Information Frictions, Pro-Competitive Effects, and the Search for Quality*

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Abstract

We study the pro-competitive effects of reducing information frictions on product quality across space. To do so, we introduce monopolistic competition, heterogeneous firms, and quality upgrading into a sequential search model with trade (Allen, 2014). In our general equilibrium model, heterogeneous producers must search to learn about quality-augmented price index elsewhere and decide whether to compete in a specific destination based on the degree of local competition. Our model predicts that a fall in information frictions such as the building of ICT infrastructure (e.g., faster mobile networks) will lead to spatial penetration of cheaper and higher-quality products, enhance local competition, and induce quality upgrading. We qualitatively test the predictions of our model using unit value data and variation in ICT infrastructure across Chinese cities. We are currently calibrating the general equilibrium model to discuss its quantitative implications over welfare, and we are exploiting for more empirical evidences using China Custom data.

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1. Introduction

Goods are of inferior quality in remote locations. Two hypotheses may explain the persistence of low-quality products in secluded regions. First, high transportation costs or ice-berg trade costs in general prevent firms from upgrading their product quality, because they face poor market access and hence cannot afford to upgrade product quality which requires additional costs. This is often the focus of the studies on quality in the international trade literature. Second, perhaps less studied, information frictions may also prevent outside firms from competing in distant locations. Because it is costly for outside firms producing higher-quality goods to acquire information regarding the market conditions there, they may not enter and compete in such locations. As a result, lower-quality goods sold by local producers may survive and prevail in such markets.

In this paper, we study the latter hypothesis, that is how information frictions matter in determining quality of tradable products across space, through the lens of a sequential search model with trade (Allen, 2014). To do so, we introduce monopolistic competition, firm heterogeneity, and quality upgrading into Allen (2014). In our model, heterogeneous firms must search for market conditions elsewhere in order to decide whether to enter and compete in distant locations. As search is costly, firms hold a reservation strategy in that they will only enter a location if the market condition there is lucrative enough to recover the fixed cost of search. This is different from the setup in Melitz (2003), in which firms with constant marginal cost will always sell their goods to each destination. In particular, the reservation strategy of the firms is summarized by a reservation price index weighted by transportation cost. This index summarizes the market conditions of respective locations. A higher index would imply that the ideal price index in the region is high and hence a less competitive market either because the firms there are less productive or that the product quality there is lower. As such, firms stand to make a higher profit in such a destination.

We derive several key predictions from our model, given a positive search technology shock, such as building of Information and Communication Technology (ICT) infrastructures, that reduces the information frictions in searching for market conditions. First, as the fixed cost of search decreases, firms would hold a higher reservation price index. The intuition is that as the cost of search decreases, firms would want to search more intensively for a lucrative destination market. As such, firms are more likely to enter the least competitive regions which are usually remote locations. Second, as the fixed cost of search decreases, firms would upgrade the quality of their products. Intuitively, information frictions would restrict the extent of the market and hence the market access that firms have. The prospective profits of firms are restricted in the presence of higher search cost. With lower information frictions and larger market access, firms would be able to earn a higher profit and be able to afford costly quality upgrading. Third, a more productive firm would choose a higher reservation price index as well as a higher production quality. This is because a more productive firm can afford to search more intensively and pay the fixed costs for quality upgrading. As a result, they are more likely to enter less competitive regions and they specialize in higher-quality products.

Together, these qualitative results deliver some novel implications. Our model implies that decreasing information frictions would lead to more competition in previously less-competitive regions, and that this pattern is more pronounced for more productive firms. This is the pro-competitive effect that we want to capture in our analysis. Building of ICT infrastructure strengthens spatial competition because more productive firms would have more information about remote locations. Therefore their products have a higher chance to penetrate in those markets. In particular, these firms are not just more competitive in terms of their cost efficiency. They are also more competitive in the sense that the quality of their products are higher. Ceteris paribus, our paper implies that building of ICT infrastructure would result in spatial penetration of cheaper and higher-quality goods. In addition, firms across space would also upgrade their product quality because their market access is larger given the positive shock to information technology.

Thus, our model features two margins of gains from building ICT infrastructure and reducing information frictions. The first margin is an “extensive margin” in which cheaper or higher-quality products are being sold to more destinations that are previously less competitive. The second margin is an “intensive margin” such that as information technology gives firms a larger market access, they are also able to afford upgrading their production quality which benefits consumer welfare.

Next, we take the model to data and examine the empirical relevance of our theoretical predictions. We first examine one specific prediction that building of ICT infrastructure induces firms to upgrade product quality, through the lens of intra-national trade and spatial variation in ICT development across Chinese cities. Key to our empirical strategy are a set of stringent fixed effects that control for omitted variable bias and an alternative measure of “information access” that address for endogeneity concerns. In general, we find that proliferation of ICT infrastructure in the origin city which supposedly would have reduced information frictions lead to substantial quality upgrading behaviors by firms. The magnitude of the effects are such that doubling the ICT penetration would have induced firm to upgrade quality by 7%. This effect is twice larger if instead the overall ICT penetration across all destination markets are doubled. We are also currently exploiting an instrumental variable that is based on least cost algorithm to provide for further identification. To examine the other predictions on pro-competitive effects, we are now using the Chinese Custom data to provide such evidences.

The rest of the paper is organized as follows. Section 2 provides a brief literature review and discusses the contributions of our paper. Section 3 describes our model and discuss its implications. Section 4 takes the theoretical predictions into the data and qualitatively examines the empirical evidences. Section 5 concludes. In future work, we also plan to fully calibrate the general equilibrium and discuss the rich quantitative implications of our model.

2. Literature Review

Our work is relevant to two strands of literature. First, our paper contributes to the study of quality specialization in the international trade literature. Previous works have predominantly focused on how firm heterogeneity (Feenstra and Romalis, 2014; Antoniades, 2015; Fan et al., 2017) and non-homothetic demand (Hallak, 2010; Fajgelbaum et al., 2011, 2015; Dingel, 2017) interact with trade costs in shaping quality specialization across countries. Few of these literature, which are mostly based on general equilibrium frameworks, focus on how information frictions matter. Some exceptions include Chen and Wu (2016), Bai (2018), Bai et al. (2018), and Zhao (2018) which are mostly based on partial equilibrium structural estimations of an industry model and focus more on how asymmetric information affects the quality choice of consumers. Our work, which builds on the general equilibrium framework of Allen (2014), abstracts from asymmetric information and focuses on the supply-side effect that information frictions have on quality upgrading among heterogeneous firms. In particular, our work also studies the pro-competitive effect in the sense that reducing information frictions allows higher-quality firms to penetrate more markets and fosters competition across regions along the quality channel.

In addition, our paper contributes to the study of information frictions and economic activities across space. Prior works in this literature include Allen (2014), Eaton et al. (2014), Arkolakis et al. (2018), Eaton et al. (2018), Steinwender (2018), and Juhsz and Steinwender (2019). Our work directly builds on Allen (2014) and extends the model with quality upgrading of heterogeneous firms. We contribute to this literature in several dimensions. First, our work is capable of studying pro-competitive effect of reducing information frictions, regardless whether there is any quality upgrading. Previous works such as Allen (2014) only study the agricultural sector in perfectly competitive regional markets. Thus, any pro-competitive effect of lowering trade barriers is absent. By introducing monopolistic competition and heterogeneous firms into the model, we will be able to study the pro-competitive effect of reducing information frictions, and this is absent in the current literature to the best of our knowledge. Second, our work complements Allen (2014) in studying an additional quality margin of gains from reducing information frictions. This is important because quality upgrading behavior may not be reflected from changes in trade flows, which is what Allen (2014) focuses on. As such, welfare effects of eliminating information frictions may be understated if the quality margin is not accounted for. Our paper partly contributes to the understanding of this question.

3. The Model

In this section, we will lay down the foundation of our model and derive the critical comparative statics. Though we aim to build a general equilibrium model and calibrate the equilibrium, we will only take the equilibrium prices as given in this section, so that we can meaningfully discuss the predictions of the model. The model will be closed later in general equilibrium where we introduce clearing conditions in the goods and factor markets.

3.1 Consumers

We follow Allen (2014) and Lucas and Prescott (1974) to consider an economy with a continuum of geographically segregated regions.[1] In each region $j \in \mathcal{J} \equiv [0,1]$, there are L_j consumers with wage w_j. We assume that the preference of a consumer in region j is a CES function over a continuum of goods sold by firms each indexed by φ,

$$U_j = \left[\int_{\varphi \in \Omega_j} \Phi(\varphi, q)^{\frac{1}{\sigma}} c_j(\varphi)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}.$$

[1]This is a simplifying assumption to derive intuitive analytical solutions. However, this may resemble reality well, especially given the context of information frictions. One may think of each county in a country as a different region, and therefore there is a large number of regions which can be approximated by the continuum assumption.

where Ω_j is the set of available varieties in region j, $\Phi(\varphi, q)$ is a demand-shifter for variety φ with quality q, $c_j(\varphi)$ denotes the consumption of variety φ, and σ is the elasticity of substitution.

