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A Model of Trade with Endogenous Product Design

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Keywords Product design, Heterogeneous firms, Trade liberalization, Consumer search

JEL Codes F10, F12, L15

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1 Introduction

A standard source of gains from trade liberalization is the pro-competitive effect: when facing increasing competition from imported goods, local firms decrease their markups in response to a lower demand for their goods. However, this may not be the complete story. In reality, firms may respond in other ways to increasing competition or less-favorable market conditions. One alternative for local firms is to shift to a niche market segment where foreign firms lack comparative advantage in order to avoid head-to-head competition with foreign firms.[1] Alternatively, in order to exploit the increasing business opportunities available in foreign markets after trade liberalization, firms may have to adapt their product designs and marketing strategies in order to meet the tastes and cultural traits of foreign customers. This type of firm adjustments, in additional to the extensive and intensive-margin adjustments highlighted by the large stand of literature with heterogeneous-firm models, may have important welfare implications for trade liberalization. On one hand, when facing external competition, firms could afford to increase their markups by moving to a niche market segment that lacks closely substitutable products to avoid competition. On the other hand, with increasing foreign market potential, firms may switch to board design products to accommodate consumer tastes from different countries. From the consumers' perspective, welfare decreases if the market is flooded with standardized generic products which offers little consumer surplus. To analyze the endogenous product design choice and its welfare implications, we propose a model of international trade that incorporates firms' decisions in product design into a standard heterogeneous firm model. We show that trade liberalization could affect firms' product-design choices, which have non-trivial welfare consequences.

Our model focuses on the market of a single goods. In this market, there is a continuum of firms, each supplying a differentiated product. On top of the usual production, pricing, and export decisions, firms in our model also have to choose between two product designs: a board design that targets the general customers, or a niche design that targets a specific market segment. For example, in the beverage market, Coca-cola and Pepsi are board products that appeal to the mainstream market segment, whereas traditional herbal teas are niche products that appeal to a specific market segment. In the movie industry, Disney typically produces mainstream movies, whereas independent producers with a small budget often target more niche segments.[2] A key assumption of our model is that local firms have a large absolute advantage

[1] Hsu et al. (2014) find that the sales fraction of custom-made products increases in the face of increased competition using Chinese firm-level data.

[2] This sales pattern and market structure is refereed to as the long-tail and superstar phenomenon in the industrial organization

in producing niche products for the local market. A natural justification is that local firms have better knowledge in the local culture, as well as the tastes and preferences of local customers. Therefore, they are in a better position to design products that tailor specific needs of the local customers. In the examples above, local producers are better informed about local peoples' beliefs in the health benefits/side-effects of herbs, as well as the local humor for making a comedy for the local market.[3] To capture the aforementioned absolute advantage, we assume that niche products can only be profitably supplied by local firms.[4]

Following an extensive search literature in industrial organization (Wolinsky 1986, Anderson and Renault 1999, Bar-Isaac, Caruana, and Cunat, 2012), we model the market of differentiated products by assuming that consumers search sequentially for a satisfactory product offer. After paying a search cost, a consumer observes her match quality of the product offered, and the price charged by a randomly-sampled firm. A product with a board design has less variance in match quality; a typical customer would not have a strong preference or aversion towards it. On the other hand, a consumer's match quality with a niche product has a high variance; it is likely that she either likes it a lot, or extremely hates it. This difference in consumers' intensity of preferences for different product designs translates into different elasticities of demand: a board design gives a more elastic demand, whereas a niche design gives a less elastic demand.

As shown in Bar-Isaac, Caruana, and Cunat (2012), the more efficient firms in the industry would adopt a board product design, whereas the less efficient firm would adopt a niche product design. This observation is quite intuitive. To make the most out of its low production cost, an efficient firm wants to maximize sales, making a board design more profitable. On the other hand, inefficient firms find it difficult to compete directly against the efficient firms in price; they would rather occupy a more niche market segment, in which

literature. See Bar-Isaac, Caruana, and Cunat (2012) for example.

[3]Holmes and Stevens (2014) also assume each industry has a *primary* segment and some *specialty* segments. The segments differ in their products' tradability. This assumption is similar to ours in the sense that we simply assume that niche products can only be provided by local firms and cannot be exported. We further assume that different product designs generate heterogeneous demand elasticities, as will be shown below, whereas Holmes and Stevens (2014) assumed constant elasticity of substitution. This is our key structure to generate new welfare implications.

[4]The marketing literature has long pointed out that product standardization across markets in different countries can be a profitable strategy because it brings economies of scale in production and advertising (Levitt, 1983) and improvement in product quality (Yip, 1989). In an extensive survey, Shoham (1995) state that about 50% of firms report fairly high levels of standardization of their product mix. More recently, empirical studies have shown that marketing standardization across countries can improve firms' performance provided that the managers are sufficiently experienced (O'Donnell and Jeong (2000)), a fitting marketing strategy is adopted (Katsikeas, Samiee, and Theodosiou (2006)), and the firm has a homogeneous product offering (Schilke, Reimann, and Thomas (2009)).

they can charge a higher markup without losing too many customers in that niche segment. We find that a similar pattern holds in our open-economy setting. Furthermore, only the most efficient firms (if any) would adopt a board design and export their products.

