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Crisis-Induced Innovation: Quality Upgrading in Chinese Industrial Clusters

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Abstract

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1. Introduction

Although market competition stimulates entrepreneurs' creativity and ingenuity, it does not necessarily induce firms to innovate and develop high-quality products (Schumpeter, 1934; Aghion and Howitt, 1992; Hausmann and Rodrik, 2003).[1] Empirical evidence suggests that competition fosters quality upgrading—an important outcome of innovation—only in countries with a minimum institutional quality (Amiti and Khandelwal, 2013). Having recognized the importance of institutions and policies in determining the nexus of competition and innovation, an unsettled question arises: How in the first place does a country or region create an enabling institutional environment in which competition can promote quality upgrading? The paper aims to answer this question using China as an example. The key message is that quality-supporting institutions and policies often emerge in response to crises.

In developing countries, the protection of intellectual property is often weak, making it costly for a firm to establish branding that differentiates products from similar unbranded products. In this case, it is not profitable for firms to produce high-

[1] There is a large body of literature testing the relationship between competition and innovation. However, the empirical findings are mixed. Using data from publicly traded manufacturing firms in the United States, Hashmi (2013) finds a mildly negative relationship between competition and innovation, offering some support to the Schumpeterian view. In the case of these firms, exporting to the larger international market may lead to improvements in product quality (Mallick and Marques, 2016), in particular for those firms located closer to the destination countries (Wagner, 2016). In contrast, a few empirical studies based on UK data (Blundell, Griffith, and van Reenen, 1999; Bloom, Draca, and van Reenen, 2016) reveal a positive correlation between competition and innovation. To reconcile the conflicting findings, Aghion et al. (2005) expanded the Schumpeterian model and proposed an inverted U-shape relationship between competition and innovation. In their model, whether the relationship is positive or negative depends on a product's distance to the world technology frontier, which in turn may be determined by institutions and policies.

quality products, even if they have the capacity to do so, because consumers cannot fully distinguish between unbranded low- and high-quality products. This reality leads to an equilibrium in which emerging markets are saturated with low-cost and low-quality products.

Because most industrial activities take place in clusters,[2] local governments can play a positive role in overcoming negative externalities by protecting local brands, setting up quality inspection centers, or taking similar initiatives. However, such initiatives are not free. It is costly to build up local quality-enhancing institutions. In the case of a shock, entrepreneurs and local governments are more likely to take collective action to improve product quality than under normal market conditions, because the cost of not doing so looms larger than previously. Without taking action, the whole local industry may collapse, cutting off the revenue stream of local governments. Of course, it is challenging to coordinate the interests of different parties and take collective action amid a crisis. Whether or not crises can successfully induce a cluster to upgrade quality remains largely an empirical question.

In this paper, we first present two case studies to illustrate the role of crises in quality upgrading. Then we develop a monopolistic competition model to highlight the mechanisms of quality upgrading. Finally, we use a panel of county-level data from the Chinese province of Zhejiang between 1990 and 2008 to test our model's

[2] A cluster means that a large group of similar producers is concentrated in the same location. See Porter (1990) for a general discussion on clusters and Sonobe and Otsuka (2006) for descriptions of clusters in Asia. Cluster-based industrial production has become increasingly evident in China (Ruan and Zhang, 2009; Li and Lu, 2009; Lu and Tao, 2009; Long and Zhang, 2011).

predictions. Based on primary crisis data and secondary information on the number of patents, number of quality certifications, and fraction of professional and technical staff in the local labor force, our empirical analyses uncover a robust correlation between crises and subsequent quality upgrading. In accordance with our hypothesis, we also find that local governments are more likely to come up with quality-enhancing policies after a crisis strikes.

Although this study is based on Chinese data, the insights apply to other developing countries as well. For example, a ban imposed by developed countries on the import of low-quality surgical instruments produced in Pakistan's Sialkot surgical instruments industry cluster compelled local governments and business communities to take collective action and achieve quality upgrading (Nadvi, 1999).

This paper builds on and contributes to a few strands of the literature. First, it contributes to the literature on firm quality choice (Kugler and Verhoogen, 2012; Mallick and Marques, 2016). Although the existing literature highlights the importance of firm heterogeneity in quality choices, it neglects the role of local policies and institutions in facilitating firms' quality production, which is the focus of this paper.

Second, the paper is related to the literature on the emergence of regulations. The existing literature commonly argues that the presence of information asymmetry is one of the major driving forces behind the emergence of market regulations (Law, 2003; Law and Kim, 2005).[3] Information asymmetry also often leads to poor product quality (Akerlof, 1970). However, the literature largely ignores the timing of regulation enactment. Our paper argues that regulations designed to reduce information asymmetry are more likely to emerge after a crisis than they are under normal economic conditions.

Third, this paper is related to the literature on rising product quality in China. Foreign investment has been found to be a key driver of technology spillover and product quality improvement in the host country (Xu, 2000; Cheung and Lin, 2004; Hatani, 2009). Engaging in processing trade and exporting can also help improve a firm's export sophistication and product quality (Feenstra and Romalis, 2014; Mallick and Marques, 2016; Wagner, 2016). However, more than 70 percent of China's economic growth in the past three decades has been driven by the domestic private sector (Wei and Zhang, 2011). Therefore the observed dramatic quality upgrading cannot be solely attributed to foreign investment and trade.

Bai, Gazze, and Wang (2019) highlight the importance of collective reputation in Chinese dairy industry using the scandal of contaminated baby milk formula in 2008 as a natural experiment. However, the paper does not investigate whether the crisis has induced the development of quality-upgrading institutions.

[3] The literature on regulations is too broad to review comprehensively (Coase, 1959; Joskow and Rose, 1987). Here we mention a few pieces of literature related to the emergence of regulations.

2. Product Quality, Industrial Clusters, and Crises in China

2.1 Rising Product Quality in China

Product quality in China has improved dramatically in the past three decades. During China's planned economy era (prior to 1977), the quality of its manufactured products was on a par with that of other developing countries. As the following facts demonstrate, since the reforms of the late 1970s, the quality of China's manufactured goods has been quickly catching up with that of developed countries (Alvarez and Claro, 2006; Hallak and Schott, 2011). First, over 1983–2019, the share of exports in China's gross domestic product (GDP) jumped from 7.4 to 17.4 percent. Consequently, China's share in total world exports rose from 1.2 percent in 1983 to over 12 percent in 2019, and the country is now the world's largest exporter. Since exported goods are generally of higher quality than those sold in the domestic market (Henn, Papageorgieou, and Spatafora, 2013; Amiti and Khandelwal, 2013), such a rapid increase in export likely implies an improvement in Chinese product quality.

Second, the number of registered trademarks in China has experienced dramatic growth: starting from a mere 18,565 in 1982, applications for trademark registration in China exceeded 664,000 (the most in the world) in 2005, and further tripled to 7.84 million by 2019 (China State Administration of Industry and Commerce, 2020). This represents a more than 400-fold increase over about four decades.

Third, since the 1990s, patent applications have also seen phenomenal growth in China, increasing from 41,469 in 1990 to 2,377,061 in 2013, a 56-fold increase (China National Bureau of Statistics, 2014). This was the fastest increase in the world in that period (Wei, Xie, and Zhang, 2017). The number further increased to 3.75 million by 2019. Zhejiang Province performed extremely well in patent applications.

Finally, the proportion of merchandise sampled for quality inspection that passed the first grade or above increased from 49.6 percent in 1995 to about 94 percent in 2019 (China National Bureau of Statistics, 2020). Each of these facts indicates rapid improvement in the quality of Chinese manufactured products.

Zhejiang performed better than most provinces in quality upgrading. For example, the number of total patent applications in Zhejiang reached 0.46 million (11.1 percent of total patent applications for China as a whole) in 2018, ranking the third among all the provinces (China National Bureau of Statistics, 2019). The number of patent applications per 10,000 people was 79 in Zhejiang, ranking the first among all the provinces. Zhejiang's first quality certification occurred in Wenzhou in

1997.[4] Since then, the number of quality-certified companies in the province has steadily increased, reaching 832,267 by 2019, ranking third among all the provinces.[5]

2.2 Cluster Development in Zhejiang

We selected Zhejiang for our empirical study because it is China's manufacturing powerhouse. Located on the country's eastern coast, Zhejiang province has rather limited natural resources compared with many other provinces in China. During China's planned economy era before 1978, the central government strategically made less public investment in Zhejiang province than in most other provinces. The province's proximity to the war frontier with Taiwan was cited as the major reason. As a result, the share of state-owned enterprises in Zhejiang province was much lower than in many other provinces.

When economic reforms began in 1978, per capita GDP in Zhejiang was 331 yuan (US$255), ranking it 13th among 30 provinces. By 2019, Zhejiang's per capita GDP reached 109,000 yuan (US$16,000), placing it among the five richest provinces (China National Bureau of Statistics, 2020). Industrial development played a key role in Zhejiang's rapid economic growth. According to the China Economic Census, in

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[4] People's Republic of China Product Quality Certification Regulations were introduced in 1991. The China Quality Certification Centre (CQC) was created to provide quality certifications as a professional certification body. It is optional for a firm to apply for a quality certification, which is also costly (about $2,000 for each certification). CQC sends auditors to inspect factories and assess whether their product quality is compliant with a certain standard. The most common standard is ISO 9001, drafted by the International Organization for Standardization. The certification helps firms signal their product quality and increase exports.

[5] This information can be found on the webpage of the Certification and Accreditation Administration of the People's Republic of China (http://www.cnca.gov.cn/).

2004, Zhejiang had nearly 190,000 industrial enterprises—more than any other province in the nation. Among these were more than 40,000 industrial enterprises with annual sales income exceeding five million yuan, also more than any other province (China National Bureau of Statistics, 2006).

Zhejiang's industrial development is largely cluster-based (Table 1). The phrases "one village, one product" and "one industry in one county" have been commonly used in the media to describe the concentration of industrial production in Zhejiang. In 2000, there were 529 industrial clusters with an annual gross output of more than 100 million yuan and 149 industrial clusters with an annual output value of more than one billion yuan. The average cluster among these 149 larger clusters generated a gross output value of 3.3 billion yuan, hired more than 20,000 workers, and contained 1,400 enterprises.

By the end of 2004, the number of clusters that produced more than 100 million yuan in industrial output increased to 839. The total industrial output value created by the clusters was as high as US$187 billion, accounting for 78.6 percent of total provincial industrial output, and total profit reached US$9.6 billion, accounting for 76.5 percent of total profit in the province's manufacturing sector. In 2007, the Chinese Academy of Social Sciences published a list of the top-100 industrial clusters in China, 36 of which were in Zhejiang (China Business Times, 2007). In summary, over the past several decades, Zhejiang has followed a highly successful cluster-based industrialization path.

2.3 Crises and Industrial Policies in Zhejiang Clusters

In China, local governments have strong incentives to promote local economic development for at least two reasons. First, the promotion of local officials largely hinges on local economic performance (Li and Zhou, 2005). Second, fiscal revenues are shared between the local and central governments (Jin, Qian, and Weingast, 2005; Xu, 2011). In China, county-level governments play a key role in industrial development and most industrial policies are at the county level (Cheung, 2011).