3.2 Firms and Entry

A firm with productivity φ employs labor to produce goods with quality q. The marginal cost is constant but increasing in q, in the sense that it is more costly to produce goods with higher quality. For simplicity, we follow Antoniades (2015) in assuming that a firm φ uses $l = 1/\varphi$ amount of labor and αq units of cost to produce one unit of output with quality q. Furthermore, the firm must pay βq^2 units of fixed cost to upgrade their quality. In addition, we assume that trade across space is costly in the sense that firms incur an iceberg transportation cost $\tau_{ij} \geq 1$ to ship goods from region i to region j, with $\tau_{ii} = 1$ for all $j = i$. Suppose that a no-arbitrage condition holds, then in region j, the price of goods with quality q produced by a firm φ from region i is

$$p_{ij}(\varphi) = \tau_{ij} p_i(\varphi).$$

Under perfect information, the corresponding price index in region j then becomes

$$P_j = \left[\int_{i\in\mathcal{J}}\int_{\varphi} \Phi_i(\varphi, q) p_{ij}(\varphi, q)^{1-\sigma} dF_i(\varphi) di\right]^{\frac{1}{1-\sigma}} = \left[\int_{i\in\mathcal{J}}\int_{\varphi} \Phi_i(\varphi, q)\left[\tau_{ij} p_i(\varphi, q)\right]^{1-\sigma} dF_i(\varphi) di\right]^{\frac{1}{1-\sigma}}.$$

Thus consumption of region j on goods from region i produced by firm φ is

$$c_{ij}(\varphi, q) = \Phi(\varphi, q)\left[\frac{p_{ij}(\varphi, q)}{P_j}\right]^{-\sigma}\frac{E_j}{P_j} = \Phi(\varphi, q)\left[\frac{\tau_{ij} p_i(\varphi, q)}{P_j}\right]^{-\sigma}\frac{E_j}{P_j}. \tag{3.1}$$

Given our assumption of the geography and demand structure, we can write the profit maximization problem of a firm φ from region i as

$$\max_{p_i, q} \int_{j\in\mathcal{J}} \tau_{ij} p_i(\varphi, q) c_{ij}(\varphi, q) - (\frac{1}{\varphi} w_i + \alpha q)\tau_{ij} c_{ij}(\varphi, q)\, dj - \beta q^2.$$

We can solve this problem step by step. First, we take the quality choice as given and solve for the pricing decision of the firm. This is standard and a firm will simply charge a constant markup over its marginal cost.

$$p_i(\varphi, q) = \frac{\sigma}{\sigma - 1}(\frac{1}{\varphi} w_i + \alpha q)$$

Next, we solve for the quality choice of the firm. Substituting the pricing decision back to the optimization problem, we can first show that the profit function of the firm becomes

$$\begin{aligned}
\pi(\varphi, q) &= \int_{j\in\mathcal{J}} \frac{\tau_{ij}}{\sigma - 1}(\frac{1}{\varphi} w_i + \alpha q)\cdot \Phi(\varphi, q)\left[\frac{\tau_{ij}\frac{\sigma}{\sigma-1}(\frac{1}{\varphi} w_i + \alpha q)}{P_j}\right]^{-\sigma}\frac{E_j}{P_j}\, dj - \beta q^2 \\
&= \int_{j\in\mathcal{J}} \frac{\Phi(\varphi, q)}{\sigma}\left(\tau_{ij}\right)^{1-\sigma}\left[\frac{\frac{\sigma}{\sigma-1}(\frac{1}{\varphi} w_i + \alpha q)}{P_j}\right]^{1-\sigma} E_j\, dj - \beta q^2 \\
&= \frac{\Phi(\varphi, q)}{\sigma^\sigma(\sigma - 1)^{1-\sigma}}(\frac{1}{\varphi} w_i + \alpha q)^{1-\sigma}\underbrace{\int_{j\in\mathcal{J}} \left(\tau_{ij}\right)^{1-\sigma} P_j^{\sigma-1} E_j\, dj}_{\text{region i's market access}} - \beta q^2
\end{aligned}$$

$$= \frac{\Phi(\varphi, q)}{\sigma^{\sigma}(\sigma-1)^{1-\sigma}} \cdot \tilde{c}^{1-\sigma} \cdot MA_i - \beta q^2$$

where we use $\tilde{c} \equiv w_i/\varphi + \alpha q$ to denote the marginal cost of production. The first-order condition of this problem then entails that the net operational benefit from quality upgrading should be equated with the increase in fixed cost of quality upgrading,

$$\pi^*(\varphi, q^*) \left[\frac{\partial \Phi(\varphi, q^*)}{\partial q} \frac{1}{\Phi(\varphi, q^*)} + \frac{(1-\sigma)}{\tilde{c}} \frac{\partial \tilde{c}}{\partial q} \right] = 2\beta q^*$$

where $\pi^* \equiv \sigma^{-\sigma}(\sigma-1)^{\sigma-1}\Phi(\varphi, q)\tilde{c}^{1-\sigma}MA_i$ is the operational profit of the firm excluding the fixed cost of quality upgrading. This first-order condition then pins down the optimal choice of q. Two observations are in order. First, optimal quality choice increases with firm's productivity. This is intuitive as higher productivity of firms leaves more room for costly quality upgrading. Second, a larger market access would also induce a firm to upgrade the quality of its products. Both claims are summarized in Proposition 1.

Proposition 1. *Under perfect information, the optimal choice of quality is determined by a firm's productivity φ and its location i. Furthermore, a firm will choose a higher product quality if it is more productive or has access to a larger market, i.e., $\frac{\partial q^*}{\partial z} > 0$ and $\frac{\partial q^*}{\partial MA_i} > 0$.*

Proof. Obvious. Invoking the Implicit Function Theorem and the second-order condition of profit maximization will show the positive signs of comparative statics. □

Finally, we assume that firms are heterogeneous in their productivity φ, à la Melitz (2003). In particular, we assume that a firm in region i draws its productivity φ from a region-specific Pareto distribution $F_i(\varphi) = 1 - \varphi^{\theta_i}$ with shape parameter θ_i. To enter into production, a firm also has to incur a fixed cost of production f_p. Furthermore, a firm also has to incur a fixed cost of exporting f_e, in order to ship its product to another region.

3.3 Information Frictions and Search Process

We introduce information frictions into the model using a setup that is similar to the agriculture settings in Allen (2014). First, we assume that firms only have complete information with regard to the local market conditions of the region they locate in, such that all firms from region $i \in J$ know about the local price index P_i. However, for the other regions, firms have to engage in a sequential search process in order to learn about the market conditions.

Following Allen (2014), we assume that there are two types of information frictions: the fixed costs of each search and search probability. In each period, a firm will pay a search cost $f_i^S > 0$ to randomly draw a region $k \in J$, and learn about the price index there. After learning the price index of one destination market, the firm decides the amount of goods sold to that market and whether to stop search or not. If it decides to search again, the firm draws another region again (with replacement) and learn the price index there. This sequential search process continues until the firm stops searching. Search costs f_i^S are paid in every period.

In addition, we assume that there is a search probability $s_{ij} > 0$, which is defined as the probability that a producer from region i draws and learns information about region j in each search. For simplicity, the search process is with replacement so that the search probability for each destination remains constant during the search. In addition, the search probability is assumed to be the same for all producers from region $i \in J$.

3.4 Optimal Search and Production

In this section, we characterize the timing of the events and the subsequent searching behaviour. Firms in region i can sell their products home or to other regions. Specifically, a firm in region i can ship their goods to region j after incurring ice-berg transportation costs $\tau_{ij} \geq 1$, with $\tau_{ii} = 1$ for all $j = i$.

The timing of the event is such that firms will choose their production plans and the total mass of markets to enter before they begin to search and trade. Then, they will search for the market conditions elsewhere and decide whether to sell their manufactures in other regions.[2] We summarize the timing of events as follows. Building on Allen (2014), we assume that firms engage in a sequential

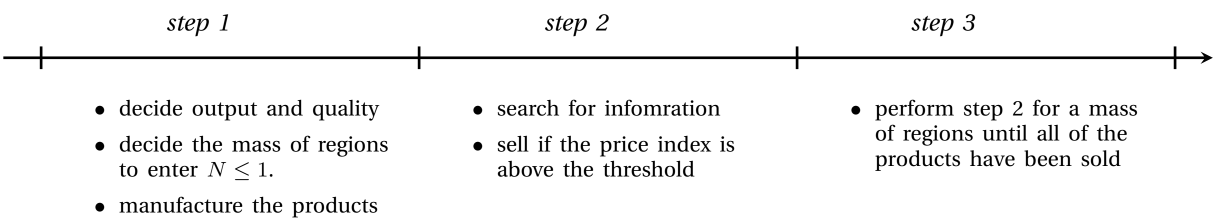


Figure 1: Timeline of events

search process to sell the goods that they have manufactured. If there is perfect information and the search costs are zero, then firms will keep searching for prices of all destinations until they sell all of their manufactures. With non-zero search costs, the producers cannot indefinitely search for information across all regions. They face a trade-off such that they may draw a region with larger market but in the meantime they incur a cost to search for an additional time.