We identify two main channels through which trade liberalization affects firms' product design decisions. First, if a firm plans to take advantage of the business opportunities in the foreign market, it would adopt a board design. On the other hand, if a country receives an abundance of low-cost imported board products, the relatively-inefficient firms that focus on the local market may find it more profitable to differentiate themselves from the mainstream products and adopt a niche design.

By taking the product-design decision into account, we discover a number of novel effects of trade liberalization. First, consumer welfare may decrease after trade liberalization. As mentioned above, a lower trade cost encourages exporting board-design products. If the board-design products bring a lower consumer surplus on average, then the abundance of such products in the market could be bad for consumers. Second, trade liberalization can lead to a reduction in industry's total profit. To see this possibility, suppose under autarky, all firms adopt a niche design, which is more profitable. Trade liberalization could make them switch to a board design; though less profitable in an individual market, a board design allows them to sell in multiple markets hence making more profit than a niche design. However, if a lot of firms switch to board design and export, the eventual sale of each firm would remain unchanged, leading to a reduction in profit. This scenario is somewhat similar to a prisoners' dilemma: whereas firms in each country could jointly benefit from supplying (the more profitable) niche products only locally, the dominant strategy of each firm is to supply (the less profitable) board-design products in order to expand into the foreign markets. Finally, we show that trade liberalization could lead to an increase in the price markup charged by firms, a negative pro-competitive effect. This could happen if a firm switches from a board design to a niche design to mitigate direct competition, as a niche product is associated with a less elastic demand and hence a higher markup. If enough firms are switching into niche-design products, the average markup may actually increase after trade liberalization.

Our paper is related to the debate in the sociology literature on whether trade liberalization, or more broadly speaking, globalization, leads to homogenization or heterogenization of consumer culture, and whether its effect (if any) is positive or negative. In his survey of the sociological literature on globalization and consumer culture, Goodman (2007) state, "The question as to whether globalization increases cultural homogeneity by establishing common codes and practices or whether it increases a heterogeneity of newly emerging differences seems now, to many analysts, to have been answered. Globalization does both." Our analysis provides an explanation to why globalization can lead to both an increase in homogeneous products and an increase in newly-emerging heterogenous products at the same time. With easier access to low-cost board-design products from abroad, less-efficient local firms feel the need to differentiate, and thus develop new products that tailor to the specific tastes of local consumers, as it has absolute advantage over their foreign competitors in the local market segment. Relatedly, the spread of standardized products across the globe, termed as coca-colonization and McDonalization in the sociology literature, has been criticized for threatening cultural diversity (Tomlinson, 1991). Our analysis illustrates formally that trade liberalization can potentially harm consumers if a lot of firms respond by switching to supplying board-design products, and if these products bring less consumer surplus on average.

Our paper is also related to the large strand of literature on firm heterogeneity and welfare gains from trade. We add to this line of research by formally incorporating product design choice into firm optimization and analyzing its implications on consumer welfare. Most existing models emphasize firm heterogeneity in productivity following the seminal work by Melitz (2003). Baldwin and Harrigan (2011), and Hallak and Sivadasan (2013) also allow firms to be differentiated in quality additional to productivity. Bernard, Redding, and Schott (2010) develop a multi-product model with heterogeneity not only at the firm level but also at the level of product-specific attributes. Holmes and Stevens (2014) introduces heterogeneous tradability of firms' products to explain the plant size distribution and its relationship with geography. Our model features firm heterogeneity along both the dimensions of firm productivity and product design. Though our assumption that niche-design products are only supplied locally is similar to the tradability assumption of Holmes and Stevens (2014), the unique feature that heterogeneous product design brings in is the heterogeneous demand elasticity. A board (niche) product design means high (low) price elasticity of consumer demand. It is worth noting that product design is different from product quality, as quality shifts the consumer demand up and down through the quality-adjusted price while product design rotates the consumer demand curve. In our model, firms compete not only by absolute cost advantage but also through their product designs. In particular, less efficient firms who cannot compete with low cost can still choose a niche product design and make profit by exploiting the resulting low demand elasticity. The welfare implication from our framework is consistent with the theorem 2 in Helpman (1984) where gains from trade exist if trade liberalization expands the output of industries with large monopolistic marginal profits while contracts those with small monopolistic marginal profits. Markusen (1981) has similar predictions on gains from trade with imperfect competition. Similarly in our framework, board product design is associated with smaller marginal monopolistic profit and niche product design has larger marginal monopolistic profit. Loss from trade may happen when trade liberalization expands the set of firms choosing board product design and contracts the faction of firms choosing niche product design. We show that there are many circumstances in which this may happen. When comparing with the recent literature on welfare gains from trade, for instance Arkolakis et al. (2012), Costinot and Rodríguez-Clare (2014) and Feenstra (2018), our model shows an additional source of welfare changes. We abstract away from love of variety and our setup for consumer behavior is different from standard trade literature. As a result, we view our welfare implications as complements to the existing literature and want to highlight the role of endogenous product design.