Industrial development at the county level or lower is largely cluster-based. Cluster development generally follows two phases, quantity explanation and quality improvement (Sonobe and Otsuka, 2006). The quantity explanation phase is marked by rapid entries through imitation. The second phase of quality upgrading depends more on innovation. Sonobe and Otsuka (2006) underline the role of training programs in stimulating innovation. In China, local governments adopt a wide range of industrial policies beyond training programs, such as tax breaks, subsidies, land concessions, quality inspection, and generic promotions (Cheung, 2009). However, quality-enhancing policies normally do not come about in the very beginning. They are more likely to occur after a crisis, as shown in the following case of Wenzhou shoes.[6]

Wenzhou's footwear production cluster first formed in the late 1970s. The clustering mode of production lowers the capital barriers to entry because many

[6] For details, please refer to Ruan and Zhang (2010).

production steps are dispersed among different family workshops or firms (Huang, Zhang, and Zhu, 2008). As a result, the number of enterprises soared, and total output expanded dramatically. Faced with price pressures, many enterprises adopted a low-quality and low-cost strategy. Some of them even started to use fake raw materials to reduce the cost of producing shoes. Their behavior damaged the reputation of the whole industry in Wenzhou. Most producers at the time did not have their own brands, and consumers, who were unable to differentiate producers, simply assumed that all shoes made in Wenzhou were of poor quality. Wenzhou shoes were called “day shoes,” “week shoes,” and “falling-heel shoes,” synonymous with counterfeiting.

Consumer dissatisfaction with Wenzhou shoes climaxed on August 8, 1987, when China’s Hangzhou Industrial and Commercial Administration burned 5,000 pairs of Wenzhou-made shoes in Wulin Plaza in Hangzhou in a televised broadcast. In April 1988, consumers destroyed a shop selling Wenzhou shoes in a large shopping center in Nanjing. Subsequently, many other cities followed suit. Even as far away as Russia, signs with messages like “No Wenzhou goods” and “Wenzhou people out of Russia” were displayed on the streets (Chen, 2006).

Facing the threat of being wiped out by the crisis, local business communities and the government took a series of collective actions to improve product quality to save the footwear industry. A group of industry veterans set up the Wenzhou District Footwear Association in June 1988. It established various regulations to curb vicious competition, punish producers of poor-quality products, and restore trust among its members (China Footwear Information Network, 2007). For example, the association created a new intellectual property rights committee to protect and promote the launch of new products and inhibit the spread of fake products. The association blacklisted enterprises with a bad reputation, thus shaming these enterprises among the other members.

Furthermore, local governments took serious administrative actions. Led by the Lucheng district government of Wenzhou City, the Bureau of Quality and Technical Supervision, the Administration of Industry and Commerce, and several other related agencies jointly established the Lucheng Footwear Quality Management Office. Since then, all the shoes produced in Wenzhou have had to be certified by the office. When enterprises renew their production license with the Administration of Industry and Commerce, they must provide the quality certifications for their products (Li, 2006).

In 1993, the Wenzhou municipal government implemented a strategy to create a regional brand, requiring that all shoes made in Wenzhou be marked “Made in Wenzhou.” In addition, the government began providing various incentives to encourage local enterprises to create brands. For example, if a firm earned the title of “China Famous Brand” for its products from the State Administration of Industry and Commerce, the local government would award it one million yuan (Li, 2006). Moreover, the association and local governments worked together to regulate advertising. Enterprises that were blacklisted by the association because of their bad reputations were banned from posting advertisements of any form in Wenzhou. Because it is the major shoe production and market center, it is difficult for punished enterprises to gain business without advertisements.

With these measures, the quality of Wenzhou shoes improved dramatically. This case illustrates that a crisis triggered an opportunity for enterprises and local government in Wenzhou to work together to improve product quality in the footwear industry.

Apart from demand-side shocks, as shown in the case of boycotts of Wenzhou shoes, there are also supply-side shocks. For example, on September 14 and October 19 in 2006, two fatal fire accidents killed 22 people in the Zhili children's garment cluster (Fleisher et al., 2010). The accidents were widely covered by media. In response, the local government mandated all the family workshops (which tended to produce low-quality clothes) to install exterior stairs to meet the new safety regulation. Large exporting firms producing high-quality products for the international market did not need to do so, because their factory buildings already met the international standard as part of the export requirements. The shock provided an opportunity for high-quality firms to expand their market share.

To test whether the insight drawn from the two case studies holds up for a larger sample, we conducted field surveys in major clusters in Zhejiang province. Due to a lack of comprehensive statistical data for all the clusters, we could only observe large and well-known clusters with publicly available information. *Zhejiang Yearbook* (China National Bureau of Statistics, 2003) lists 149 clusters with gross output value of more than one billion yuan in 2000. In addition, 36 clusters were included in the top-100 national clusters by the Chinese Academy of Social Sciences Survey in 2007 (China Business Times, 2007). Zhejiang Small and Medium Enterprise Bureau also maintained a list of industrial clusters in Zhejiang in 2007.[7] Together, the three lists cover 158 clusters.

Some less developed counties do not have large clusters, whereas some developed regions have more than three large industrial clusters. Due to budget constraints, it was impossible for us to survey all the clusters. After consulting with informants and local officials, we reached a comprise by surveying at most three clusters in each county. In counties with more than three clusters, we kept only the top three clusters in the list. The trimming procedures dropped 33 clusters. Among the 125 remaining clusters, we randomly surveyed 85 clusters.

The development of Zhejiang industrial clusters has been associated with various crises. The crises include demand-side shocks and supply-side shocks. The demand-side shocks, such as consumer boycotts and export barriers, depress demand. Shocks related to changes in factor prices (such as wage, land, energy, and other raw material prices), macro policy and regulations by the central government, and

[7] The data, which are not available to the public, were provided by Zhejiang Bureau of Small and Medium Business.

accidents (such as fires and explosions) are counted as supply-side shocks, because they primarily affect the cost of production.

There are no official records of crisis-related statistical data for industrial clusters. In the summer of 2012, we surveyed 85 clusters. By interviewing key informants in the local government and business associations, we recorded the milestones in the process of cluster development, such as major crises encountered and subsequent policy responses. Since crises are salient events, the key informants could vividly recall the major shocks, if any. Nonetheless, informants may be subject to recall errors. As a robustness check, we also searched the internet and media reports to create an alternative crisis measure.

Table 2 reports the number of crises by type and year. Quality crises accounted for the largest share, while crises related to export barriers ranked second. All the crises in this category happened after 2004, probably reflecting China's fast growth in exports after joining the World Trade Organization in 2001. Some industries occasionally ran into sudden, unfavorable policy changes. For instance, in 2004, China's National Development and Reform Commission announced a new regulation imposing an investment threshold for entry into the automobile and motorcycle industries, which struck a heavy blow to the clusters of automobile parts suppliers in Wenling and Yuhuan. Overall, crises have occurred more frequently since 2000. Five crises can be categorized as accidents. For example, on October 21, 2006, the Zhili Children's Garment cluster suffered an accidental fire, killing eight people and injuring five. After the accident, the government imposed strong safety regulations, requiring all "three-in-one" workshops to install fire exit stairs and separate production space from living areas.[8]

Having defined the crisis variable, next we check if there were obvious differences between counties with crises (treatment group) and without crises (control group). Given the high concentration of shocks in 2004 and 2005, for illustration purposes, we define the treatment group as counties that were subject to shocks in 2004/2005 and the control group as counties that never experienced a shock over the whole sample period. The three panels in Figure 1 depict the trend for the two groups. The two lines are largely indistinguishable prior to 2004 but exhibit a widening gap after 2004. The difference between the two groups before 2004 is statistically indifferent from zero for all three outcome variables.

Figure 2 shows the number of major local government policies enacted prior to and after a crisis.[9] We considered 11 types of industrial policies: (1) providing infrastructure, (2) building marketplaces, (3) setting up an industrial park, (4) establishing a logistics center, (5) training workers, (6) creating an industrial association, (7) providing firms with financial incentives, (8) undertaking generic promotion, (9) hosting exhibitions, (10) establishing quality-inspection centers, and (11) facilitating firms' research and development. Prior to a crisis, the first four types

[8] The workshops, where workers eat, live, and work in the same place, are often called "three-in-one" workshops.

[9] As a robustness check, we also repeated the exercise by excluding crises caused by macro policies, which affected all the clusters. The main finding remains the same.

of policies in support of market expansion were more popular. After a crisis, policies (10) and (11), which are largely conducive to quality upgrading, were more likely to be put in place. It seems that the menu of industrial policies differs before and after a crisis.

To verify this point, Figure 3 shows the average number of quantity-expansion policies and quality-upgrading policies prior to and after a crisis, with the 95 percent confidence interval. Quantity-expansion policies include providing infrastructure, building marketplaces, setting up an industrial park, and establishing a logistics center. Establishing quality inspection centers and facilitating firms' research and development are defined as quality-upgrading policies. It is apparent from Figure 3 that the number of quality-upgrading policies significantly increases after a crisis, while the number of quantity-expansion policies drops. The portfolio of industrial policy changes after a crisis.

3. Conceptual Framework

3.1 Model Setup

Drawing on insights from the previous section, we present a conceptual model in this section to discuss the relationship between crises and quality upgrades in industrial clusters. According to Porter (1990), a cluster is a narrowly defined geographical location with many firms producing similar products. The definition implies two key elements. First, there must be a large number of firms in a cluster.

The number of firms captures the size of the cluster. Second, within a cluster, firms largely produce the same category of product. Our conceptual model tries to capture both factors. Specifically, we make the following assumptions to describe the market.

First, we assume a continuum of risk-neutral firms of measure 1, which is consistent with the definition of clusters that are composed of many firms in a narrowly defined location. The assumption ensures a competitive environment where each single firm cannot exert enough power to shape the aggregate market outcomes.

Second, firms in clusters produce similar yet differentiated products in the same product category in line with one of the key features of clusters—many varieties of the same product. There are two types of product differentiation: vertical product differentiation in quality, and horizontal product differentiation in design, function, appearance, and so on. For simplicity, we assume that there are two quality levels for vertical product differentiation: a high-quality (h) and a low-quality (l) product. Consumers derive higher utility value from a high-quality product than from a low-quality product, i.e., $v_h > v_l \geq 0$, where v_h and v_l denote consumer preference for a high- and low-quality product, respectively. Due to horizontal differentiation, different consumers can derive different match values from the same product. In the model, we denote a consumer's idiosyncratic match value with a product as ε, which follows a uniform distribution on the interval $[-k, k]$. The parameter k measures product variety in the market. We assume that k is sufficiently large—that is, there are enough product varieties in the market.[10] Given these product attributes, a consumer buys a unit of quality $v \in \{v_l, v_h\}$ at a price p and derives a utility $v + \varepsilon - p$. We assume a continuum of risk-neutral consumers of measure 1 and each consumer has a unitary demand.