Conditional on a firm φ in region i decide to enter and compete in region j, we know that its profit, excluding the fixed cost in producing quality q, from this trade is

$$\pi_{ij}(p_j, \varphi) = \frac{\Phi(\varphi, q)}{\sigma^\sigma(\sigma - 1)^{1-\sigma}} \left[\frac{\tau_{ij}(\frac{1}{\varphi}w_i + \alpha q)}{P_j}\right]^{1-\sigma} E_j \tag{3.2}$$

If expenditure E_j across all regions are symmetric (we will discuss heterogeneous expenditures later), then the magnitude of π_{ij} is directly proportional to $\tilde{P}_j \equiv P_j/\tau_{ij}$ which represents the degree of competition in region j weighted by the transportation cost in shipping goods from i to j. If $\tilde{P}_j$ is small, it implies that either the competition in region j is high because most firms in this region are low-cost producers manufacturing high-quality products, or that the transportation cost in shipping to region j is high. Either way, the firm φ from region i would find it difficult to sell and compete in region j. Hence, the profit π_{ij} from this trade is small when $\tilde{P}_j$ is small.

Assuming that firms have perfect foresight and know their prospective profit if they decide to enter a market, then a firm's decision can be characterized by a threshold strategy, such that they would

[2]This setting is similar to the "produce then trade" setup in Angeletos and La'O (2013).

enter a region j if and only if they have drawn a large enough $\tilde{P}_j$ which implies that either this market is less competitive or that geography makes shipping to this destination more attractive. Given our descriptions of the timeline, we can write down the value function as follows,

$$V_i(\tilde{P}_j;\varphi) = \max_{sell,search} \left\{ \pi_{ij}(\tilde{P}_j,\varphi), \int_{\tilde{P}_k^{min}}^{\tilde{P}_k^{max}} V_i'(\tilde{P}_k',\varphi)dF^i(\tilde{P}_k') - f_i^S \right\} \tag{3.3}$$

If we denote the reservation transportation-weighted price index of the firm as $\tilde{P}_j^R$, then for the firm to be indifferent in selling the manufactures and search for another period, it must be the case that

$$\begin{aligned}
\pi_{ij}(\tilde{P}_j^R,\varphi) &= \int_{\tilde{P}_k^{min}}^{\tilde{P}_k^{max}} V_i'(\tilde{P}_k',\varphi)dF^i(\tilde{P}_k') - f_i^S \\
&= \int_{\tilde{P}_k^{R}}^{\tilde{P}_k^{max}} \pi_{ik}(\tilde{P}_k',\varphi)dF^i(\tilde{P}_k') + \int_{\tilde{P}_k^{min}}^{\tilde{P}_k^{R}} V_i'(\tilde{P}_k',\varphi)dF^i(\tilde{P}_k') - f_i^S
\end{aligned}$$

which is equivalent to

$$\begin{aligned}
f_i^S &= \int_{\tilde{P}_k^{R}}^{\tilde{P}_k^{max}} \pi_{ik}(\tilde{P}_k',\varphi)dF^i(\tilde{P}_k') + \int_{\tilde{P}_k^{min}}^{\tilde{P}_k^{R}} V_i'(\tilde{P}_k',\varphi)dF^i(\tilde{P}_k') - \int_{\tilde{P}_k^{R}}^{\tilde{P}_k^{max}} \pi_{ij}(\tilde{P}_j^R,\varphi)dF^i(\tilde{P}_k') - \int_{\tilde{P}_k^{min}}^{\tilde{P}_k^{R}} \pi_{ij}(\tilde{P}_j^R,\varphi)dF^i(\tilde{P}_k') \\
&= \int_{\tilde{P}_k^{R}}^{\tilde{P}_k^{max}} \pi_{ik}(\tilde{P}_k',\varphi) - \pi_{ij}(\tilde{P}_j^R,\varphi)\; dF^i(\tilde{P}_k') + \int_{\tilde{P}_k^{min}}^{\tilde{P}_k^{R}} V'(\tilde{P}_k',\varphi)\; dF^i(\tilde{P}_k') - \int_{\tilde{P}_k^{min}}^{\tilde{P}_k^{R}} \pi_{ij}(\tilde{P}_j^R,\varphi)\; dF^i(\tilde{P}_k') \\
&= \int_{\tilde{P}_k^{R}}^{\tilde{P}_k^{max}} \pi_{ik}(\tilde{P}_k',\varphi) - \pi_{ij}(\tilde{P}_j^R,\varphi)\; dF^i(\tilde{P}_k')
\end{aligned} \tag{3.4}$$

The last equality is true because if $\tilde{P}_k' \in [\tilde{P}_k^{min}, \tilde{P}_k^R]$, then the firm will not enter and compete in market k. In this case, the value of searching again is the same regardless the value of $\tilde{P}_k'$. In particular, the following is true,

$$V'(\tilde{P}_k',\varphi) = V'(\tilde{P}_k^R) = \pi_{ij}(\tilde{P}_j^R,\varphi).$$

which implies that

$$\int_{\tilde{P}_k^{min}}^{\tilde{P}_k^{R}} V'(\tilde{P}_k',\varphi)\; dF^i(\tilde{P}_k') = \int_{\tilde{P}_k^{min}}^{\tilde{P}_k^{R}} \pi_{ij}(\tilde{P}_j^R,\varphi)\; dF^i(\tilde{P}_k').$$

Given the model parameters, the reservation price index weighted by transportation costs of a firm φ is then pinned down by equation (3.4), which is reproduced in below

$$f_i^S = \int_{\tilde{P}_k^{R}}^{\tilde{P}_k^{max}} \pi_{ik}(\tilde{P}_k',\varphi) - \pi_{ij}(\tilde{P}_j^R,\varphi)\; dF^i(\tilde{P}_k').$$

The implications of this equation are as follows. First, if the fixed cost of searching decreases, the reservation price index weighted by transportation costs will increase, ceteris paribus. This is because as the fixed cost per search decreases, firms are more willing to search for one more time if they draw a lower $\tilde{P}_k$ which implies that the competition in region k is fierce or that the location is remote. As a result, firms are now more likely to enter and compete in a location with higher $\tilde{P}$, in which there is less competition or that the region is nearby the location of the firm. This is the pro-competitive effect of reducing information frictions that we want to document. Second, if the a firm is more efficient, then its reservation price index weighted by transportation costs will increase. The intuition is that as the firm is more efficient, then it can afford to search for a less competitive place more since it can make a higher profit in that destination. We summarize these discussions in Proposition 2.

Proposition 2. *Under information frictions, a firm is more likely to enter a less competitive market weighted by transportation cost if the fixed cost of search is lower or if the firm is more productive, in the sense that,* $\frac{\partial \tilde{P}_k^R}{\partial f_i^S} > 0$ *and* $\frac{\partial \tilde{P}_k^R}{\partial \varphi} > 0$.

Proof. The proof is provided jointly in Proposition 3. □

3.5 Quality Upgrading Under Information Frictions

We now complete the descriptions of firm behavior in the presence of information frictions. Given that searching for information is costly, firms do not enter all destination markets. In particular, the probability that a firm φ has not drawn a transportation-cost augmented price index larger than its reservation after $m-1$ searches is $F^i(\tilde{P}_k^R)^{m-1}$, and the probability that the firm reaches market k after m searches is $F^i(\tilde{P}_k^R)^{m-1}s_{ik}$. Hence, we can write the total profit of the firm as