Our modelling of consumer search for differentiated products follows the literature in industrial organization. In his seminal work, Wolinsky (1986) points out that this class of model is able to capture all key features of monopolistic competition. Namely, (i) a large number of firms selling differentiated products; (ii) each firm is negligible in the sense that it can ignore its impact on, and hence reactions from, other firms; and (iii) each firm faces a downward sloping demand curve and its equilibrium price exceeds its marginal cost. Anderson and Renault (1999) shows that the more differentiated the products are, the higher the markup firms charge. Bar-Isaac, Caruana, and Cunat (2012) extend their model by allowing firms with heterogeneous quality/productivity to choose product designs, and show that a reduction in search cost could lead to both the long-tail effect and the superstar effect. We further extend this framework into an open economy setting based on Bar-Isaac, Caruana, and Cunat (2012).

The paper is organized as follows. The model is setup in Section 2. The equilibrium characterization of the general model is analyzed in Section 3. Section 4 studies the special cases of uniform taste distributions and illustrate how trade liberalization can affect consumers' welfare and firms' profits through endogenous product design adjustment. Finally, Section 5 concludes.

2 Model

There are two countries, Country H and Country F. We focus on the market of a single product. In each country $l \in \{H, F\}$, there is a continuum of potential consumers and firms in the market for the product.

Consumers' problem In country l, there is a measure n_l of ex-ante identical and risk-neutral consumers. There is a measure M_l of risk-neutral firms each offering a differentiated variety for this product.

Each consumer searches among these varieties to choose one for consumption.[5] A consumer j receives a payoff

$$u_{ji}(p_i) = \varepsilon_{ji} - p_i,$$

if she buys the product offered by firm i at a price p_i. Here ε_{ji} is the match value between consumer j and firm i's product, and we assume that ε_{ji} is distributed independently across firms and consumers. The distribution F_{s_i} of ε_{ji} depends on the product design $s_i \in \{B, N\}$ chosen by firm i. Firm i's product can either be of a board design (denoted by $s_i = B$) or a niche design (denoted by $s_i = N$). The choice of product design will be discussed in more details when we describe the firms' problem.

Consumers engage in a random (non-directed) search for products in the local market, but not in the foreign market. A consumer j incurs a search cost $c > 0$ to learn about the price p_i and the match value ε_{ji} for the product offered by firm i. She searches sequentially, and collects a payoff

$$u_{ji}(p_i) = \varepsilon_{ji} - p_i - zc,$$

if she buys from firm i after visiting z firms.

It is a standard result in the literature that under the optimal search strategy, consumers do not return to previously sampled firms. Therefore, it is without loss to assume that the consumer's search is without recall. It is then straightforward that the optimal search strategy is a simple stopping rule: stopping the search and buying from the current firm i is optimal if and only if $\varepsilon_{ji} - p_i \geq U$, where U is consumer i's continuation value of search (under the optimal strategy). Note that as the consumer's search problem and thus the continuation value U are history-independent, the strategy of consumers in country l can simply be characterized by a cutoff value U_l.

Firms' problem In each country l, there is a mass M_l of firms. Each firm has a constant marginal cost of production, and the marginal cost of a generic firm is denoted by k. The costs are distributed according to a continuous distribution function G_l with support $[\underline{k}_l, \bar{k}_l]$ for some $\underline{k}_l, \bar{k}_l \geq 0$. Firms with cost that is too high may find it optimal not to produce at all. If it decides to produce at marginal cost k, then it simultaneously sets (i) its product design s_i; (ii) its price in the local market $p_{k,l}$, and (iii) its price in the foreign market $q_{k,l}$, if it also decides to export. Exporting requires a fixed cost $\phi_x \geq 0$ and a unit cost $\tau \geq 0$.

[5]We abuse the term of variety here though the way we model consumption at the product level is different from standard trade literature, CES between different varieties for example. However, our framework can be easily extended to the standard models of consumption by allowing many products. In the current study, we only focus on the market for a single product.

There are two product designs available for each firm. Consumers derive different match value from different designs. Specifically, design $s_i = B$ has a board appeal and leads to a distribution of match value $F_B(\varepsilon_j)$, whereas design $s_i = N$ is niche and leads to a distribution over match value $F_N(\varepsilon_j)$. Assume each F_s has support on a bounded interval $[\underline{\theta}_s, \bar{\theta}_s]$, and has a log-concave density function f_s that is positive everywhere. For board-design product, consumers have similar taste, whereas for niche-design product, consumers' taste is more diverse. As a result, the cumulative distribution for consumer match value F_B is steeper than F_N. Loosely speaking, F_N has a wider spread in match value than F_B. Note that we assume the marginal cost of an individual firm is constant at k, irrespective of the design chosen. And on the other hand, irrespective of the marginal cost, all board (niche) design products have the same match value distribution F_B (F_N).

It is natural that the local firms have absolute advantage over foreign firms in producing niche product in the local market, particularly when the niche design has some local specific ingredient.[6] To capture the notion that local firms have an absolute advantage in supplying niche products for the local market, we assume that the match value of an imported niche product (or its distribution, strictly speaking) is so low that exporting niche products to a foreign country is never profitable. A justification for the bias against imported niche products is that the taste of customers typically varies from country to country, and the variance is particularly large for products that target a niche market. It is therefore difficult for a foreign firm to design a product that meets the niche preference of local consumers. However, the problem is much less severe for a generic and standardized product. Thus, the match value of a product with a board design is assumed to be drawn from the same distribution F_B, regardless of in which country the product is made and sold. Thus, if a firm chooses to export, it necessarily adopts a board design.