Third, to study a market of monopolistic competition, we further assume that a consumer incurs a positive search cost ($s > 0$) to discover the price and value of ε of a product. In a cluster, because there are so many firms producing the same type of product with many varieties (for example, varying by design, functionality, and quality), it is impossible for a consumer to visit all the firms and get to know their products in a cluster before making a purchase. Therefore, consumers end up visiting only a small number of firms before buying, regardless of the total number of firms in the market (the size of the market). The presence of search friction enables small firms to obtain positive profits even if the number of firms goes to infinity, creating "true monopolistic competition," as mentioned in the seminal paper by Wolinsky (1986).[11]

Next, we describe a firm's quality-upgrading decision. First, assume that all firms initially produce low-quality products at marginal cost c_l. To produce a high-quality product, a firm needs to make an investment. A firm will upgrade its quality

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[10] A key feature of clusters is that there are many varieties for the same product. Technically, this is also a sufficient condition to guarantee that firms' incentive to upgrade quality decreases *globally* when there are more high-quality firms in the market (Fishman and Levy, 2015).

[11] If $s = 0$, as the number of firms goes to infinity, the firm's profit goes to zero regardless of the quality level.

successfully with (ex ante) probability $\mu \in [0,1]$ if it invests $I(\mu)$. The two limiting cases are $\mu = 0$ and $\mu = 1$: if $\mu = 0$, then firms will not upgrade product quality; if $\mu = 1$, then firms will upgrade quality with certainty. We assume $I(0) = 0$, $I'(0) = 0$, $I'(\mu) > 0$, and $I''(\mu) > 0$—that is, a larger μ is associated with higher investment costs, and the cost function is convex in μ. In a symmetric equilibrium in which firms choose the same strategy, μ also represents the proportion of high-quality firms in the market.

Higher fixed and variable costs are required to produce high-quality goods (Berry and Waldfogel, 2010). The fixed costs ϕ include but are not limited to those of registering trademarks and promoting brands. We assume that ϕ depends on the level of quality-enhancing public goods provided by the government. It is generally more costly to produce and market a high-quality product than a low-quality product at the margin (Kugler and Verhoogen, 2012)—that is, $c_h > c_l$. If a firm succeeds in upgrading product quality, it implies $v_h - c_h > v_l - c_l$, i.e., it is more profitable to produce a high-quality product than a low-quality product.

It would be ideal to create a dynamic model with an infinite horizon. However, given the infinite number of firms, such a dynamic model would become intractable. As a viable alternative, we develop a two-stage model to incorporate interactions between firms and consumers. In stage 1, each firm chooses μ and makes appropriate investments in product quality. In stage 2, firms set prices, while consumers search products in the market and determine when and where to buy. In subsection 3.4, we incorporate the government's role by adding stage 0.

In spirit, our theoretical framework closely follows Fishman and Levy (2015). While they focus on the effects of decreasing search costs, we study the impacts of demand and supply shocks on firms' quality-upgrading decisions and the government's incentive to invest in quality-enhancing public goods.

3.2 Equilibrium

We solve the game by backward induction. First, given μ, the proportion of high-quality firms in the market, we solve the market equilibrium in stage 2. Then we derive the firm's optimal choice of quality upgrading, denoted by μ^*, in the first stage. In a symmetric equilibrium, it must be that $\mu = \mu^*$, where μ^* represents the proportion of high-quality firms in the market. The symmetric equilibrium means that (1) firms choose the same μ^* in the first stage, and (2) firms producing the same quality of products charge the same price in the second stage.

Let p_h and p_l be the prices of high- and low-quality firms, respectively. As documented in the search literature (Wolinsky, 1986; Fishman and Levy, 2015), a consumer's optimal strategy is characterized by a reservation value u, such that she stops searching and buys a product if and only if the product provides her utility greater than or equal to u, that is, $v_i - p_i + \varepsilon \geq u$. Consumers' search in the marketplace brings about competitive pressures on all the firms.

With a continuum of firms, a single firm's pricing strategy does not affect consumer behavior, thus having nothing to do with the measure of consumers who visit its store, M.[12] Given consumers' optimal searching rule, consumers will buy products from a firm with quality v_i if and only if $v_i + \varepsilon - p \geq u$. Hence, each consumer's visit will generate the following profit for a firm:

$$\pi(p, u, v_i, c_i) = (p - c_i)\big(1 - F(p + u - v_i)\big),$$

where $F(\varepsilon) = \frac{1}{2k}(\varepsilon + k)$ is the cumulative distribution function of ε. A high-quality firm solves $max_p\, \pi\,(p, u, v_h, c_h) \cdot M$, while a low-quality firm solves $max_p\, \pi\,(p, u, v_l, c_l) \cdot M$. Lemma 1 characterizes the equilibrium outcome of the product market.

Lemma 1: *Given μ, the equilibrium prices and consumers' reservation utility*

$$\{p_h^*(\mu), p_l^*(\mu), u^*(\mu)\}$$

are uniquely determined by:

$$2ks = \mu \int_{\frac{k+u^*-v_h+c_h}{2}}^{k} \left[\varepsilon - \frac{k+u^*-v_h+c_h}{2}\right] d\varepsilon + (1-\mu) \int_{\frac{k+u^*-v_l+c_l}{2}}^{k} \left[\varepsilon - \frac{k+u^*-v_l+c_l}{2}\right] d\varepsilon, \quad (1)$$

$$p_l^* = \frac{k-u^*+v_l+c_l}{2}, \quad (2)$$

$$p_h^* = \frac{k-u^*+v_h+c_h}{2}. \quad (3)$$

Proof: See Appendix B.■

Given μ, let Π_i be the expected profit of a firm with quality v_i in equilibrium. Specifically, for $i = l, h$,

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[12] Here we use measure because of the continuum of consumers and firms. In the real world with a finite number of firms and consumers, the measure means "the number."

$$\Pi_i = (p_i^* - c_i)(1 - F_i^*)M,$$

where $F_i^* = F(p_i^* + u^* - v_i)$, $i = h, l$, and

$$M = \frac{1}{\mu(1 - F_h^*) + (1 - \mu)(1 - F_l^*)}$$

is the number of consumers visiting each firm. Then it is easy to verify Lemma 2.

Lemma 2: $\Pi_h(\mu) > \Pi_l(\mu)$ for any μ.

Proof: See Appendix B.■

Lemma 2 indicates that given μ, it is more profitable for a firm to produce high-quality products than low-quality products, regardless of the fixed and investment costs.

Next, consider the firm's decision at stage 1. Given a continuum of firms, a single firm's decision does not affect the proportion of high-quality firms in the market. Hence, each firm will take μ in the market as given to determine its own probability of upgrading. If a firm chooses $\hat{\mu} > 0$, it will maximize

$$\max_{\hat{\mu}} R(\hat{\mu}; \mu, v_h, c_h, v_l, c_l; \phi) \equiv \hat{\mu}[(\Pi_h(\mu) - \phi) - \Pi_l(\mu)] - I(\hat{\mu}). \quad (4)$$

$R(\hat{\mu}; \mu, v_h, c_h, v_l, c_l)$ is the expected increase in profit if the firm chooses $\hat{\mu}$, given a proportion μ of high-quality firms in the market. The firm needs to pay a fixed cost ϕ to verify that it produces high-quality products. Thereby, the profit of producing high-quality products is $\Pi_h(\mu) - \phi$, regardless of the fixed and variable costs.

A symmetric equilibrium consists of $\{\mu^*; \hat{\mu}^*(\mu), p_h^*(\mu), p_l^*(\mu), u^*(\mu)\}$, such that

$\{ p_h^*(\mu), p_l^*(\mu), u^*(\mu)\}$ satisfies (1) to (3), $\hat{\mu}^*(\mu)$ maximizes (4), and $\hat{\mu}^*(\mu^*) = \mu^*$.

Proposition 1 characterizes μ^* in equilibrium.

Proposition 1: *In equilibrium:*

(1) If $\phi \geq \Pi_h(0) - \Pi_l(0)$*, then* $\mu^* = 0$.

(2) If $\phi \leq \Pi_h(1) - \Pi_l(1) - I'(1)$*, then* $\mu^* = 1$.

(3) If $\phi \in \left(\Pi_h(1) - \Pi_l(1) - I'(1), \Pi_h(0) - \Pi_l(0)\right)$*,*[13] *then* $\mu^* \in (0,1)$ *and is implicitly determined by* $\Pi_h(\mu^*) - \Pi_l(\mu^*) - \phi - I'(\mu^*) = 0$.

Proof: See Appendix B.

Proposition 1 implies that if ϕ is too large, then in equilibrium, no firm will choose to upgrade quality. If ϕ is sufficiently small, then in equilibrium, firms will choose to upgrade quality with certainty. If ϕ is moderately large, then for each firm the probability of upgrading is between 0 and 1. Because all firms are identical ex ante, μ^* also represents the proportion of firms that upgrade their product quality.

3.3 Comparative Statics

Our story emphasizes that when low-quality firms are exposed to shocks, they are more likely induced to upgrade quality. Therefore, we focus on a decrease in v_l or c_l, which captures demand or supply shocks on the low-quality products. An example of a demand shock is the consumer boycotts of low-quality shoes in Wenzhou, as

[13] In Appendix B, we show that $\Pi_h(\mu) - \Pi_l(\mu) - \phi - I'(\mu)$ decreases in μ such that $\Pi_h(0) - \Pi_l(0) > \Pi_h(1) - \Pi_l(1) - I'(1)$. Therefore, the domains in Proposition 1 are well defined.

mentioned in section 2. In our model, the boycotts can be written as a decline in v_l, a lower utility value for consumers. The boycotts caused a decline in demand for low-quality products.

Moreover, we regard a change in c_l as a supply-side shock. Although c_h and c_l can increase simultaneously, after a supply-side shock, the increase in c_l is often greater than the increase in c_h. As manifested by the fatal fire accidents in the Zhili children's garment cluster, the "three-in-one workshops" (low-quality firms) bore the burden of installing exterior fire exits, while high-quality firms did not incur the cost because their factory buildings already met the new regulation. This example case demonstrates that a supply shock generates a larger effect on c_l than c_h. Hence, for illustration purposes, in this part we focus on the impact of an increasing c_l as a result of supply-side shocks. We first consider the interior solution, i.e., ϕ is moderate such that $\mu^* \in (0,1)$. Thus, we have Proposition 2.

Proposition 2: *If the fixed cost of upgrading ϕ is moderate—that is, $\phi \in \left(\Pi_h(1) - \Pi_l(1) - I'(1), \Pi_h(0) - \Pi_l(0)\right)$, then:*

*(1) (**Demand shock**) $\frac{d\mu^*}{dv_l} < 0$. The proportion of high-quality firms increases when v_l decreases.*

*(2) (**Supply shock**) $\frac{d\mu^*}{dc_l} > 0$. The proportion of high-quality firms increases when c_l increases.*

Proof: See Appendix B. ■

Next, suppose $\phi \geq \Pi_h(0) - \Pi_l(0)$ at (v_l, c_l) such that $\mu^* = 0$ in equilibrium.