$$
\begin{aligned}
\pi(p_i,\varphi) &= \int_{\tilde{P}_k^R}^{\tilde{P}^{max}} \sum_{m=1}^{\infty} \left[\left(\pi_{ik}(p_i,\varphi) - m f_i^S\right) F^i(\tilde{P}_k^R)^{m-1} s_{ik} \right] d\tilde{P}_k - \beta q^2 \\
&= \int_{\tilde{P}_k^R}^{\tilde{P}^{max}} \sum_{m=1}^{\infty} \left[\left(\frac{\Phi(\varphi,q)}{\sigma^\sigma(\sigma-1)^{1-\sigma}} \left[\frac{\tau_{ij}(\frac{1}{\varphi}w_i + \alpha q)}{P_k} \right]^{1-\sigma} E_k - m f_i^S \right) F(\tilde{P}_k^R)^{m-1} s_{ik} \right] d\tilde{P}_k - \beta q^2 \\
&\equiv \kappa_i(\varphi,q) \int_{\tilde{P}_k^R}^{\tilde{P}^{max}} \sum_{m=1}^{\infty} \left[\left((\tau_{ik})^{1-\sigma} P_k^{\sigma-1} E_k \right) F^i(\tilde{P}_k^R)^{m-1} s_{ik} \right] d\tilde{P}_k - \int_{\tilde{P}_k^R}^{\tilde{P}^{max}} \sum_{m=1}^{\infty} m f_i^S F^i(\tilde{P}_k^R)^{m-1} s_{ik}\, d\tilde{P}_k - \beta q^2 \\
&= \underbrace{\kappa_i(\varphi,q) \int_{\tilde{P}_k^R}^{\tilde{P}^{max}} \frac{s_{ik}}{1-F^i(\tilde{P}_k^R)} \cdot \tilde{P}_k^{\sigma-1} E_k\, d\tilde{P}_k}_{\text{market access of firm } \varphi \text{ in region } i} - \underbrace{\int_{\tilde{P}_k^R}^{\tilde{P}^{max}} \sum_{m=1}^{\infty} m f_i^S F^i(\tilde{P}_k^R)^{m-1} s_{ik}\, d\tilde{P}_k}_{\text{total expected search costs}} - \beta q^2 \\
&= \kappa_i(\varphi,q) \cdot \widetilde{MA}_{i,\varphi} - \underbrace{\frac{F^i(\tilde{P}_k^R)}{1-F^i(\tilde{P}_k^R)} f_i^S}_{\text{total expected search costs}} - \beta q^2
\end{aligned}
$$

where if necessary we can interchange the integral and summation using Tonelli's Theorem, and we simplify the expression using the sum of a geometric series. We can apply Tonelli's Theorem because the integrand is non-negative, and that the domain is a closed interval over $\mathbb{R}$ which is Lebesgue-measurable. $\kappa_i(\varphi,q) \equiv \frac{\Phi(\varphi,q)}{\sigma^\sigma(\sigma-1)^{1-\sigma}}(\frac{1}{\varphi}w_i + \alpha q)^{1-\sigma}$ is a term that summarizes the demand shifter q and cost conditions (φ, w_i) of firm φ in region i. $\widetilde{MA}_{i,\varphi}$ is the information-augmented market access of firm φ in region i. Note that this is different from the market access expression in the absence of information frictions. First, under perfect information, firms do not face any cost in accessing information in other markets. In that case, their reservation strategies are simply that they choose to sell in the least-competitive market (weighted by transportation cost). In contrast, under information frictions, firms face a fixed cost per search. They cannot afford to search indefinitely and have a lower reservation price index. Firms are now willing to enter a more competitive market given the price index there is no smaller than its reservation strategy. In this sense, markets with less competition are protected by the presence of information frictions in that firms now are more likely to accept a draw with higher competition and hence are less likely to enter less-competitive markets.

Second, under information frictions, the information-augmented market access measure $\tilde{MA}_{i,\varphi}$ is now firm-region specific. This is because with information frictions, more efficient firms would search more intensively, in the sense that their reservation price index is higher. As a result, although more efficient firms would only consider a narrower set of markets, these destinations are markets with less competition. Hence, more efficient firms stand to earn a larger profit from these trades *on average*. Consequently, we show in Lemma 1 that the actual market access of a firm with higher reservation price index is larger. In contrast, without information friction, the market access measure is only region specific, and all firms from the same region would have the same access because firm heterogeneity does not affect search behavior.

Lemma 1. *In the presence of information frictions, a firm with a larger reservation price index weighted by transportation cost has a larger market access, i.e.,* $\frac{\partial \widetilde{MA}_{i,\varphi}}{\partial \tilde{P}_k^R} > 0$.

Proof. It can be shown that we can manipulate the market access term $\widetilde{MA}_{i,\varphi}$ as follows

$$\begin{aligned}\widetilde{MA}_{i,\varphi} &= \int_{\tilde{P}_k^R}^{\tilde{P}^{max}} \frac{s_{ik}}{1 - F^i\left(\tilde{P}_k^R\right)} \cdot \tilde{P}_k^{\sigma-1} E_k \, d\tilde{P}_k = \int_{\tilde{P}_k^R}^{\tilde{P}^{max}} \frac{s_{ik}}{1 - F^i\left(\tilde{P}_k^R\right)} \cdot \overline{\tilde{P}_k^{\sigma-1} E_k}^R \, d\tilde{P}_k \\ &= \frac{\overline{\tilde{P}_k^{\sigma-1} E_k}^R}{1 - F^i\left(\tilde{P}_k^R\right)} \int_{\tilde{P}_k^R}^{\tilde{P}^{max}} s_{ik} \, d\tilde{P}_k = \frac{\overline{\tilde{P}_k^{\sigma-1} E_k}^R}{1 - F^i\left(\tilde{P}_k^R\right)} \left[1 - F^i\left(\tilde{P}_k^R\right)\right] = \overline{\tilde{P}_k^{\sigma-1} E_k}^R,\end{aligned}$$

where $\overline{\tilde{P}_k^{\sigma-1} E_k}^R$ is denoted as the average value of $\tilde{P}_k^{\sigma-1} E_k$ for any $\tilde{P}_k \geq \tilde{P}_k^R$. Given this algebraic manipulation, it is obvious that $\frac{\partial \widetilde{MA}_{i,\varphi}}{\partial \tilde{P}_k^R} > 0$ because the average value of $\tilde{P}_k^{\sigma-1} E_k$ for $\tilde{P}_k \geq \tilde{P}_k^R$ increases with $\tilde{P}_k^R$. □

Given the profit expression, the optimal choice of quality q^* is then characterized by the first-order condition,

$$\widetilde{\pi}^*(\varphi, q^*) \left[\frac{\partial \Phi(\varphi, q^*)}{\partial q} \frac{1}{\Phi(\varphi, q^*)} + \frac{1-\sigma}{\tilde{c}} \frac{\partial \tilde{c}}{\tilde{q}} \right] = 2\beta q^* \tag{3.5}$$

where $\widetilde{\pi}^*(\varphi, q^*) \equiv \sigma^{-\sigma}(\sigma-1)^{\sigma-1}\Phi(\varphi, q)\tilde{c}^{1-\sigma}\widetilde{MA}_{i,\varphi}$. Notice that equation (3.5) is similar to the first-order condition in the perfect information case, except that the operational profit expression now contains an information-augmented market access $\widetilde{MA}_{i,\varphi}$. Intuitively, similar comparative statics should hold in the presence of information frictions, in that a larger market access or a positive productivity shock would lead to quality upgrading by firms. In this sense, this is the quality upgrading behavior that we want to capture, as a smaller fixed cost of search f_i^S would lead to a higher reservation price index and hence would induce the firms to upgrade quality. However, the comparative statics are now more complicated as firm optimization are jointly determined by search behavior (3.4) and quality decision (3.5). We now formally state the comparative statics under information frictions in Proposition 3,

Proposition 3. *Building of Information and Communications Technology (ICT) infrastructure, which lowers the fixed cost of search* f_i^S*, leads to a higher reservation price index and quality upgrading of firms, i.e.,* $\frac{\partial \tilde{P}_k^R}{\partial f_i^S} > 0$ *and* $\frac{\partial q^*}{\partial f_i^S} > 0$. *Similarly, a more efficient firm would also choose a higher quality and a higher reservation price index, i.e.,* $\frac{\partial \tilde{P}_k^R}{\partial \varphi} > 0$ *and* $\frac{\partial q^*}{\partial \varphi} > 0$.

Proof. See Appendix A. □

3.6 General Equilibrium

So far our discussions of the model have been taking equilibrium prices as given. We will now briefly define a general equilibrium. More details can be found in the Appendix. In the future, we will also fully utilize the general equilibrium and discuss the quantitative implications of our model.

1. Consumers optimize and their demand is given by equation (3.1).
2. Firms optimize their production (3.4) and search (3.4) behavior.
3. Goods and factor markets are cleared.
4. Firms earn zero profit in expectation.
5. Firms are fully rational and have correct beliefs on the distribution of prices.

4. Intra-national Empirical Evidences

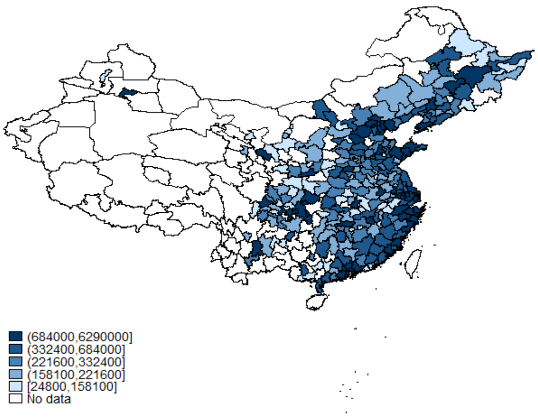
We now bring the theoretical predictions of our model to the data. In particular, we use several datasets to test the qualitative predictions of our model. First, we examine the prediction that building of ICT infrastructure would induce quality upgrading behaviors by firms across Chinese cities. This is done by combining two firm-level datasets in China, which are the Annual Survey of Industrial Firms (ASIF) and the Chinese Industrial Firms Product Quantity Database (CIFPQD). Our empirical strategy relies on a battery of stringent fixed effects that address omitted variable bias. To address concerns that firms may choose to upgrade product quality because they become more productive given the use of ICT technology, we further exploit the variation of ICT infrastructure in regions other than the location of firms to identify the effect of decreasing fixed cost of search on quality upgrading. To further address endogeneity concerns that construction of ICT infrastructure may be endogenous to location characteristics, we are now constructing a separate set of regressions that utilize the opening of airports and alternative opening plans based on an least-cost algorithm as an instrumental variable.

