.244)
Exclusive classic TCM formulae			0.170 (0.297)
Rural population			−4.335 (5.492)
Local hybrid TCM density			−0.022 (0.031)
Foreign hybrid TCM density			0.018 (0.022)
Western medicine competition	0.740 (0.233)	0.082 (0.107)	−0.384 (0.563)
Rural disposable income	0.010 (0.009)	−0.001 (0.007)	−0.025 (0.019)
Urban disposable income	−0.007 (0.007)	0.001 (0.008)	−0.007 (0.024)
FDI	0.125 (0.174)	−0.124 (0.167)	0.230 (0.559)

Variable	1991–2000 sample Market level model 1	Firm level model 2	1991–1996 sample of small firms Firm level model 3
Year dummies	Yes	Yes	Yes
Constant	−1.351	0.247	−2.064
	(0.469)	(0.580)	(2.413)
Number of observations	248	4918	1932
Number of provinces/firms	29	1646	668
Goodness of fit	Log pseudolikelihood = 110.12	$F = 8.75$	$F = 8.90$

Note: Robust standard errors, clustered at the province/firm level, are reported in parentheses. *p*-values are reported for independent variables between square brackets. The increase in firm numbers in Model 2, besides a longer study period, was driven by the privatization and reorganization of state-owned firms following the "Proposals on the Reform and Development of State-owned Enterprises" issued by the State Economic and Trade Commission (1997).