A generic strategy of a firm in country l is denoted by $\sigma_{k,l} \equiv (\nu_{k,l}, s_{k,l}, p_{k,l}, q_{k,l}, e_{k,l})$. For a firm with marginal cost k, its decision of quitting and production is represented by $\nu_{k,l} = 0$ and $\nu_{k,l} = 1$ respectively; its design chosen is represented by $s_{k,l} \in \{B, N\}$; local price and foreign price are represented by $p_{k,l} \in \mathbb{R}_+$ and $q_{k,l} \in \mathbb{R}_+$ respectively; its decisions of exporting and not exporting are represented by $e_{k,l} = 1$ and $e_{k,l} = 0$ respectively. For consistency, we impose that if a firm chooses not to produce $\nu_{k,l} = 0$, then it has to choose $e_{k,l} = 0$. Importantly, whereas a firm can choose different prices for its goods sold locally and abroad, *its product design must be identical across the two markets.*

[6]This is similar to Holmes and Stevens (2014), where they introduce local specific inputs in the production of specific industry segment.

To summarize, events unfold in the following order:

1. Each firm learns its constant marginal cost of production k, drawn independently from distribution G_l.

2. Each firm decides whether to proceed to production or quit.

3. Each producing firm chooses its product design, local price, and foreign price (if it also decides to export).

4. Consumers in each country search sequentially and randomly in the local market, which may consist of both locally-made goods and imported goods.

In an equilibrium, every consumer and firm behaves optimally.

Definition 1 *A strategy profile* $\left(U_l^*, \sigma_{\cdot,l}^*\right)_{l\in\{H,F\}}$ *constitutes an equilibrium if and only if in each country* $l \in \{H, F\}$*,*

- each consumer's search strategy U_l^* is optimal, given the correct belief about product designs, export and pricing decisions of the firms $\sigma_{\cdot,H}^*$ and $\sigma_{\cdot,F}^*$;

- for every cost realization k, each firm's strategy $\sigma_{k,l}^*$ is optimal, given the correct belief about the strategies of other firms and the search strategy of the consumers $\{U_l^*\}_{l\in\{H,F\}}$.

3 Equilibrium

We first consider the equilibrium under autarky before analyzing the equilibrium under open-economy.

3.1 Autarky

Under autarky, importing and exporting is prohibitively costly. As a result, only local firms can supply each market, and each firm sets a single price for its products in the local market.

Consumers' behavior Suppose a consumer decides to search and expects that firms choose designs and prices according to respective strategy $p_{k,l}$ and $s_{k,l}$. A consumer j stops searching and makes the purchase from firm i if and only if she finds that $\varepsilon_{ji} - p_i \geq U_l$, where ε_{ji} is the match value drown from $F_{s_{k,l}}$ depending on firm i's design choice $s_{k,l}$ and $p_i = p_{k,l}$ is the price for firm i's product. Moreover, she understands that only firms with marginal cost in the set $\{k : \nu_{k,l} = 1\}$ would engage in production. Therefore, the distribution of marginal cost of firms that the consumer would encounter is $\left(\int_{\{k:\nu_{k,l}=1\}} dG_l(k)\right)^{-1} G_l(k)$. As a result, the consumer's payoff U_l under the optimal search is characterized by the following equation.

$$c = \frac{1}{\int_{\{k:\nu_{k,l}=1\}} dG_l(k)} \int_{\{k:\nu_{k,l}=1\}} \int_{U_l+p_{k,l}}^{\infty} (\varepsilon - p_{k,l} - U_l)\, dF_{s_{k,l}}(\varepsilon)\, dG_l(k). \tag{1}$$

Given the consumer's equilibrium payoff U_l, the expected probability that she stops and buys from a randomly drawn firm in country l is given by:

$$\rho_l \equiv \frac{1}{\int_{\{k:\nu^*_{k,l}=1\}} dG_l(k)} \int_{\{k:\nu_{k,l}=1\}} \left(1 - F_{s_{k,l}}(U_l + p_{k,l})\right) dG_l(k). \tag{2}$$

Firms' behavior We first compute the demand curve facing an individual firm with design s in country l. Suppose the individual firm sets a price p. Conditional on a consumer visiting the firm, the probability that the consumer purchases is $\Pr(\varepsilon - p \geq U_l | s) = 1 - F_s(U_l + p)$. Suppose the mass of operating firms is $\tilde{M}_l$. Then, as the number of consumers is n_l, and each makes $(\rho_l)^{-1}$ visits on average before making a purchase, the average number of consumer visits shared by an individual firm is $\frac{n_l}{\rho_l \tilde{M}_l}$. As a result, the demand curve for this firm is given by $\frac{n_l}{\rho_l \tilde{M}_l}(1 - F_s(U_l + p))$. Consequently, the profit function is given by $\frac{n_l}{\rho_l \tilde{M}_l}(p - k)(1 - F_s(U_l + p))$. It is immediate that the profit-maximizing price is independent of the market size. By the first-order condition, the profit-maximizing price $p_{k,s,l}$ is defined implicitly by

$$p_{k,s,l} = k + \frac{1 - F_s(U_l + p_{k,s,l})}{f_s(U_l + p_{k,s,l})}. \tag{3}$$

The assumption that f_s is log-concave ensures that $p_{k,s,l}$ is well-defined and has intuitive behavior: a higher value of U_l is associated with a lower price.