Second, as our Chinese firm-level data do not contain any intra-national trade information, we will not be able to test the predictions concerning whether firms have sold more to less competitive markets. To provide empirical evidences on these predictions, we exploit the Chinese Custom data which contains product-level unit value information as well as destinations that the products are being sold to. For this design, we are relying on the international variation in ICT infrastructure to corroborate the empirical hypotheses. There are also less endogeneity concerns because construction of ICT infrastructures across nations is not coordinated by any single organization. We are currently constructing the variables for this regression.

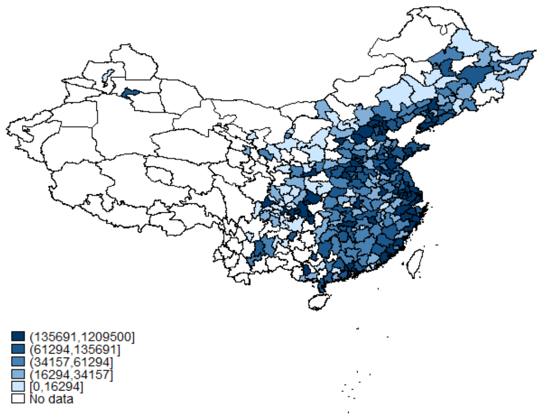
4.1 Data

Next, we will describe the data sources used in the empirical studies. We choose to focus on the time period from 2001 to 2007, during which China experiences a drastic increase in telecommunication infrastructure construction and mobile phone penetration. Another reason that we choose to focus

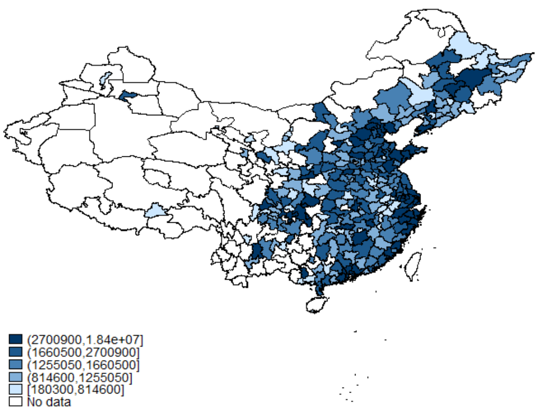
Figure 1: Spatial Distribution of Telecommunication Development in China, Year 2001-2007



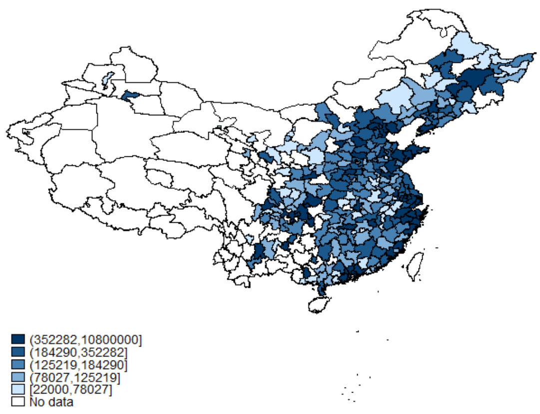
A. Mobile Phone Owners, 2001



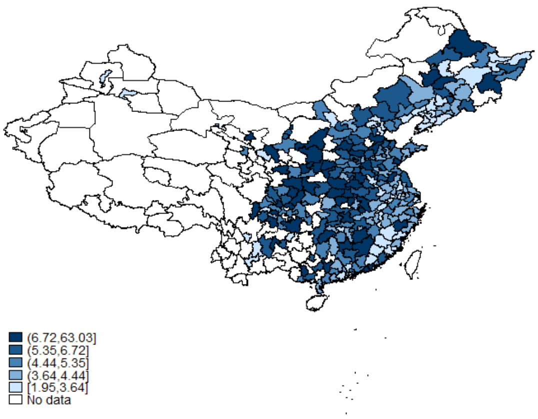
B. Broadband Internet Subscribers, 2001



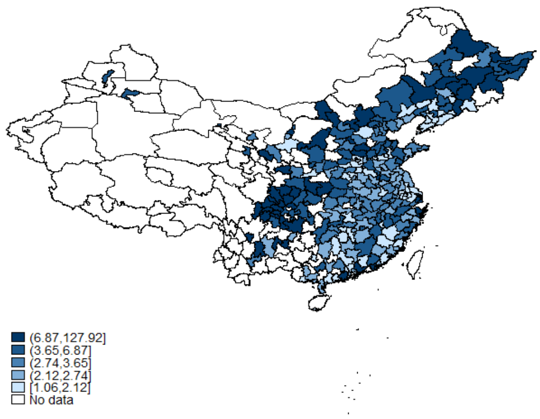
C. Mobile Phone Owners, 2007



D. Broadband Internet Subscribers, 2007



E. Growth of Mobile Phone Owners



F. Growth of Broadband Internet Subscribers on this time period is that, this is the longest time span that our datasets permit, given what we have in hand.

Data on Firm-level Production. The firm-level data is from the Annual Survey of Industrial Firms (ASIF), constructed by the National Bureau of Statistics in China (NBSC). The sample period is from 2001 to 2007. ASIF database covers manufacturing firms with gross sales more than 5 million RMB of that year, both state-owned and non-state-owned. It reports detailed firm-level financial and production information such as gross output, value added, capital stock, number of employees, wage payable and supplementary benefit payable. The approach we use to construct the panel database is largely adapted from Brandt et al. (2012). We match firms by their legal ID, firm name, legal person representative, telephone number as well as administrative area (prefecture) code sequentially.

Data on Unit Value. The product level information is obtained from the Chinese Industrial Firms Product Quantity Database (CIFPQD) collected by the NBSC from 2001 to 2007. This database provides information on physical output quantity at 5-digit Chinese Product Code (CPC) level, which enables us to extract market share as well as price information for single product firms if the sales information for this firm in ASIF database is available. Because the sales information is only provided at firm-level in ASIF database, we keep firms of single product in the physical quantity database and merge with the ASIF database according to firm identity code (ID) and firm name in each year.

Data on ICT Infrastructure. The third dataset is China City Statistical Year Book (CCSYB). "City" here refers to a prefecture, which is a geographically administrative unit in China. There were 265 prefectures in year 2000 and 283 in year 2007. The city statistical yearbooks report Chinese telecommunication development at prefecture level, including the number of broadband internet subscribers and the number of mobile phone users. On top of telecommunication information, other information such as GDP, GDP per capita, total industrial outputs are also reported in this yearbook. Figure 1 plots the spatial variation in the number of mobile phone owners and broadband internet subscribers. The first four Panels A, B, C, D plot the levels of telecommunication development at prefecture level in China in year 2001 and 2007. Panel E and F show the spatial distribution of telecommunication growth rate between 2001-2007 at prefecture level. For the two telecommunication measures, we find coastal areas exhibit higher level relative to those in inland areas in both year 2001 and 2007. Though, inland areas experience higher growth rates than those of coastal areas in telecommunication development.

4.2 Empirical Strategies

The theoretical framework predicts that the reduction in information frictions would lead to larger market access and hence induce quality upgrading by firms. In the data, we proxy the decrease in information frictions by using the log of number of broadband internet and mobile phones users as proxies. The results are similar if we use the percentage of users as proxies instead. The baseline regression we run is

$$Q_{gjist} = \beta_1 \ln TeleCom_{it} + \beta_2 \ln MA_{it} + \mathbf{\Lambda}'\mathbf{F}_{jst} + D_g + D_t + D_i \times t + \varepsilon_{gjist},$$

where dependent variable Q_{gjist} represents the quality for product g produced by firm j of industry s in prefecture i at time t. We use three different measures of quality separately to proxy for product quality, which are prices, market shares and the estimated quality. We compute unit value as price of a product by dividing the sales with quantities of firm j in year t. As for market shares of a firm, we divide the output quantities of a firm's product by the sum of quantity within each 5-digit product-code category. The assumption for the first two measures is that within a product group[3], products with higher prices, or products that have captured larger market shares have higher quality. We also apply the approach of Khandelwal (2010) to provide an estimate of product quality, which explores the information on both prices and market shares of a product to estimate quality based on a nested logit model.