This situation corresponds to the case where no firm upgrades quality in the first place. Proposition 3 implies that, after a demand or supply shock, for some ϕ, quality upgrading will take place.

Proposition 3: *Suppose at* (v_l, c_l)*, the equilibrium outcome is* $\mu^* = 0$ *and no firm invests to upgrade product quality. When* v_l *decreases to* $v_l' < v_l$ *(or* c_l *increases to* $c_l' > c_l$*), there exists* $\phi > 0$ *such that* $\mu^* = 0$ *is no longer an equilibrium outcome.*

Proof: See Appendix B.■

Propositions 2 and 3 indicate that firms are more likely to upgrade quality when the demand for low-quality products decreases or the cost of low-quality products increases.

3.4 Government Investment in Quality-Enhancing Public Goods

Now we introduce the role of government in investing in quality-enhancing public goods. Suppose there exists a stage, stage 0, before stage 1. At stage 0, the government chooses to invest or not to invest an amount $G > 0$ in quality-enhancing public goods. If the government invests G, then the fixed cost for firms (ϕ) is reduced to 0.

Given that there is no change in the size of firms in the market, we assume the government's utility, denoted $W(\mu^*)$, increases in μ^*, with $W'(\cdot) > 0$ and $W(0) = 0$. For illustration purposes, we consider a case in which ϕ is relatively large, that is, $\phi \geq \Pi_h(0) - \Pi_l(0)$, such that all the firms choose $\mu^* = 0$, producing only low-quality products (the first case in Proposition 1). After a shock, in the absence of quality-enhancing public goods, the inequality still holds and no firms upgrade their product quality. In this case, it makes more sense for the government to invest in quality-enhancing public goods after a shock occurs.

Proposition 4: *Suppose at* (v_l, c_l)*, the equilibrium outcome is* $\mu^* = 0$ *and there is no provision of quality-enhancing public goods. Consider a demand shock in which* v_l *decreases to* $v_l' < v_l$ *(or a supply shock in which* c_l *increases to* $c_l' > c_l$*), and suppose that without government's investment the equilibrium outcome is still* $\mu^{*\prime} = 0$*. Then there exists* $G > 0$ *such that the government chooses to invest* G *in quality-enhancing public goods after the shock.*

Proof: See Appendix B.

After a shock, the profit of low-quality firms is squeezed. Therefore, firms will have a greater incentive to upgrade their product quality. However, in the absence of the necessary public goods, the barrier to do so is too large. If the local government provides public goods, the fixed cost of upgrading quality will be lower for firms, and thus more firms will be able to upgrade their product quality. Knowing the greater role of public investment in facilitating firms' quality upgrading after a crisis and having in mind the objective of increasing the share of high-quality firms in clusters, local governments are willing to provide the necessary local public goods to improve quality.

4. Empirical Analyses

In this section, we empirically test the impact of crises on quality upgrades in clusters using two approaches: standard regressions and event studies.

4.1. Estimating the Average Effect of Crises on Quality Upgrading

To estimate the impact of crises on quality upgrading, we used county-level data from Zhejiang province and the following the specification:

$$Q_{it} = \alpha * Crisis_{it} + \beta X_{it} + Year_t + County_i + \epsilon_{it}, \quad (5)$$

where Q_{it} stands for quality measures in county *i* in year *t*.

It would have been ideal to use quality measures at the cluster level. However, such data were not systematically available. Instead, we base our analysis at the county level. We consider three outcome variables: patents per capita, quality certifications per capita, and share of professional and technical personnel in total population. These three variables are in logarithms. The patent data were obtained from the website of the China Intellectual Property Office. The number of firms with quality certification is from the Zhejiang Bureau of Quality and Technical Supervision. The number of professional and technical personnel is from the *Zhejiang Statistical Yearbook* (China National Bureau of Statistics, various years).

$Crisis_{it}$ is defined as the total number of accumulative crises that county *i* has encountered by time *t*. Among the 85 clusters in our sample, most were at the county level in Zhejiang, but some were at the township level (one level below the county). However, because the cluster-level data were not systematically available, we used the county-level data to measure variables related to clusters in our analysis. If a county had more than one cluster, we defined the crisis variable as the total number of crises that had occurred at time *t* (or *t-1*) in all the clusters sampled in a county. As a result, the value of crisis can be greater than 1.

X_{jt} is a set of control variables at the county level in year *t*, such as per capita GDP and per capita foreign direct investment (FDI). Initial conditions from the world technology frontier have been found to be mitigating factors in the decision to upgrade (Verhoogen, 2008; Amiti and Khandelwal, 2013). We controlled for per capita GDP to proxy the distance to the world frontier. Since the literature has found that FDI is a driver of quality upgrading in China, we included per capita FDI. To avoid potential reverse causality, we used lagged crisis, lagged per capita GDP (log), and lagged per capita FDI (log) in the regressions. Table 3 presents the descriptive statistics of the key variables used in the regression analyses.

We first regressed the number of patents per capita in logarithm on the crisis variable and other control variables according to equation (1). The first two regressions (R1 and R2) in Table 4 report the estimation results using only the lagged crisis variable without any control variables. The difference between R1 and R2 is that R2 includes year fixed effects. The coefficient for the patent variable in R2, which includes county and year fixed effects, is 0.469, statistically significant at the 1 percent level. In the third regression, lagged per capita GDP (log) and lagged per capita FDI (log) are added as control variables. The coefficient for the crisis variable remains highly significant, dropping to 0.432. Based on the estimate in R3, one occurrence of crisis increases the number of patents per 10,000 people by 54.3 percent (=exp(0.432)*100-100). In R4, we replace year fixed effects with county-specific time trends. The time trend is defined as year 1990. The coefficient for the crisis variable drops slightly to 0.375, significant at 1 percent.

The coefficients for GDP and FDI in R3 are positive and yet insignificant. However, the coefficients for both variables become significantly negative in R4. The puzzling results on GDP and FDI are likely due to high multicollinearity of the two variables with the county-specific time trend. The variance inflation factor (VIF) for lagged per capita GDP is 13.27, higher than the commonly used cutoff of 5, indicating strong multicollinearity. The VIF for lagged per capita FDI is 4.86, which is close to the threshold of high multicollinearity. This probably explains why the two variables flip signs from R3 to R4.

Table 5 reports the estimation results, with the number of quality certifications as the outcome variable. Since quality certification did not take place until 1997 and the data are no longer publicly available after 2006, we restricted our sample to 1997–2006 in the regressions on this variable. As shown in R1, when only the crisis variable and county fixed effects are included, it is highly significant and positive (2.385). Including year fixed effects in R2, the coefficient for the crisis variable drops to

0.443. Including more control variables (GDP and FDI) on top of R2, the coefficient declines to 0.423 in R3. When controlling for county-specific time trends in R4, the coefficient increases to 0.583.

Table 6 repeats Table 4, replacing the dependent variable with the share of professional and technical personnel in the total population. Because the provincial yearbook did not report this variable until 1995, the sample period for the regressions in this table covers 1995–2008 and contains fewer observations than in Table 4. The coefficient for the crisis variable is significant in each of the four specifications. In R3 (a two-way fixed-effect model with GDP and FDI as controls), the highly significant coefficient for the crisis variable indicates that one occurrence of crisis would boost the share of professional and technical staff by 33 percent (=exp(0.286)*100-100).

There is a concern about potential recall errors of the crisis variable. As a robustness check, we also searched Baidu, a Chinese search engine, by combining cluster names with some keywords, such as bankruptcy, layoff, and drop in sales, to define an alternative crisis variable. However, this approach may miss some important crises, as not all the crises were covered by the media. As shown in Table A1 in the appendix, which repeats R3 in Tables 4-6, the results are robust to the alternative crisis measure.

There is a concern about spurious correlations between the crisis variable and the outcome variables. One way to deal with the potential common trend problem between the accumulative crisis variable and the outcome variables is to define the crisis variable as a dummy variable as follows: the value is 1 if there is a crisis in time *t* or time *t*-1 and 0 otherwise. Table 7 reports the regression results using the newly defined dummy variable. For each outcome variable, in the first regression, a dummy variable indicating a crisis in year *t* is included. In the second regression, we replace the current dummy variable with the lagged crisis dummy. In the third specification, the current and lagged dummy variables are simultaneously included. The coefficient for the dummy variable is positive in all nine regressions. It is statistically significant in six regressions on the number of patents and number of quality certifications, regardless of whether the current or lagged dummy variable is separately or jointly included.

In the case that a county has more than three clusters, we kept only the top three clusters in our sampling list in the above analysis. This may result in some sample selection bias. To remedy this concern, we ran two robustness checks, which are reported in Table 8. First, panel A shows the results for only the counties with one cluster in our sample. The counties are more comparable in this subsample. With this restriction, the number of observations drops by nearly half. The coefficient for the crisis variable is positive in all three regressions and statistically significant in two of the three regressions. Second, we include the number of clusters in a county as a control variable on top of R3 in Tables 4 to 6 and report the results in Table 8, panel B. The coefficient for the crisis variable closely resembles that corresponding to R3 across Tables 4 to 6.

Despite various robustness checks, there may still be concern about a potential endogeneity problem with the crisis variable. We use the lagged share of the average export tariff in GDP at the county level as an instrumental variable for the crisis variable. As the export tariff drops, an export-oriented cluster will export more. The massive imports of Chinese products will likely collide with local competitors in the destination countries. In response, destination countries may launch retaliatory measures toward Chinse exports, sending a demand shockwave back to the clusters in China.

As the United States is China's largest trading partner, we use the U.S. tariff rate on Chinese manufactured products during 1990–2008, obtained from the World Bank trade database, to compute the average tariff rate at the two-digit level. However, the two-digit industry level data at the county level are only available for 1995 and 2004, when the China Industrial Census and China Economic Census were conducted. As a second best, for 1990–2000 and 2001–2008, we use the share of gross output value of each two-digit industry in total gross industrial output value at the county level in 1995 and 2004, respectively, as the weights for computing the average tariff rate at the county level. The average tariff rate should matter more in areas where exports account for a larger share of the local economy. Therefore, we use the share of the average tariff rate in local GDP as an instrument variable. Table A2 presents the first-stage instrumental variable regression and two-stage least squares estimates. As shown in panel B, the instrumental variable is highly significant, and the F-test values in the regressions for the three outcome variables are, respectively, 27.16, 8.42, and 16.97, which are reasonably large. In the second-stage regression, the crisis variable is statistically significant and positive in all three regressions, as indicated in Table A2, panel A.

4.2. Event Studies

The regressions in subsection 4.1 consider only the average effect of crisis. In this subsection, we use the following event study to examine the effect of crisis over time.

$$Q_{it} = \alpha_k \sum_{k=-6}^{6} D_{i,k} + \beta X_{it} + Year_t + County_i + \epsilon_{it} \quad (6)$$

where Q_{it} stands for one of the three quality variables in county i and year t. To visualize the impact of crisis, we allow the dummy variable to change every three years. The three-year window is marked as k, with negative and positive values implying the periods before and after a crisis, respectively. α_k is the key coefficient of interest in relation to the timing of crisis. Other control variables are the same as in equation (5).