An individual firm's profit depends also on the design it chooses. Specifically, the firm's profit of choosing a design $s \in \{B, N\}$ is given by

$$\pi_{k,s,l} \equiv \frac{n_l}{\rho_l \tilde{M}_l}(p_{k,s,l} - k)(1 - F_s(U_l + p_{k,s,l})). \tag{4}$$

A firm is willing to produce after learning k if and only if there is a design under which its profit is nonnegative:

$$\max\{\pi_{k,B,l}, \pi_{k,N,l}\} \geq 0. \tag{5}$$

Clearly, this requires k to be sufficiently small. Denote the cutoff by $\hat{k}_l \in [\underline{k}_l, \bar{k}_l]$, i.e.,

$$\hat{k}_l \equiv \begin{cases} \max\left\{k \in [\underline{k}_l, \bar{k}_l] : \max\left\{\pi_{k,B,l}, \pi_{k,N,l}\right\} \geq 0\right\} & \text{if the set is nonempty} \\ \underline{k}_l & \text{otherwise} \end{cases}. \tag{6}$$

As a firm finds it profitable to operate if and only if $k \leq \hat{k}_l$, the support of the operating firms' marginal cost is $\left[\underline{k}, \hat{k}_l\right]$. Consequently, the mass of operating firm $\tilde{M}_l = M_l G_l\left(\hat{k}_l\right)$.

Next, provided that $k \in \left[\underline{k}_l, \hat{k}_l\right]$, a firm is indifferent between the two designs if k satisfies

$$\pi_{k,B,l} = \pi_{k,N,l}. \tag{7}$$

Define the cutoff for design choice $\kappa_l : \left[\underline{k}, \hat{k}_l\right] \to \left[\underline{k}, \hat{k}_l\right]$ as follows:

$$\kappa_l = \begin{cases} \hat{k}_l & \text{if } \pi_{k,B,l} > \pi_{k,N,l} \text{ for all } k \in \left[\underline{k}, \hat{k}_l\right] \\ k & \text{if } \pi_{k,B,l} = \pi_{k,N,l} \\ \underline{k} & \text{if } \pi_{k,B,l} < \pi_{k,N,l} \text{ for all } k \in \left[\underline{k}, \hat{k}_l\right] \end{cases}. \tag{8}$$

By Bar-Isaac, Caruana, and Cuñat (2012), κ_l is well-defined: there is at most one solution to equation (7).[7] Therefore, firms with $k < \kappa_l$ would adopt a board design, whereas firms with $k > \kappa_l$ would adopt a niche design. Using the definitions of cutoffs $\hat{k}_l$ and κ_l in equation (6) and (8), the consumer-search equation (1) can be simplified into

$$c = \frac{1}{G_l\left(\hat{k}_l\right)}\left[\int_{\underline{k}}^{\kappa_l}\int_{U_l+p_{k,B,l}}^{\infty}\left(\varepsilon - p_{k,B,l} - U_l\right) dF_B\left(\varepsilon\right) dG_l\left(k\right) + \int_{\kappa_l}^{\hat{k}_l}\int_{U_l+p_{k,N,l}}^{\infty}\left(\varepsilon - p_{k,N,l} - U_l\right) dF_N\left(\varepsilon\right) dG_l\left(k\right)\right]. \tag{9}$$

Summarizing the discussion above, the autarky equilibrium in country l is a tuple $\left(U_l, \hat{k}_l, \kappa_l\right)$ that satisfies equations (6), (8), and (9).

3.2 Open Economy

In an open economy setting, firms may export its products to the foreign market after incurring some fixed export cost ϕ_x. Now consumers in each country can potentially have access to both locally produced goods and imported goods.

[7] See Proposition 3 of Bar-Isaac, Caruana, and Cuñat (2012). Note that we do not need strong assumptions on the two match value distributions F_s, only need a log-concave density function f_s that is positive everywhere in its support.

Consumers' behavior The consumer's search problem is similar to that in autarky, except that the consumers would rationally anticipate a mixture of locally produced goods and imported goods in his search. With a slight abuse of notations, denote the mass of firms that sell in country l by

$$\tilde{M}_l = M_l \int_{\{k:\nu_{k,l}=1\}} dG_l(k) + M_{l'} \int_{\{k:e_{k,l'}=1\}} dG_{l'}(k). \tag{10}$$

Under random sampling, the probability that a locally-made goods is drawn, denoted by Ψ_l, is therefore $\left(M_l \int_{\{k:\nu_{k,l}=1\}} dG_l(k)\right) / \tilde{M}_l$.