Independent variable $\ln TeleCom_{it}$ measures the development of telecommunication in prefecture i where a firm locates at time t. We use the number of mobile phone owners and broadband internet subscribers as proxies for this variable. Given our specification, we are partly exploiting the time series variation in the number of internet or cell users in each city in identifying the effect of ICT infrastructure on product quality. The results are qualitatively similar if we use percentage of internet or mobile users instead, which may arguably be better proxies for ICT penetration ratio in a city. These results are available upon requests.

To isolate the effects of prefecture-level information frictions on product quality, we control for a transportation cost based market access measure MA_{it}. This is to distinguish between the effects of transportation cost based market access and information-based market access measures. We construct market access MA_{it} of a city i following the approach in Donaldson and Hornbeck (2016) and Allen and Atkin (2016). Following the literature, we define market access as the sum of total income in all prefectures weighted by respective trade costs between the prefectures and the corresponding location that a firm locates in. We extract the measures for trade costs from Ma and Tang (2019) which utilizes various transportation modes and realistic geography in computing the trade cost matrix. We expect the coefficient of market access to be positive, because firms closer to higher-income locations may choose a higher product quality to cater the non-homothetic demand in those location (Fajgelbaum et al., 2011, 2015; Dingel, 2017). In addition, there is also a concern with transportation cost based market access, because in our model this will also lead to quality upgrading behavior by firms.

We include an additional vector of control $\mathbf{\Lambda}'\mathbf{F}_{jt}$ to control for firm-level characteristics such as productivity, employment size, and export status.[4] Firms with higher productivity find it more affordable to upgrade product quality whereas employment size is used to proxy for the levels of economies of scales. We expect the coefficients for these two variables to be positive, because firms of higher productivity and scale economies should find it more appealing to produce higher quality goods. Finally, export status is a dummy variable that indicates whether a firm exports in a given year. This exporter dummy controls the possible effect through non-homothetic demand from high-income foreign countries. To further control for omitted variables, we also include product fixed effects and time fixed effects which subsume all the product-specific or time-specific determinants of product quality. Finally, $D_i \times t$ are city-specific linear time trends that subsume any time-series persistence in some unobservable variables which may change both firms quality choices and ICT infrastructure

[3] The product group is 5-digit Chinese Product Code, which is the finest disaggregated level we have.
[4] The productivity estimation adopts the approach of Olley and Pakes (1993).

construction in a prefecture.

To further alleviate the concerns on omitted variable bias, we also run a more stringent specification that includes a full battery of fixed effects which our data permit. The most stringent set of fixed effects would include product-year specific fixed effects and city-product fixed effects. Ideally, product-year fixed effects would have controlled for any product specific economic shocks over time such as technological progress, changes in availability of high-quality inputs, and for times-series variation in consumer demand and preferences for different goods. City-product fixed effects would have controlled for comparative advantage patterns across space (Chor, 2010), which may confound the empirical relationship we are interested in. One possibility is that internet or mobile penetration ratio could be high in the coastal regions which may have comparative advantage in producing higher quality products. Note, however that we do not include these fixed effects in our specification because the sample size is not large enough to provide meaningful identification for tens of thousands of coefficients.

$$Q_{gjist} = \beta_1 \ln TeleCom_{it} + \beta_2 \ln MA_{it} + \mathbf{\Lambda}'\mathbf{F}_{jst} + D_{gt} + D_i \times t + \varepsilon_{gjist}.$$

Finally, we cluster standard errors at the prefecture-industry level to take into account possible correlated idiosyncratic shocks at the firm level within an industry in a prefecture. The results are similar if we cluster the standard error at the prefecture level.

4.3 Baseline Results

We report the baseline findings in Table 1 and Table 2. Table 1 reports the results with product fixed effects and year fixed effects. We run the regression for three different measures of product quality as the dependent variable. Column (1) to (4) report the results using market shares as the dependent variables. In particular, Column (1) and (3) report the first regressions without any fixed effects of city-specific time trends using log of mobile and internet users as a proxy for ICT infrastructure respectively. The results are similar if we use the percentage of internet or mobile users instead.[5] Although the estimates are both economically and statistically significant in the first regression, the coefficients for transportation based market access measures are in the wrong direction. The estimates for market access in the first regression suggest that firms in cities with larger market access would choose a lower production quality. One reason that this may be true is that there could be city-specific time persistence such that market shares of a firm's product become smaller overtime due to technological progress, the entry of new products, or increasing competition. In particular, this trend may be more pronounced in the big cities or coastal areas which usually have a larger market access. In addition, as we are running a spatial regression, there are also concerns such that there may be spatial correlation in various characteristics that may lead to over-significant estimates (Kelly, 2019). As such, it is particularly important to include fixed effects such as product fixed effects, time fixed effects, and city-specific linear time trends.

We run the regressions with corresponding fixed effects and city-specific time trends in Column (2) and (4) of Table 1. Several observations emerge from this exercise. First, the coefficient estimates

[5] These results will be included soon in the latest draft.

for the main variables of interest are still economically significant thought it is now only statistically significant at 10% level for mobile users in Column (2). Our estimates suggest that when ICT penetration in a city doubles, firms would have on average upgraded their product quality by 10%. Second, we find that the coefficient estimates for market access become both positive and economically and statistically significant in both columns. This corroborates our previous speculation that the negative coefficient estimates in Column (1) and (3) may be due to city-specific time trends or any other omitted variables which are now subsumed by the product fixed effects or time fixed effects. Third, our coefficient estimates for other factors such as employment size or firm productivity remain economically and statistically significant throughout Column (1) to (4), and the estimates are in the intuitive directions.

Column (5) to (12) use alternative variables as proxies for quality. The results remain quantitatively and qualitatively stable except for unit value of products. In this regression, the results are not statistically significant in Column (10) and the quantitative magnitude attenuates across using either mobile or internet users. In addition, the coefficient estimates for market access are also not statistically significant, and they are intuitively in the wrong directions.

To further address for omitted variable bias, we run a more stringent specification in Table 2 which includes product-time specific fixed effects. Ideally, we should have included city-product fixed effects which control for comparative advantage patterns. As discussed earlier, we do not enough sample size to meaningful identify the large amount of fixed effects. We will include a set of results with city-industry fixed effects in the future. The results in Table 2 suggest that our findings survive a more stringent specification, and the qualitative implications remain stable. Quantitatively, our coefficient estimates for the main variables are slightly attenuated but are still economically and statistically significant. To interpret our estimates, the results in Table 2 suggest that doubling the ICT penetration in a city would have induced firms to upgrade product quality by 7%, in comparison to that of 10% in Table 1. These results suggest that our estimates in Table 1 are slightly biased upward due to omitted variables that are subsumed in product-time fixed effects. This could be due to any product-specific economic shocks over time such as technological progress that improves product quality over time, changes in availability of high-quality inputs which are indispensable in quality upgrading, and for time-series variation in consumer demand that maybe a result of growing income over time and non-homothetic preference.

4.4 Identification Challenges

One implicit threat to the identification of our baseline regression is that the proliferation of ICT technology in a city may boost firm productivity when the firms employ more ICT devices in their daily production. If we observe that ICT penetration leads to quality upgrading of firms, it could be a consequence of firms upgrading quality when their productivity is higher. To alleviate this concern, we exploit the spatial and time-series variations in ICT infrastructure in cities other than the location that the firm is in. The implicit assumption behind our logic is that, for a particular prefecture building of ICT infrastructure in other cities other than itself would not change firm productivity in that prefecture. In addition, we assume that the improvement in ICT infrastructure elsewhere would have reduced a firm's search cost to obtain information. This may be justified, in the sense that, a person who uses internet or mobile phone in an origin city would have increased her communication efficiency if there are more internet or mobile users in the destination city.

We construct the variation in ICT infrastructure in the destination cities as the sum of inverse distance weighted ICT infrastructure, and this variable is labeled as a measure of "information access", IA_{it} of local market i at time t since it follows the approach to construct a conventional measure of transportation cost based market access,

$$IA_{it} = \sum_{j \neq i} \left(\frac{1}{d_{ij}^{\epsilon}} \right) TeleCom_{jt},$$

where d_{ij} is the geographic distance between city i and city j.[6]

4.5 Robustness Results

We report our findings using the alternative measure of information access as the main variables of interest in Table 3 and Table 4. Our results remain qualitatively stable across all variables of interest and across each specification. Again, the results for unit value of products are not as good as the others when we use the alternative measure. And we attribute this again to the the quality of measure itself. Quantitatively, the coefficient estimates become twice larger than those using the ICT development of the origin city as proxies. Our interpretation of this finding is such that communications require inputs from both parties in the origin and destination cities. Since we are summing over ICT development across all potential destinations, it is only natural that the estimates from this regression are much larger. Intuitively, if ICT development only happens at the origin city or any single destination market, this does not reduce the search friction significantly because search is random in our model and is not directed any particular market. In contrast, a significant reduction of information frictions across all destination markets would have shrunk search frictions substantially for firms in the origin region. Hence, this alternative measure should have registered a larger effect in the robustness check regressions, as so reported in Table 3 and Table 4. In the latest draft, we will also include the results from using region-specific measures on the building of ICT infrastructures to provide an additional set of robustness checks.