Figure 4 plots the coefficient α_k corresponding to the three outcome variables. For all three quality-upgrading variables, the coefficient is not significantly different from zero prior to a shock. After a crisis, the effect increases over time and turns statistically significant after two or three periods. Thus, crises seem to have a long-term impact on firms' quality upgrading.

To examine the impacts of demand-side and supply-side shocks, we repeat the event study separately for the two types of shocks and plot the coefficient α_k in Figure A1. For both types of shocks, the pre-crisis coefficient is negative or close to zero in regressions on all three outcome variables. The post-crisis coefficient for the three outcome variables is generally positive, although it is not always statistically significant. The distinction between demand-side shocks and supply-side shocks is minimal.

Our theoretical model predicts that low-quality firms would upgrade quality after a crisis. However, there is a possibility that the improvement in product quality is due to the exit of low-quality firms. Using firm exit data from the China Business Registration Database, which is maintained by the State Administration of Industry and Commerce, we check whether the numbers of existing, new, and existing firms are associated with the occurrence of crisis by employing the same event study specification. As is shown in Figure A2, crisis has little to do with firm dynamics.

5. Conclusion

The quality of products manufactured in China has improved significantly in the past several decades. In this study, we aimed to understand the mechanism of the quality-upgrading process. Crises reshape entrepreneurs' and local governments' perceptions of the payoffs and costs of quality upgrading. When facing a harsh external environment, the public and private sectors are more likely to take collective action to improve product quality. Using data from 85 industrial clusters in Zhejiang province, we empirically examined the impact of crises on the quality-upgrading process. We found that the number of patents, the number of enterprises with quality certification, and the share of professional and technical staff in the clusters all show a significant increase after a crisis. Therefore, crises imply an opportunity for upgrading product quality in clusters.

However, the positive correlation between crises and quality upgrades does not mean that crises would automatically solve all the quality problems. It is only when crises are successfully addressed that they can become a catalyst for institutional change.

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Table 1 Distribution of industrial clusters in Zhejiang province

Sector	Number of clusters	Gross industrial output value (hundred million, Chinese yuan)	Ratio of gross industrial output value of all manufacturing clusters (%)		Sector	No. of clusters	Gross industrial output value (hundred million, Chinese yuan)	Ratio of gross industrial output value of all manufacturing clusters (%)
Processing of food from agricultural products	25	281.8	1.8		Manufacture of textile wearing apparel, footwear, and caps	44	760.1	4.9
Manufacture of foods	6	50.5	0.3		Manufacture of leather, fur, feather, and related products	20	680.8	4.4
Manufacture of beverages	10	59.2	0.4		Processing of timber; manufacture of wood, bamboo, rattan, palm, and straw products	18	165.6	1.1
Manufacture of textiles	56	2,669.6	17.3		Printing, reproduction of recording media	32	184.1	1.2
Manufacture of furniture	11	90.7	0.6		Manufacture of articles for culture, education, and sports activities	18	182.8	1.2
Manufacture of paper and paper products	45	396.6	2.6		Manufacture of raw chemical materials and chemical products	51	988.6	6.4
Manufacture of medicines	1	40.9	0.3		Smelting and pressing of ferrous metals	6	93.5	0.6
Manufacture of chemical fibers	4	306.8	2		Smelting and pressing of nonferrous metals	15	293.6	1.9
Manufacture of rubber	13	80	0.5		Manufacture of electrical machinery and equipment	51	1595	10.3
Manufacture of plastics	58	854.2	5.5		Manufacture of communication equipment, computers, and other electronic equipment	22	672	4.3
Manufacture of nonmetallic mineral products	58	624.4	4		Manufacture of measuring instruments and machinery for cultural activity and office work	18	181.4	1.2
Manufacture of metal products	57	748.9	4.8		Manufacture of artwork and other manufacturing	36	323.8	2.1
Manufacture of general purpose machinery	68	1,660.2	10.7		Recycling and disposal of waste	3	28.9	0.2
Manufacture of special purpose machinery	47	474.4	3.1		Manufacture of transport equipment	46	986.3	6.4

Source: Zhejiang Manufacturing Cluster Empirical Research Group (2007).

Table 2 Major crises in Zhejiang clusters

Year	Crises by type					Total
	Quality crisis	Export barriers	Macro policy	Factor price	Accidents and others	
1990	2	0	0	0	0	2
1992	0	0	1	0	0	1
1995	3	0	0	0	0	3
1996	1	0	0	0	0	1
1997	1	0	0	0	0	1
1998	1	0	0	1	0	2
1999	1	0	0	0	0	1
2001	2	0	0	0	0	2
2002	0	0	1	1	0	2
2003	0	0	0	1	1	2
2004	1	0	4	2	2	9
2005	3	6	3	3	0	15
2006	0	1	0	2	1	4
2007	0	1	1	1	1	4
2008	1	2	1	0	0	4
Total	16	10	11	11	5	53

Note: The table reports the number of crises by type and year. The financial crisis in 2008 was not included, as it affected all clusters.

Table 3 Descriptive statistics of key variables

Variable	No.	Mean	SD	Min	Max
Patents per 10,000 people (log)	1,314	-0.14	1.38	-3.94	4.10
Number of enterprises with quality certifications (log)	730	1.27	1.68	0.00	6.57
Share of professional and technical personnel in total population (log)	1,021	-3.78	0.65	-5.57	-1.66
Lagged crisis	1,314	0.19	0.48	0.00	3.00
Lagged per capita gross domestic product (log) (10,000 yuan)	1,314	-0.17	1.00	-2.87	5.55
Lagged per capita foreign direct investment (log) (US dollars)	1,314	1.85	2.60	-4.81	6.76

Source: The numbers of approved patents come from the National Intellectual Property Office (http://search.sipo.gov.cn/). The numbers of enterprises with quality certifications are from the Zhejiang Quality and Technology Supervision Office. The numbers of professional and technical personnel, per capita gross domestic product, and per capita foreign direct investment are obtained from *Zhejiang Statistical* (China National Bureau of Statistics, various years). “Crisis” is defined as the total number of accumulative crises that county *i* has encountered by time *t*.

Table 4 Crises and number of patents

	Patents per capita (logarithm)			
	R1	R2	R3	R4
Lagged crisis	1.552***	0.469***	0.432***	0.375***
	(0.138)	(0.127)	(0.122)	(0.100)
Lagged per capita GDP (log)			0.267	-0.235***
			(0.305)	(0.089)
Lagged per capita foreign direct investment (log)			0.039*	-0.039**
			(0.020)	(0.016)
County fixed effect	YES	YES	YES	NO
Year fixed effect	NO	YES	YES	NO
County fixed effect * Time	NO	NO	NO	YES
Adj-R^2	0.52	0.82	0.83	0.87
AIC	3,546.69	2,233.92	2,212.08	1,724.87
Number of observations	1,314	1,314	1,314	1,314

Note: The sample period is from 1990 to 2008. Time = year – 1990. Standard errors clustered at the county level are in parentheses. The symbols *, **, and *** represent significance levels at 10%, 5%, and 1%, respectively.

Table 5 Crises and number of quality certifications

	Number of enterprises with quality certifications (logarithm)			
	R1	R2	R3	R4
Lagged crisis	2.385***	0.443***	0.423***	0.583***
	(0.242)	(0.109)	(0.108)	(0.191)
Lagged per capita GDP (log)			0.509	4.393***
			(0.513)	(0.687)
Lagged per capita foreign direct investment (log)			-0.019	0.116***
			(0.031)	(0.036)
County fixed effect	YES	YES	YES	NO
Year fixed effect	NO	YES	YES	NO
County fixed effect * Time	NO	NO	NO	YES
Adj-R^2	0.20	0.86	0.86	0.86
AIC	2,583.18	1,339.44	1,338.62	1,243.00
Number of observations	730	730	730	730

Note: The sample period is from 1997 to 2006. Time = year – 1997. Standard errors clustered at the county level are in parentheses. The symbols *, **, and *** represent significance levels at 10%, 5%, and 1%, respectively.

Table 6 Crises and the share of professional and technical personnel in total population

	Share of professional and technical personnel in total population (logarithm)			
	R1	R2	R3	R4
Lagged crisis	0.680***	0.315***	0.286***	0.160**
	(0.078)	(0.083)	(0.082)	(0.064)
Lagged per capita GDP (log)			0.556**	0.287*
			(0.234)	(0.146)
Lagged per capita foreign direct investment (log)			0.023	0.022
			(0.017)	(0.013)
County fixed effect	YES	YES	YES	NO
Year fixed effect	NO	YES	YES	NO
County fixed effect * Time	NO	NO	NO	YES
Adj-R^2	0.53	0.70	0.71	0.82
AIC	1,187.40	729.49	695.05	141.94
Number of observations	1,021	1,021	1,021	1,021

Note: The sample period is from 1995 to 2008. Time = year – 1995. Standard errors clustered at the county level are in parentheses. The symbols *, **, and *** represent significance levels at 10%, 5%, and 1%, respectively.

Table 7 Robustness check: Defining crisis as a dummy variable

	Number of patents			Number of certifications			Number of professional and technical staff		
	R1	R2	R3	R4	R5	R6	R7	R8	R9
Crisis_new	0.185**		0.203**	0.354**		0.353**	0.05		0.051
	(0.093)		(0.081)	(0.134)		(0.134)	(0.077)		(0.077)
Lagged Crisis_new		0.244**	0.242**		0.381***	0.380***		0.096	0.097
		(0.102)	(0.095)		(0.142)	(0.135)		(0.088)	(0.088)
Lagged per capita GDP (log)	0.398***	0.35	0.343	0.591	0.593	0.55	0.673***	0.671***	0.667***
	(0.070)	(0.354)	(0.351)	(0.529)	(0.524)	(0.517)	(0.247)	(0.245)	(0.244)
Lagged per capita Foreign direct investment (log)	0.049***	0.044**	0.044**	-0.022	-0.018	-0.019	0.024	0.024	0.024
	(0.014)	(0.021)	(0.021)	(0.031)	(0.031)	(0.030)	(0.018)	(0.018)	(0.018)
County fixed effect	YES	YES	YES	YES	YES	YES	YES	YES	YES
Year fixed effect	YES	YES	YES	YES	YES	YES	YES	YES	YES
Adj-R^2	0.82	0.82	0.82	0.85	0.85	0.86	0.69	0.69	0.69
AIC	2,591.52	2,281.14	2,278.10	1,352.44	1,351.93	1,344.74	767.08	765.18	766.38
Number of observations	1,387	1,314	1,314	730	730	730	1,021	1,021	1,021

Note: The crisis variable is defined as 1 if there is a crisis in year *t* and 0 otherwise. Standard errors clustered at the county level are in parentheses. The symbols *, **, and *** represent significance levels at 10%, 5%, and 1%, respectively.