Under the assumption that exporting a niche product is unprofitable, all foreign goods found in country l have a board design. Recall the price of an exported goods of a country l' firm with marginal cost k is denoted by $q_{k,l'}$. The equilibrium consumer payoff U_l of a consumer in country l therefore satisfies:

$$\begin{aligned} c &= \Psi_l \frac{1}{\int_{\{k:\nu_{k,l}=1\}} dG_l(k)} \int_{\{k:\nu_{k,l}=1\}} \int_{U_l+p_{k,l}}^{\infty} (\varepsilon - p_{k,l} - U_l)\, dF_{s_{k,l}}(\varepsilon)\, dG_l(k) \\ &\quad + (1-\Psi_l) \frac{1}{\int_{\{k:e_{k,l'}=1\}} dG_{l'}(k)} \int_{\{k:e_{k,l'}=1\}} \int_{U_l+q_{k,l'}}^{\infty} \left(\varepsilon - q_{k,l'} - U_l\right) dF_B(\varepsilon)\, dG_{l'}(k). \end{aligned} \tag{11}$$

The first integration represents domestic products and the second integration represents imported foreign board-design products. Similarly, the expected probability that a consumer in country l stops and buys from a randomly drawn firm selling in the local market becomes:

$$\begin{aligned} \rho_l &= \Psi_l \frac{1}{\int_{\{k:\nu_{k,l}=1\}} dG_l(k)} \int_{\{k:\nu_{k,l}=1\}} \left(1 - F_{s_{k,l}}(U_l + p_{k,l})\right) dG_l(k) \\ &\quad + (1-\Psi_l) \frac{1}{\int_{\{k:e_{k,l'}=1\}} dG_{l'}(k)} \int_{\{k:e_{k,l'}=1\}} \left(1 - F_B\left(U_l + q_{k,l'}\right)\right) dG_{l'}(k). \end{aligned} \tag{12}$$

Firms' Behavior In addition to the choice between board and niche designs, now each firm also has to decide whether to supply locally only, or export its goods as well.

If a firm has a marginal cost k and a design s (Board or Niche) and it sells only locally, its profit $\pi_{k,s,l}$ is still given by equation (4), where $\tilde{M}_l$ is now given by equation (10). On the other hand, a firm may adopt the board design and sell to both the local and the foreign markets if its k is low enough. By choosing a local price $p_{k,l}$, and a foreign price $q_{k,l}$, its profit is given by:

$$\pi_{k,B,ll'}(p_{k,l}, q_{k,l}) \equiv \frac{n_l}{\rho_l M_l}(p_{k,l} - k)(1 - F_B(U_l + p_{k,l})) + \frac{n_{l'}}{\rho_{l'} M_{l'}}(q_{k,l} - \tau - k)(1 - F_B(U_{l'} + q_{k,l})) - \phi_x.$$

The first-order conditions for profit-maximizing prices are characterized by

$$p_{k,l} = k + \frac{1 - F_B\left(U_l + p_{k,l}\right)}{f_B\left(U_l + p_{k,l}\right)}; \text{ and } q_{k,l} = \tau + k + \frac{1 - F_B\left(U_{l'} + q_{k,l}\right)}{f_B\left(U_{l'} + q_{k,l}\right)}.$$

Denote the maximized profit $\pi_{k,B,ll'} \equiv \pi_{k,B,ll'}\left(p_{k,l}, q_{k,l}\right)$. Similar to the autarky case, we can define the equilibrium firm sorting as follows.

A firm is willing to produce after learning k if and only if there is a design and export decision under which its profit is nonnegative:

$$\max\left\{\pi_{k,B,l}, \pi_{k,N,l}, \pi_{k,B,ll'}\right\} \geq 0. \tag{13}$$

Clearly, this requires k to be sufficiently small. Denote the cutoff by $\hat{k}_l \in [\underline{k}, \infty)$:

$$\hat{k}_l \equiv \begin{cases} \max\left\{k \in \left[\underline{k}_l, \bar{k}_l\right] : \max\left\{\pi_{k,B,l}, \pi_{k,N,l}, \pi_{k,B,ll'}\right\} \geq 0\right\} & \text{if the set is nonempty} \\ \underline{k} & \text{otherwise} \end{cases}. \tag{14}$$

Thus, a country-l firm finds it profitable to operate if and only if $k \leq \hat{k}_l$. As a result, the support of the operating firms' marginal cost in country l is $\left[\underline{k}, \hat{k}_l\right]$. Additionally, a firm finds it optimal to export provided that $\pi_{k,B,ll'} \geq \max\left\{\pi_{k,B,l}, \pi_{k,N,l}\right\}$, which gives us the cutoff marginal cost for exporters in country l. Denote the cutoff by $k_l^x \in [\underline{k}, \infty)$:

$$k_l^x \equiv \begin{cases} \hat{k}_l & \text{if } \pi_{k,B,ll'} > \max\left\{\pi_{k,B,l}, \pi_{k,N,l}\right\} \text{ for all } k \in \left[\underline{k}, \hat{k}_l\right] \\ k & \text{if } \pi_{k,B,ll'} = \max\left\{\pi_{k,B,l}, \pi_{k,N,l}\right\} \\ \underline{k} & \text{if } \pi_{k,B,ll'} < \max\left\{\pi_{k,B,l}, \pi_{k,N,l}\right\} \text{ for all } k \in \left[\underline{k}, \hat{k}_l\right] \end{cases}. \tag{15}$$