As discussed earlier, though we have included an exhaustive set of fixed effects as well as an alternative measure of ICT development to address omitted variable bias and other endogeneity concerns, our specifications still suffer from endogeneity in particular from selection issues such that the central government may only choose to build the ICT infrastructures based on location specific characteristics. As we do not have the detailed geo-coded data of the ICT backbone network in China, it's impossible to construct an instrumental variable based on least-cost algorithms. In future works, we will exploit the information on the opening of airports during the same period. Opening of airports would have improved increased face-to-face contact between the origin city and the destination city, and hence it would have reduced information frictions. Opening of airports also do not affect the transportation costs as intra-national trade in China are mostly moved through railroads, high-ways, and water-ways. Since we can access the geo-coded information of the airports, we would be able to construct an alternative network of travel routes via air that could connect the destinations with least

[6] In our baseline regression we simply assume $\epsilon = 1$.

cost and use this alternative network as an instrument for our specification.

In addition, in the present scope of our paper, we only test the qualitative predictions that improving information frictions would have induced quality upgrading. Other predictions especially those concerning pro-competitive effects are less tested. We will address these issues through the lens of international trade using China Custom data. This approach is immune from endogeneity concerns such that the ICT development is associated with the location characteristics since there is no single organization that is coordinating the building of ICT infrastructure across all countries.

5. Conclusion and Future Works

In this paper, we study the pro-competitive effects associated with reducing information frictions. We corroborate our hypothesis by introducing monopolistic competition, heterogeneous firms, and quality upgrading into a sequential search model with trade (Allen, 2014). Given the setup of our model, a firm's strategy in costly search for information is characterized by a reservation strategy, such that it will only compete in a destination if the firms are not that efficient and/or that they supply goods with inferior quality. The predictions from our model are that reducing the fixed cost of search would lead more efficient firms to compete in less competitive markets which are usually the remote locations. In addition, it would also lead to all firms to upgrade their product quality because improving information frictions provides the firms with better information-based market access.

We then take the model to firm-level data in China, together with spatial variation in ICT infrastructure across Chinese cities. The qualitative tests largely corroborates our stories using different variables as proxies for ICT development and different variables as proxies for quality. Our results are robust across specifications as well as including additional controls that address endogeneity concerns. For future works, we are currently calibrating the full-blown general equilibrium to supply richer quantitative implications of our model. Second, we are building an instrumental variable to better address other endogeneity issues in our empirical investigation. Furthermore, we are exploiting international variation in ICT infrastructure, together with the product-level information in the Chinese Custom data, to provide more credible and also richer evidence on pro-competitive effects of reducing information frictions.

Table 1: Telecommunication Development and Product Quality, Product FE and Year FE

Dependent Variable	Log of Market Shares				Estimated Quality				Log of Prices			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Mobile Phones	0.061***	0.082*			0.027***	0.093*			-0.074***	0.018		
	(0.004)	(0.047)			(0.006)	(0.053)			(0.007)	(0.016)		
Internet			0.088***	0.102***			0.072***	0.121***			-0.068***	0.032**
			(0.004)	(0.019)			(0.006)	(0.021)			(0.006)	(0.013)
Market Access	-0.394***	0.616***	-0.421***	0.480**	-0.711***	0.563***	-0.768***	0.399**	0.040	-0.070	0.021	-0.119
	(0.015)	(0.190)	(0.014)	(0.190)	(0.024)	(0.161)	(0.023)	(0.144)	(0.028)	(0.160)	(0.027)	(0.154)
Employment	0.629***	0.737***	0.626***	0.736***	-0.119***	0.338***	-0.123***	0.337***	-0.256***	0.115***	-0.254***	0.115***
	(0.004)	(0.017)	(0.004)	(0.017)	(0.007)	(0.015)	(0.007)	(0.015)	(0.007)	(0.018)	(0.007)	(0.018)
TFP	0.149***	0.345***	0.154***	0.345***	0.072***	0.425***	0.078***	0.426***	0.024***	0.113***	0.023***	0.113***
	(0.003)	(0.019)	(0.003)	(0.019)	(0.005)	(0.022)	(0.005)	(0.022)	(0.005)	(0.027)	(0.005)	(0.027)
City FE $\times$Time trend	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Product FE	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Year FE	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
R-squared	0.125	0.489	0.127	0.489	0.007	0.924	0.008	0.924	0.008	0.858	0.008	0.859
N	185938	185938	185370	185370	185938	185938	185370	185370	185938	185938	185370	185370

Notes: " Mobile Phones" is the log of number of mobile phone owners in a city. "Internet" is the log of number of broadband Internet subscribers in a city. "Market Access" represents the log of sum of inversed distance city income. Firm-level controls are employment, TFP, and exporter dummy. Robust standard errors are clustered at city-industry level for regressions (2),(4), (6), (8), (10), (12) and are reported in parentheses. * denotes for $p < 0.1$, ** denotes for $p < 0.05$, and *** denotes for $p < 0.01$.

Table 2: Telecommunication Development and Product Quality, Product-Year FE

Dependent Variable	Log of Market Shares				Estimated Quality				Log of Prices			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Mobile Phones	0.061***	0.058*			0.027***	0.070*			-0.074***	0.016		
	(0.004)	(0.032)			(0.006)	(0.040)			(0.007)	(0.016)		
Internet			0.088***	0.068***			0.072***	0.089***			-0.068***	0.030**
			(0.004)	(0.014)			(0.006)	(0.013)			(0.006)	(0.012)
Market Access	-0.394***	0.440**	-0.421***	0.353**	-0.711***	0.418***	-0.768***	0.301**	0.040	-0.037	0.021	-0.081
	(0.015)	(0.165)	(0.014)	(0.169)	(0.024)	(0.120)	(0.023)	(0.116)	(0.028)	(0.128)	(0.027)	(0.126)
Employment	0.629***	0.746***	0.626***	0.745***	-0.119***	0.347***	-0.123***	0.347***	-0.256***	0.116***	-0.254***	0.116***
	(0.004)	(0.017)	(0.004)	(0.017)	(0.007)	(0.015)	(0.007)	(0.015)	(0.007)	(0.018)	(0.007)	(0.018)
TFP	0.149***	0.348***	0.154***	0.348***	0.072***	0.429***	0.078***	0.429***	0.024***	0.115***	0.023***	0.115***
	(0.003)	(0.021)	(0.003)	(0.021)	(0.005)	(0.023)	(0.005)	(0.023)	(0.005)	(0.027)	(0.005)	(0.027)
City FE $\times$Time trend	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Product-Year FE	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
R-squared	0.125	0.531	0.127	0.531	0.007	0.944	0.008	0.945	0.008	0.863	0.008	0.863
N	185938	185937	185370	185369	185938	185937	185370	185369	185938	185937	185370	185369

Notes: " Mobile Phones" is the log of number of mobile phone owners in a city. "Internet" is the log of number of broadband Internet subscribers in a city. "Market Access" represents the log of sum of inversed distance city income. Firm-level controls are employment, TFP, and exporter dummy. Robust standard errors are clustered at city-industry level for regressions (2),(4), (6), (8), (10), (12) and are reported in parentheses. * denotes for $p < 0.1$, ** denotes for $p < 0.05$, and *** denotes for $p < 0.01$.

Table 3: Information Access and Product Quality, Product FE and Year FE

Dependent Variable	Log of Market Shares				Estimated Quality				Log of Prices			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Info. Access (Mob. Phones)	-0.064***	0.245**			-0.297***	0.240**			-0.427***	0.013		
	(0.009)	(0.102)			(0.014)	(0.089)			(0.016)	(0.048)		
Info. Access (Internet)			0.021**	0.180**			-0.308***	0.180***			-0.590***	0.016
			(0.010)	(0.076)			(0.015)	(0.062)			(0.016)	(0.043)
Market Access	-0.213***	0.411	-0.332***	0.470*	-0.215***	0.374	-0.282***	0.428*	0.589***	-0.076	0.672***	-0.081
	(0.019)	(0.258)	(0.018)	(0.250)	(0.031)	(0.252)	(0.028)	(0.230)	(0.034)	(0.147)	(0.032)	(0.153)
Employment	0.630***	0.734***	0.629***	0.734***	-0.119***	0.336***	-0.122***	0.336***	-0.257***	0.116***	-0.259***	0.116***
	(0.004)	(0.018)	(0.004)	(0.018)	(0.007)	(0.015)	(0.007)	(0.015)	(0.008)	(0.018)	(0.008)	(0.018)
TFP	0.145***	0.343***	0.145***	0.343***	0.067***	0.425***	0.066***	0.425***	0.025***	0.114***	0.021***	0.114***
	(0.003)	(0.019)	(0.003)	(0.019)	(0.005)	(0.023)	(0.005)	(0.023)	(0.005)	(0.027)	(0.005)	(0.028)
City FE $\times$ Time trend	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Product FE	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Year FE	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
R-squared	0.124	0.488	0.124	0.488	0.009	0.924	0.009	0.924	0.011	0.858	0.013	0.858
N	178468	178468	178468	178468	178468	178468	178468	178468	178468	178468	178468	178468

Notes: " Mobile Phones" is the log of number of mobile phone owners in a city. "Internet" is the log of number of broadband Internet subscribers in a city. "Market Access" represents the log of sum of inversed distance city income. Firm-level controls are employment, TFP, and exporter dummy. Robust standard errors are clustered at city-industry level for regressions (2),(4), (6), (8), (10), (12) and are reported in parentheses. * denotes for $p < 0.1$, ** denotes for $p < 0.05$, and *** denotes for $p < 0.01$.