Table 8 Robustness test: Controlling the number of clusters in a county

Panel A	Select counties with only one cluster		
	Number of patents	Number of certifications	Number of professional and technical staff
Lagged Crises	0.387	0.966***	0.318*
	(0.315)	(0.187)	(0.167)
County fixed effect	YES	YES	YES
Year fixed effect	YES	YES	YES
Adj-R^2	0.77	0.82	0.64
AIC	1,236.72	611.86	106.52
Number of observations	684	380	531
Panel B	Control the number of clusters in a county		
	Number of patents	Number of certifications	Number of professional and technical staff
Lagged Crises	0.432***	0.423***	0.286***
	(0.122)	(0.108)	(0.082)
County fixed effect	YES	YES	YES
Year fixed effect	YES	YES	YES
Total number of clusters	YES	YES	YES
Adj-R^2	0.83	0.86	0.71
AIC	2,212.08	1,338.62	695.05
Number of observations	1,314	730	1,021

Note: The lagged per capita gross domestic product, lagged per capita foreign direct investment, and lagged exports are controlled in all regressions. To save space, the results for these variables are not reported. Standard errors clustered at the county level are in parentheses. The symbols *, **, and *** represent significance levels at 10%, 5%, and 1%, respectively.

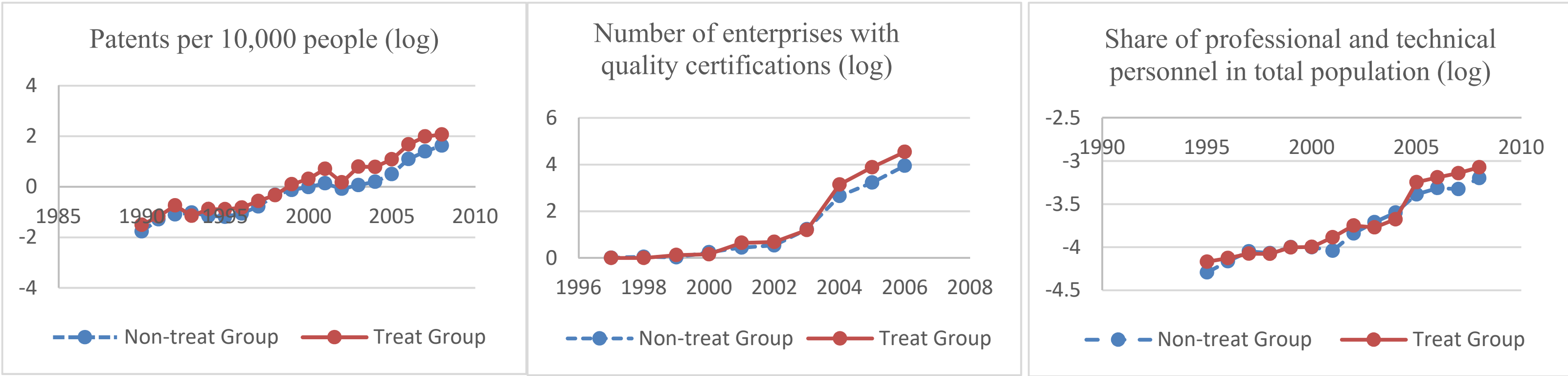

Figure 1 Three quality measures between the treatment and control groups

Note: Given the high concentration of shocks in 2004 and 2005, we define the treatment group as counties that were subject to shocks in 2004/2005 and the control group as counties that never experienced shocks in the whole sample period. Prior to 2004, the *p*-value of the t-test for patents, certifications, and professional/technical personnel between the two groups is respectively 0.1552, 0.4366, and 0.3252. None of them is statistically significant. The two groups had rather parallel trends prior to 2004. After 2004, the *p*-value of the t-test for the three outcome variables is, respectively, 0.0852, 0.1756, and 0.0187.

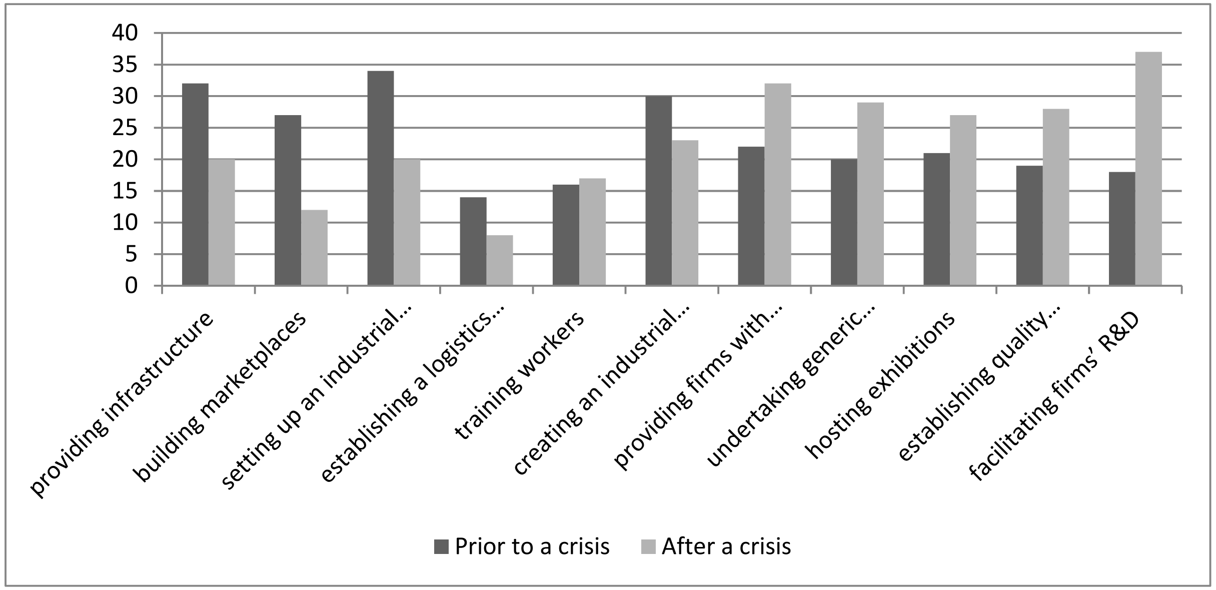

Figure 2 Major local industrial polices prior to and after a crisis

Source: Authors' surveys.

Note: In the field surveys, we asked informants (normally heads of business associations or leaders in charge of industrial policy) whether there were any major crises in the local clusters. If yes, then we further enquired about the major policies before and after a crisis. For clusters that never experienced a crisis, we asked the informants about the major supporting policies. For this subsample, it is impossible to compare policy changes in relation to crises. In this figure, we focus only on the subsample of clusters that were subject to crises during the period. In so doing, we can compare major policies before and after a crisis.

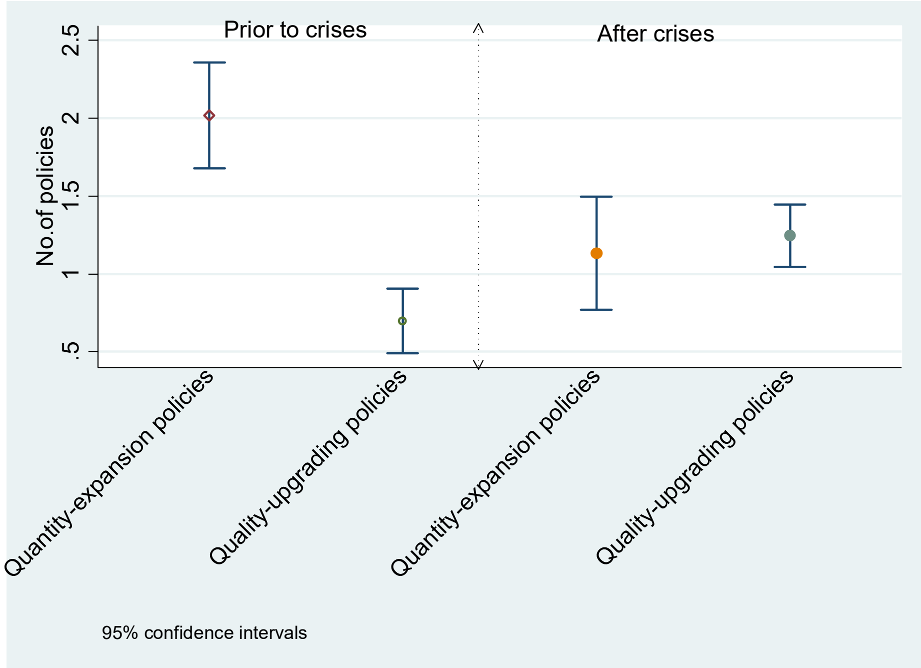

Figure 3 Number of quantity-expansion policies and quality-upgrading policies prior to and after a crisis

Note: Only the clusters that were subject to crises during the period are included in the figure. Quantity-expansion policies include providing infrastructure, building marketplaces, setting up an industrial park, and establishing a logistics center. Establishing quality inspection centers and facilitating firms' research and development are defined as quality-upgrading policies. The vertical line corresponding to each policy represents the 95% confidence interval.

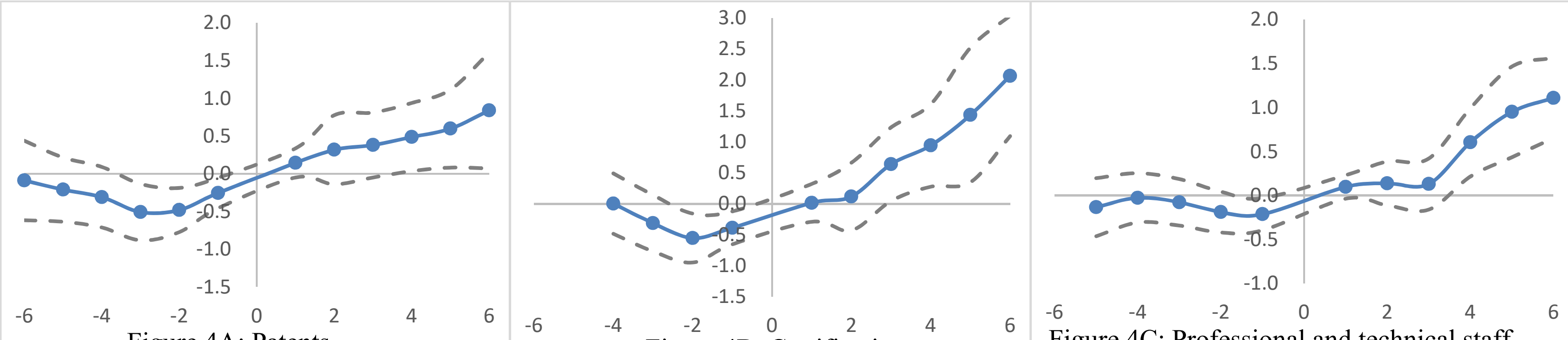

Figure 4A: Patents

Figure 4B: Certifications

Figure 4C: Professional and technical staff

Figure 4 Event study

Note: The figure plots α_k of equation (5) in relation to the timing of crisis. Each unit on the horizontal line represents a three-year window. The dotted line represents the 95% confidence interval.