Finally, a firms finds it optimal to choose the niche design if and only if $\pi_{k,N,l} \geq \max\{\pi_{k,B,l}, \pi_{k,B,ll'}\}$. The cutoff marginal cost for design choice κ_l is given by:

$$\kappa_l = \begin{cases} \hat{k}_l & \text{if } \pi_{k,N,l} < \max\{\pi_{k,B,l}, \pi_{k,B,ll'}\} \text{ for all } k \in \left[\underline{k}, \hat{k}_l\right] \\ k & \text{if } \pi_{k,N,l} = \max\{\pi_{k,B,l}, \pi_{k,B,ll'}\} \\ \underline{k} & \text{if } \max\{\pi_{k,B,l}, \pi_{k,B,ll'}\} < \pi_{k,N,l} \text{ for all } k \in \left[\underline{k}, \hat{k}_l\right] \end{cases}. \tag{16}$$

Notice that the export cutoff k_l^x is always bounded from above by the design choice cutoff κ_l and when there are some $k \in \left[\underline{k}, \hat{k}_l\right]$ such that $\pi_{k,N,l} = \pi_{k,B,ll'} \geq \pi_{k,B,l}$, the export cutoff and design choice cutoff are the same, meaning that all firms choosing board design are exporting as well and the rest choose niche design.

4 Uniform Taste Distributions

As is well-known in the search literature, an explicit characterization of equilibrium is often impossible under general taste distributions. To gain some insights into how endogenous product designs affect firms' profit and consumers' welfare, we specialize to the case of uniform taste distributions. Specifically, assume F_B and F_N are both uniformly distributed: $F_B \sim U\left[\underline{\theta}_B, \bar{\theta}_B\right]$, $F_N \sim U\left[\underline{\theta}_N, \bar{\theta}_N\right]$, where $\underline{\theta}_B > \underline{\theta}_N$, and $\bar{\theta}_B < \bar{\theta}_N$. In Section 4.1 below, we further specialize to the case of degenerate cost distribution to obtain sharp results on equilibrium strategies and possible effects of trade liberalization. In Section 4.2, we assume firms' cost follow a uniform distribution, and we illustrate the findings in Section 4.1 is robust by means of numerical simulations.

4.1 Degenerate Cost

Throughout this subsection, we assume that for each $l \in \{H, F\}$, G_l is a degenerate distribution with all the mass at k_l. Using (3), the uniform taste distribution implies that the price of products supplied by a country l's firm with cost k that adopts design s is given by $p_{k,s,l} = \frac{k+\bar{\theta}_s-U_l}{2}$. It is straightforward that, other things being equal, firms with niche products would charge a higher markup as $\bar{\theta}_N > \bar{\theta}_B$.

Under autarky, the profit for firms in country l adopting design s is $\pi_{sl} = \frac{n_l}{\rho_l M_l G\left(\hat{k}_l\right)} \frac{\left(\bar{\theta}_s - k_l - U_l\right)^2}{4\left(\bar{\theta}_s - \underline{\theta}_s\right)}$. A board design is more profitable if and only if $\pi_{Bl} \geq \pi_{Nl}$, or equivalently,

$$k_l \leq \Theta - U_l, \tag{17}$$

where $\Theta \equiv \frac{\bar{\theta}_B\sqrt{\bar{\theta}_N-\underline{\theta}_N}-\bar{\theta}_N\sqrt{\bar{\theta}_B-\underline{\theta}_B}}{\sqrt{\bar{\theta}_N-\underline{\theta}_N}-\sqrt{\bar{\theta}_B-\underline{\theta}_B}}$. The following lemma states that under the distributional assumptions made, all firms adopt an identical design in autarky.

Lemma 2 *Suppose trade cost is so high that there is no trade between the two countries. Denote* $\psi \equiv \frac{\left(\bar{\theta}_N-\Theta\right)^2}{8\left(\bar{\theta}_N-\underline{\theta}_N\right)} = \frac{\left(\bar{\theta}_B-\Theta\right)^2}{8\left(\bar{\theta}_B-\underline{\theta}_B\right)}$. *In the autarky equilibrium,*

(i) All firms adopt a niche design if and only if $c \leq \psi$*;*

(ii) All firms adopt a board design if and only if $c \geq \psi$*.*

Proof. Denote by β the fraction of board designs. Then the consumer search equation (1) can be simplified into:

$$c = \frac{1}{8}\left(\beta \frac{1}{\bar{\theta}_B - \underline{\theta}_B}\left(\bar{\theta}_B - k_l - U_l\right)^2 + (1-\beta)\frac{1}{\bar{\theta}_N - \underline{\theta}_N}\left(\bar{\theta}_N - k_l - U_l\right)^2\right). \tag{18}$$

Suppose all firms adopt a board design, then by (17), $k_l + U_l \geq \Theta$. Moreover, by the consumer search equation above, $k_l + U_l = \bar{\theta}_B - \sqrt{8c\left(\bar{\theta}_B - \underline{\theta}_B\right)}$. Therefore, $\bar{\theta}_B - \sqrt{8c\left(\bar{\theta}_B - \underline{\theta}_B\right)} \leq \Theta$, or equivalently, $c \geq \psi$.