Table 4: Information Access and Product Quality, Product-Year FE

Dependent Variable	Log of Market Shares				Estimated Quality				Log of Prices			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Info. Access (Mob. Phones)	-0.064***	0.258***			-0.297***	0.267***			-0.427***	0.018		
	(0.009)	(0.075)			(0.014)	(0.063)			(0.016)	(0.047)		
Info. Access (Internet)			0.021**	0.172***			-0.308***	0.183***			-0.590***	0.019
			(0.010)	(0.048)			(0.015)	(0.034)			(0.016)	(0.044)
Market Access	-0.213***	0.181	-0.332***	0.259	-0.215***	0.164	-0.282***	0.238	0.589***	-0.044	0.672***	-0.048
	(0.019)	(0.187)	(0.018)	(0.186)	(0.031)	(0.166)	(0.028)	(0.154)	(0.034)	(0.124)	(0.032)	(0.129)
Employment	0.630***	0.743***	0.629***	0.742***	-0.119***	0.345***	-0.122***	0.345***	-0.257***	0.116***	-0.259***	0.116***
	(0.004)	(0.017)	(0.004)	(0.017)	(0.007)	(0.015)	(0.007)	(0.015)	(0.008)	(0.018)	(0.008)	(0.018)
TFP	0.145***	0.347***	0.145***	0.347***	0.067***	0.430***	0.066***	0.430***	0.025***	0.116***	0.021***	0.116***
	(0.003)	(0.021)	(0.003)	(0.021)	(0.005)	(0.023)	(0.005)	(0.023)	(0.005)	(0.028)	(0.005)	(0.028)
City FE×Time trend	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Product-Year FE	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
R-squared	0.011	0.863	0.013	0.863	0.124	0.531	0.124	0.531	0.009	0.945	0.009	0.945
N	178468	178467	178468	178467	178468	178467	178468	178467	178468	178467	178468	178467

Notes: " Mobile Phones" is the log of number of mobile phone owners in a city. "Internet" is the log of number of broadband Internet subscribers in a city. "Market Access" represents the log of sum of inversed distance city income. Firm-level controls are employment, TFP, and exporter dummy. Robust standard errors are clustered at city-industry level for regressions (2),(4), (6), (8), (10), (12) and are reported in parentheses. * denotes for $p < 0.1$, ** denotes for $p < 0.05$, and *** denotes for $p < 0.01$.

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Appendices

A. Proof of Proposition 3

These comparative statics are derived from the optimal search (3.4) and quality decisions (3.5) which are reproduced as follows,

$$\widetilde{\pi}^*(\varphi, q^*) \left[\frac{\partial \Phi(\varphi, q^*)}{\partial q} \frac{1}{\Phi(\varphi, q^*)} + \frac{1-\sigma}{\partial \tilde{c}} \frac{\partial \tilde{c}}{\tilde{q}} \right] = 2\beta q^*$$

$$f_i^S = \int_{\tilde{P}_k^R}^{\tilde{P}_k^{max}} \pi_{ik}(\tilde{P}_k', \varphi) - \pi_{ij}(\tilde{P}_j^R, \varphi)\; dF^i(\tilde{P}_k')$$

We will prove the part of a lower f_i^S using Implicit Function Theorem. The proof of the second part concerning a more efficient firm is similar. We can manipulate the above equations as follows

$$F_1 \equiv \widetilde{\pi}^*(\varphi, q^*) \left[\frac{\partial \Phi(\varphi, q^*)}{\partial q} \frac{1}{\Phi(\varphi, q^*)} + \frac{1-\sigma}{\partial \tilde{c}} \frac{\partial \tilde{c}}{\tilde{q}} \right] - 2\beta q^* = 0$$

$$F_2 \equiv \int_{\tilde{P}_k^R}^{\tilde{P}_k^{max}} \pi_{ik}(\tilde{P}_k', \varphi) - \pi_{ij}(\tilde{P}_j^R, \varphi)\; dF^i(\tilde{P}_k') - f_i^S = 0$$

Totally differentiating these expressions with respect to f_i^S we have

$$\begin{aligned}
\frac{\partial F_1}{\partial q}\frac{\partial q^*}{\partial f_i^S} + \frac{\partial F_1}{\partial \tilde{P}_k^R}\frac{\partial \tilde{P}_k^R}{\partial f_i^S} + \frac{\partial F_1}{\partial f_i^S} = 0 \\
\frac{\partial F_2}{\partial q}\frac{\partial q^*}{\partial f_i^S} + \frac{\partial F_2}{\partial \tilde{P}_k^R}\frac{\partial \tilde{P}_k^R}{\partial f_i^S} + \frac{\partial F_2}{\partial f_i^S} = 0
\end{aligned}$$

Several observations are in order before we move on to derive the signs. First, $\frac{\partial F_1}{\partial q} < 0$ as this is guaranteed by the second-order condition of firm's optimal quality choice. Second, $\frac{\partial F_2}{\partial q} > 0$ which is very easy to check. Next, $\frac{\partial F_1}{\partial \tilde{P}_k^R} > 0$ because it is proportional to $\frac{\partial \widetilde{MA}_{i,\varphi}}{\partial \tilde{P}_k^R}$ which is larger than 0 by Lemma 1. In addition, $\frac{\partial F_2}{\partial \tilde{P}_k^R} < 0$ since the domain of the integral and the integrand would both be smaller with a larger $\tilde{P}_k^R$. Lastly, it is obvious that $\frac{\partial F_1}{\partial f_i^S} = 0$ and $\frac{\partial F_2}{\partial f_i^S} = -1$.

Given these observations, we can now apply Cramer's rule as follows. First of all, the above system can be written in matrix form as

$$\begin{bmatrix} \frac{\partial F_1}{\partial q} & \frac{\partial F_1}{\partial \tilde{P}_k^R} \\ \frac{\partial F_2}{\partial q} & \frac{\partial F_2}{\partial \tilde{P}_k^R} \end{bmatrix} \begin{bmatrix} \frac{\partial q^*}{\partial f_i^S} \\ \frac{\partial \tilde{P}_k^R}{\partial f_i^S} \end{bmatrix} = \begin{bmatrix} -\frac{\partial F_1}{\partial f_i^S} \\ -\frac{\partial F_2}{\partial f_i^S} \end{bmatrix}.$$

Solving this system requires to do the following manipulation

$$\begin{bmatrix} \frac{\partial q^*}{\partial f_i^S} \\ \frac{\partial \tilde{P}_k^R}{\partial f_i^S} \end{bmatrix} = \begin{bmatrix} \frac{\partial F_1}{\partial q} & \frac{\partial F_1}{\partial \tilde{P}_k^R} \\ \frac{\partial F_2}{\partial q} & \frac{\partial F_2}{\partial \tilde{P}_k^R} \end{bmatrix}^{-1} \begin{bmatrix} -\frac{\partial F_1}{\partial f_i^S} \\ -\frac{\partial F_2}{\partial f_i^S} \end{bmatrix} = \frac{1}{\frac{\partial F_1}{\partial q}\frac{\partial F_2}{\partial \tilde{P}_k^R} - \frac{\partial F_1}{\partial \tilde{P}_k^R}\frac{\partial F_2}{\partial q}} \begin{bmatrix} \frac{\partial F_2}{\partial \tilde{P}_k^R} & -\frac{\partial F_1}{\partial \tilde{P}_k^R} \\ -\frac{\partial F_2}{\partial q} & \frac{\partial F_1}{\partial q} \end{bmatrix} \begin{bmatrix} -\frac{\partial F_1}{\partial f_i^S} \\ -\frac{\partial F_2}{\partial f_i^S} \end{bmatrix}$$

Hence, it is obvious that

$$\text{Sign}\left(\frac{\partial q^*}{\partial f_i^S}\right) = \text{Sign}\left(\frac{\partial \tilde{P}_k^R}{\partial f_i^S}\right) = -\text{Sign}\left(\frac{\partial F_1}{\partial q}\frac{\partial F_2}{\partial \tilde{P}_k^R} - \frac{\partial F_1}{\partial \tilde{P}_k^R}\frac{\partial F_2}{\partial q}\right).$$