Appendix A Tables and Figures

Table A1 Robustness test: Alternative crisis measures based on internet search

	Number of patents	Number of certifications	Number of professional and technical staff
	R1	R2	R3
Lagged crisis_other	0.370***	0.612***	0.384***
	(0.127)	(0.152)	(0.092)
Lagged per capita GDP (log)	0.319	0.621	0.646***
	(0.336)	(0.518)	(0.228)
Lagged per capita foreign direct investment (log)	0.042**	-0.019	0.024
	(0.020)	(0.030)	(0.016)
County fixed effect	YES	YES	YES
Year fixed effect	YES	YES	YES
Adj-R^2	0.82	0.86	0.71
AIC	2,259.83	1,330.33	696.41
Number of observations	1,314	730	1,021

Note: We searched Baidu, a Chinese search engine, by using cluster names in combination with some keywords, such as bankruptcy, layoff, and drop in sales, to define an alternative crisis variable. The regressions in this table are based on this alternative crisis measure. Standard errors clustered at the county level are in parentheses. The symbols *, **, and *** represent significance levels at 10%, 5%, and 1%, respectively.

Table A2 Instrumental variable regressions

	Number of patents	Number of certifications	Number of professional and technical staff
	R1	R2	R3
	A. 2SLS estimates		
Lagged crisis	1.968***	5.799***	2.193***
	(0.438)	(1.915)	(0.510)
Lagged per capita GDP (log)	-0.05	-1.084	-0.261
	(0.126)	(0.831)	(0.298)
Lagged per capita foreign direct investment (log)	0.022	0.017	0.015
	(0.018)	(0.056)	(0.021)
Number of observations	1,314	730	1,021
Anderson canon. corr. P-value	0.000	0.002	0.000
Cragg-Donald Wald F statistic	27.16	8.42	16.97
	B. First-stage estimates		
Lagged export tariff in GDP	0.163***	0.125***	0.149***
	(0.031)	(0.043)	(0.036)
Lagged per capita GDP (log)	0.194***	0.299***	0.412***
	(0.039)	(0.109)	(0.097)
Lagged per capita foreign direct investment (log)	0.008	-0.009	0.001
	(0.008)	(0.010)	(0.010)
Adj-R^2	0.57	0.68	0.62
Number of observations	1,314	730	1,021

Note: Year and county fixed effects are controlled in all regressions. Lagged export tariff in GDP = Lagged Export tariff * Lagged (Export/GDP). Standard errors clustered at the county level are in parentheses. The symbols *, **, and *** represent significance levels at 10%, 5%, and 1%, respectively.

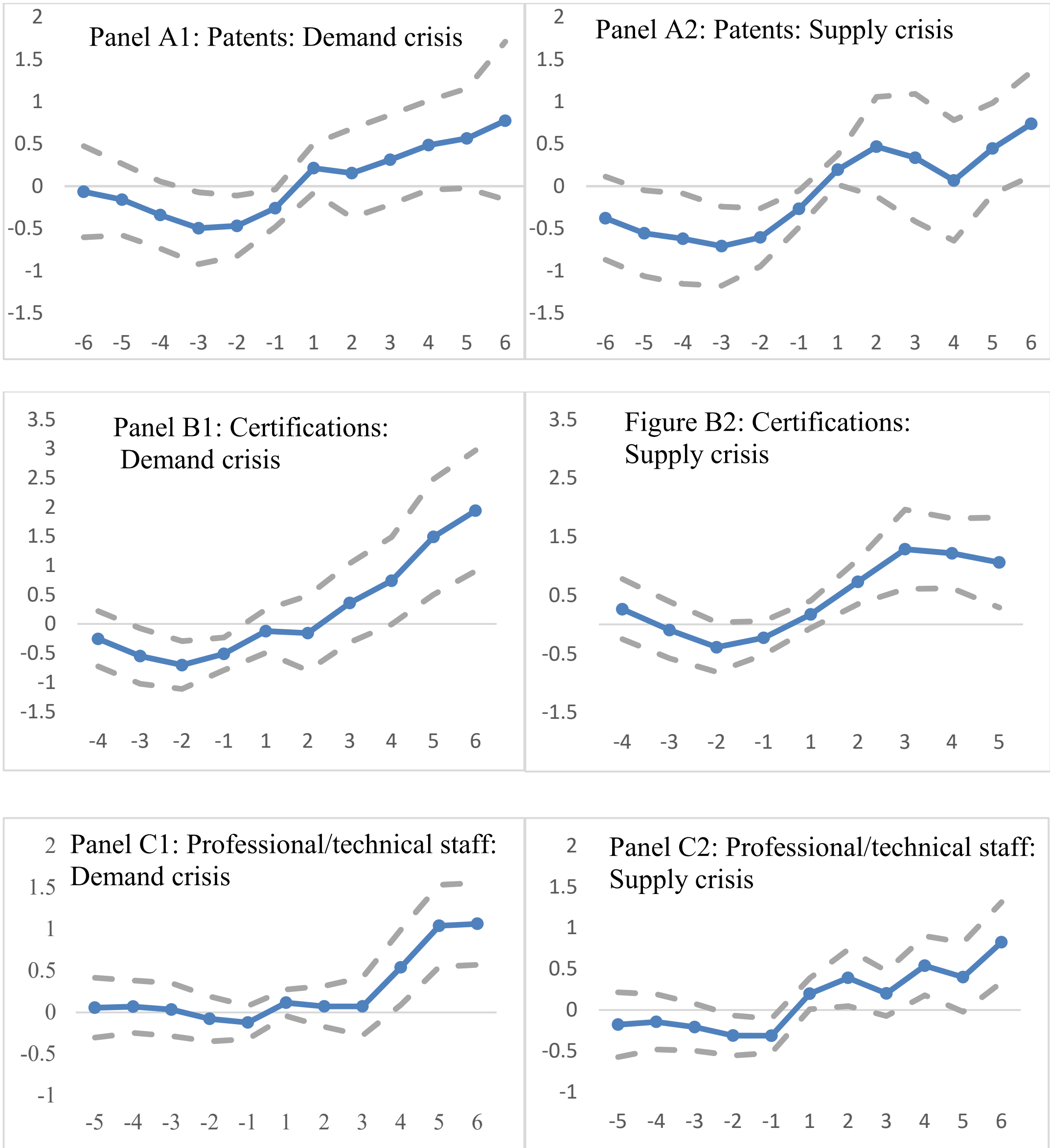

Figure A1: Event study for demand-side and supply-side shocks

Note: The event study follows equation (5). The demand-side shocks include crises that depress demand, such as consumer boycotts and export barriers. The shocks related to change in factor prices (such as wage, land, energy, and other raw material prices), macro policy and regulations by the central government, and accidents (such as fires and explosions) are counted as supply-side shocks, because they primarily affect the cost of production.

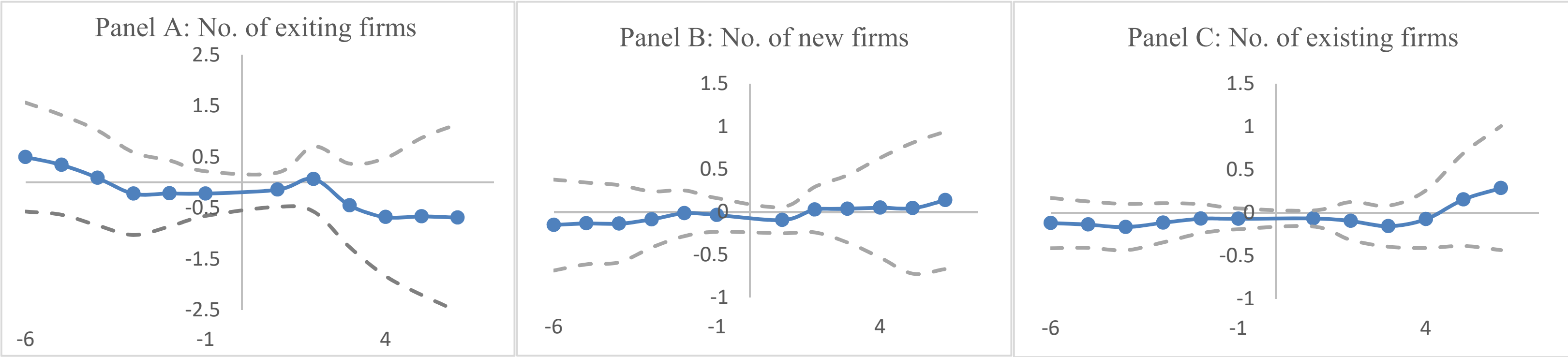

Figure A2 Event study of the impact of crisis on firms

Note: The data come from the business registration database maintained by the State Administration for Industrial and Commerce in China. The specification follows equation (5).

Appendix B Proofs

B1. Proof of Lemma 1

Proof: First, (2) and (3) are obtained from the first-order conditions of the profit maximization problem. For (1), we first denote $\varepsilon_i(u)$ as a consumer's reservation match value for a firm of type i when the consumer holds reservation utility u. $\varepsilon_i(u)$ is given by

$$\varepsilon_i(u) = p_i + u - v_i.$$

The consumer will buy the product with quality i if $\varepsilon \geq \varepsilon_i(u)$. Therefore, u is defined by:

$$\mu \int_{\varepsilon_h}^{k} \big(\varepsilon - \varepsilon_h(u)\big) f(\varepsilon) d\varepsilon + (1-\mu) \int_{-k}^{+\infty} \big(\varepsilon - \varepsilon_l(u)\big) f(\varepsilon) d\varepsilon = s, \qquad \text{(a)}$$

where $f(\varepsilon) = \frac{1}{2k}$ is the PDF of ε. Plugging (2) and (3) into (a), we can derive (1).■

B2. Proof of Lemma 2

Proof: It is straightforward to derive $\Pi_h = (p_h^* - c_h)^2 M$ and $\Pi_l = (p_l^* - c_l)^2 M$. Hence, $\Pi_h > \Pi_l$ if $p_h^* - c_h > p_l^* - c_l$. From (2) and (3), $p_l^* - c_l = \frac{k-u^*+v_l-c_l}{2}$ and $p_h^* - c_h = \frac{k-u^*+v_h-c_h}{2}$. Hence, $\Pi_h > \Pi_l$ $v_h - c_h > v_l - c_l$.

B3. Proof of Proposition 1

Proof: First, Fishman and Levy (2015) have shown that if k is sufficiently large, then

$$\frac{\partial}{\partial \mu}[\Pi_h - \Pi_l] < 0$$

for all μ (Lemma 2 in the Appendix of their paper). In other words, a sufficiently large k is a sufficient condition (but not a necessary condition) to guarantee that the incentive of firms to upgrade quality decreases as the number of high-quality firms increases in the market. The intuition is as follows. The incentive of firms to upgrade quality depends on the potential profit from producing high-quality products. When there are more high-quality firms in the market, on the one hand, the competition among the high-quality firms becomes more intense, reducing the profit margin of high-quality firms. The depressed profit will discourage firms from upgrading and we call this the competition effect. On the other hand, as there are more high-quality firms in the market, a consumer will expect that she can achieve a higher surplus when searching in the market, because she is more likely to encounter high-quality firms and a high-quality product always brings about a higher surplus. This implies that she is less likely to buy a product from a low-quality firm, from which she is more likely to derive a utility that is lower than her expectation. Therefore, the demand of a low-quality firm shrinks and the demand of a high-quality firm increases. We call this the quantity effect, which encourages firms to upgrade. Which effect dominates largely depends on the number of varieties in the market, and the quantity effect turns out to be dominated by the competition effect when the number of varieties in the market is large.

We use the following example to illustrate why the quantity effect is small when there are more varieties. Suppose there is a cap cluster. A consumer prefers red-color caps to those of other colors, such as white or black, holding everything else (such as quality) the same. In the first case, the market has only white-color caps. Due to lack of a choice of her favorite red cap, she desires to find a high-quality cap instead of a cap of her favorite color (since it is not available). In other words, in the face of very limited varieties, consumers may be induced to buy more high-quality products when they are more readily available. In this case, the quantity effect is large.

Now consider the second scenario that there are red and white caps in the cluster. Since the consumer favors red, she may still grab a low-quality red cap when walking in the market, regardless of the quality of the white cap. In this case, there is little increase in demand for the high-quality white caps when there are more white caps for sale in the market. Therefore, the quantity effect is small, and the increase in number of high-quality firms producing white caps will cause more intense competition among themselves, driving down profit, which in turn discourages them from further upgrading quality.

Because $\Pi_h - \Pi_l$ decreases in μ, $\Pi_h(\mu) - \Pi_l(\mu) - \phi - I'(\mu)$ also decreases in μ. In equilibrium, $\hat{\mu}^*(\mu^*) = \mu^*$. If $\phi \in \left(\Pi_h(1) - \Pi_l(1) - I'(1), \Pi_h(0) - \Pi_l(0)\right)$, then there exists $\mu^* \in (0,1)$ satisfying $\Pi_h(\mu^*) - \Pi_l(\mu^*) - \phi - I'(\mu^*) = 0$. This implies that, given $\mu^* \in (0,1)$, a firm's optimal choice is $\hat{\mu}^*(\mu^*) = \mu^*$. If $\phi \geq \Pi_h(0) - \Pi_l(0)$, then for all μ, $\hat{\mu}^*(\mu) = 0$, such that $\mu^* = 0$ is an equilibrium outcome. If $\phi \leq \Pi_h(1) - \Pi_l(1) - I'(1)$, then for all μ, $\hat{\mu}^*(\mu) = 1$, such that $\mu^* = 1$ in equilibrium.

B4. Proof of Proposition 2

First, according to (1) to (3), we can derive the following lemma.

Lemma A1:

(1) $\frac{\partial u^*(\mu; v_h, v_l, c_h, c_l)}{\partial v_l} \in (0,1)$, $\frac{\partial p_h^*(\mu; v_h, v_l, c_h, c_l)}{\partial v_l} < 0$, *and* $\frac{\partial p_l^*(\mu; v_h, v_l, c_h, c_l)}{\partial v_l} > 0$.

(2) $\frac{\partial u^*(\mu; v_h, v_l, c_h, c_l)}{\partial c_l} \in (-1,0)$, $\frac{\partial p_h^*(\mu; v_h, v_l, c_h, c_l)}{\partial c_l} > 0$, *and* $\frac{\partial p_l^*(\mu; v_h, v_l, c_h, c_l)}{\partial c_l} < 1$.

Proof: Consider equation (1), i.e.,

$$2ks = \mu \int_{\frac{k+u^*-v_h+c_h}{2}}^{k} \left[\varepsilon - \frac{k + u^* - v_h + c_h}{2}\right] d\varepsilon$$

$$+ (1-\mu) \int_{\frac{k+u^*-v_l+c_l}{2}}^{k} \left[\varepsilon - \frac{k + u^* - v_l + c_l}{2}\right] d\varepsilon,$$

by which u^* is uniquely determined. From the Implicit Function Theorem, it is straightforward to derive

$$\frac{\partial u^*(\mu; v_h, v_l, c_h, c_l)}{\partial v_l} > 0, \frac{\partial u^*(\mu; v_h, v_l, c_h, c_l)}{\partial c_l} < 0.$$

In addition, since $\frac{\partial u^*(\mu; v_h, v_l, c_h, c_l)}{\partial v_l} > 0$, as v_l increases, the first part of the right-hand-side expression, $\mu \int_{\frac{k+u^*-v_h+c_h}{2}}^{k} \left[\varepsilon - \frac{k+u^*-v_h+c_h}{2}\right] d\varepsilon$, decreases because u^*increases. Hence, to keep the equality, the second part of the right-hand-side expression, $(1-\mu) \int_{\frac{k+u^*-v_l+c_l}{2}}^{k} \left[\varepsilon - \frac{k+u^*-v_l+c_l}{2}\right] d\varepsilon$, must increase, implying that $u^* - v_l$ decreases. Therefore,

$$\frac{\partial u^*(\mu; v_h, v_l, c_h, c_l)}{\partial v_l} < 1.$$

By similar logic one can show $\frac{\partial u^*(\mu; v_h, v_l, c_h, c_l)}{\partial c_l} > -1$.

Moreover, because

$$p_l^* = \frac{k - u^* + v_l + c_l}{2},$$
$$p_h^* = \frac{k - u^* + v_h + c_h}{2},$$

it is straightforward to derive the other results listed in the lemma. ■

Suppose $\mu^* = \hat{\mu}^*$. Because $\Pi_h(\mu^*) - \Pi_l(\mu^*) - \phi - I'(\mu^*) = 0$,

$$\frac{\partial \mu^*}{\partial v_l} = -\frac{\frac{\partial}{\partial v_l}[\Pi_h - \Pi_l]}{\frac{\partial}{\partial \mu^*}[\Pi_h - \Pi_l] - I''(\mu^*)}.$$

Note that for any μ ,

$$\Pi_h = \frac{(p_h^*(\mu; v_h, v_l, c_h, c_l) - c_h)^2}{\mu[(p_h^*(\mu; v_h, v_l, c_h, c_l) - c_h)] + (1-\mu)(p_l^*(\mu; v_h, v_l, c_h, c_l) - c_l)}$$
$$= \frac{p_h^*(\mu; v_h, v_l, c_h, c_l) - c_h}{\mu + (1-\mu)\dfrac{p_l^*(\mu; v_h, v_l, c_h, c_l) - c_l}{p_h^*(\mu; v_h, v_l, c_h, c_l) - c_h}}$$
$$\Pi_l = \frac{(p_l^*(\mu; v_h, v_l, c_h, c_l) - c_l)^2}{\mu[(p_h^*(\mu; v_h, v_l, c_h, c_l) - c_h)] + (1-\mu)(p_l^*(\mu; v_h, v_l, c_h, c_l) - c_l)}$$
$$= \frac{p_l^*(\mu; v_h, v_l, c_h, c_l) - c_l}{\mu\dfrac{p_h^*(\mu; v_h, v_l, c_h, c_l) - c_h}{p_l^*(\mu; v_h, v_l, c_h, c_l) - c_l} + (1-\mu)}$$

Π_h increases as $p_h^*(\mu; v_h, v_l, c_h, c_l) - c_h$ is higher or $p_l^*(\mu; v_h, v_l, c_h, c_l) - c_l$ is lower, while Π_l increases as $p_l^*(\mu; v_h, v_l, c_h, c_l) - c_l$ is higher or $p_h^*(\mu; v_h, v_l, c_h, c_l) - c_h$ is lower. Hence, according to the previous lemma, it is straightforward to derive

$$\frac{\partial}{\partial v_l}[\Pi_h - \Pi_l] < 0 \; and \; \frac{\partial}{\partial c_l}[\Pi_h - \Pi_l] > 0.$$

Fishman and Levy (2015) have shown that if k is sufficiently large, then

$$\frac{\partial}{\partial \mu}[\Pi_h - \Pi_l] < 0$$

for all μ (Lemma 2 in the Appendix of their paper). Therefore, $\frac{\partial \mu^*}{\partial v_l} < 0$ and $\frac{\partial \mu^*}{\partial c_l} > 0$.

B5. Proof of Proposition 3

Proof: We have shown that

$$\frac{\partial[\Pi_h - \Pi_l]}{\partial v_l} < 0.$$

Therefore, $\Pi_h(0; v_l) - \Pi_l(0; v_l) < \Pi_h(0; v_l^{'}) - \Pi_l(0; v_l^{'})$ since $v_l^{'} < v_l$. For

$$\phi \in \left[\Pi_h(0; v_l) - \Pi_l(0; v_l), \Pi_h(0; v_l^{'}) - \Pi_l(0; v_l^{'})\right),$$

since $\phi \geq \Pi_h(0; v_l) - \Pi_l(0; v_l)$, $\mu^* = 0$ at v_l according to Proposition 1. Moreover, since $\phi \leq \Pi_h(0; v_l^{'}) - \Pi_l(0; v_l^{'})$, $\mu^* = 0$ is no longer an equilibrium outcome at $v_l^{'}$.

Similarly, note that

$$\frac{\partial[\Pi_h - \Pi_l]}{\partial c_l} > 0.$$

The proof for the c_l part follows similar steps as above.

B6. Proof of Proposition 4

Proof: Suppose $\phi \geq \Pi_h(0; v_l, c_l) - \Pi_l(0; v_l, c_l)$ at (v_l, c_l), such that $\mu^* = 0$ at (v_l, c_l). At (v_l, c_l), if the government invests in the public good, then it will induce a proportion of $\mu_0^*(v_l)$ of the high-quality firms. Note that if the government invests, then $\phi = 0$ and $\mu_0^*(v_l) > 0$ in equilibrium. In this case, the government will not invest if $W(\mu_0^*(v_l)) < G$.

Then consider a moderate crisis in demand in which v_l drops to $v_l^{'}$ but the low-quality firms still conduct business after the shock. Suppose $\phi \geq \Pi_h(0; v_l^{'}, c_l) - \Pi_l(0; v_l^{'}, c_l)$ such that the firmswill not upgrade after the shock without any government investment in quality-enhancing public goods. If the government makes the investment, let $\mu_0^*(v_l^{'})$ be the equilibrium outcome. By Proposition 1, $\frac{\partial \mu^*}{\partial v_l} < 0$. Hence, $\mu_0^*(v_l^{'}) > \mu_0^*(v_l)$. If $W(\mu_0^*(v_l)) < G < W\left(\mu_0^*(v_l^{'})\right)$, then the government will not invest at v_l, because $W(\mu_0^*(v_l))$, the government's utility of inducing $\mu_0^*(v_l)$, is lower than the cost. But the government will invest when v_l decreases to $v_l^{'}$, because now the investment will lead to a higher proportion of high-quality firms and a higher utility $W\left(\mu_0^*(v_l^{'})\right)$.

The proof for a moderate supply shock, i.e., the case in which c_l increases to $c_l^{'}$ but low-quality firms still survive, follows similar steps.