Conversely, if all firms adopt a niche design, then $\pi_{Bl} \leq \pi_{Nl}$. Following a similar argument as above, it is necessary that $k_l + U_l \leq \Theta$ and $k_l + U_l = \bar{\theta}_N - \sqrt{8c\left(\bar{\theta}_N - \underline{\theta}_N\right)}$. Consequently, $c \leq \psi$. ■

4.1.1 Welfare-Decreasing Trade Liberalization

Consider two symmetric countries with equal production costs $k_H = k_F$. Suppose $c \leq \psi$, so under autarky, firms in both countries produce only niche products. Suppose also that the initial trade cost, τ_0, is so high that export is unprofitable.[8] Suppose trade liberalization lowers the trade cost to some $\tau_1 < \tau_0$, which makes trade profitable. Each firm contemplates the following two options: (i) adopting board design and exporting, and (iii) adopting a niche design and selling only locally. The former option is more profitable if and only if $\pi_{B,HF} \geq \pi_{N,H}$, or equivalently,

$$\left(\bar{\theta}_B - k_H - U_H\right)^2 + \left(\bar{\theta}_B - \tau_1 - k_H - U_H\right)^2 \geq \frac{\bar{\theta}_B - \underline{\theta}_B}{\bar{\theta}_N - \underline{\theta}_N}\left(\bar{\theta}_N - k_H - U_H\right)^2. \tag{19}$$

We identify conditions for the existence of an equilibrium in which all firms adopt board design and export. In this case, the consumer search equation (11) reads:

$$c = \frac{1}{16}\frac{1}{\bar{\theta}_B - \underline{\theta}_B}\left[\left(\bar{\theta}_B - k_H - U_H\right)^2 + \left(\bar{\theta}_B - \tau_1 - k_H - U_H\right)^2\right]. \tag{20}$$

An equilibrium exists if the solution U_H to equation (20) also satisfies inequality (19). To see this is possible for τ_1 sufficiently small, note that if $\tau_1 = 0$, then equation (20) reduces to the search condition under autarky (18) with $\beta = 1$. For c smaller but sufficiently close to ψ, inequality (19) necessarily holds. In this case, the only equilibrium involves all firms producing and exporting board products. The following proposition summarizes the discussion above.

Proposition 3 *Consider two symmetric countries and suppose $c \leq \psi$ so that under autarky firms would produce only niche products. Suppose also that the initial trade cost, τ_0, is so high that export is unprofitable. If c is not too much smaller than ψ, and the new trade cost τ_1 is sufficiently small, then the new (unique) equilibrium involves all firms adopting a board design and exporting.*

At a high trade cost τ_0, there is no trade between the countries. In this case, the consumer welfare is $\bar{\theta}_N - k_H - \sqrt{8c\left(\bar{\theta}_N - \underline{\theta}_N\right)}$ and an individual firm's profit is $\frac{n_H}{M_H}\sqrt{2c\left(\bar{\theta}_N - \underline{\theta}_N\right)}$. At a lower trade cost τ_1,

[8] A sufficient (though not necessary) condition is $\tau_0 > \max\left\{\frac{\bar{\theta}_B}{k_H}, \frac{\bar{\theta}'_N}{k_H}\right\}$.

there is trade between the countries. The consumer welfare becomes no more than $\bar{\theta}_B - k_H - \sqrt{8c\left(\bar{\theta}_B - \underline{\theta}_B\right)}$, and an individual firm's profit becomes no more than $\frac{n_H}{M_H}\sqrt{2c\left(\bar{\theta}_B - \underline{\theta}_B\right)}$.[9] As $\bar{\theta}_B - \underline{\theta}_B < \bar{\theta}_N - \underline{\theta}_N$, firms' profit necessarily goes down after trade liberalization. Moreover, it follows from the condition $c \leq \psi$ that the post-trade consumer welfare goes down.

Corollary 4 *If the conditions in the proposition above hold, then both the consumer welfare and industry profit go down after the reduction in trade cost.*

According to the corollary, trade liberalization could potentially lead to a Pareto worsening, harming both the consumers and firms. Note that if the product designs were fixed, consumer welfare and industry profit would always be decreasing in trade cost. The welfare effect in the corollary above therefore arises from a change in the firms' product designs.

The intuition of the corollary is as follows. Fixing a U_H, a consumer's expected gain in sampling an additional firm is $\frac{\left(\bar{\theta}_s - k_H - U_H\right)^2}{4\left(\bar{\theta}_s - \underline{\theta}_s\right)}$. The assumption $c \leq \psi$ implies that the expected gain is larger if firms are adopting niche designs. Consequently, as firms switch to board designs in order to enter the foreign market, consumers in the home country suffer a lower payoff. Furthermore, the firms also suffer, as board products give a lower per-unit profit than niche products under the condition $c \leq \psi$, and the number of consumers per firm is unchanged after trade liberalization. The scenario therefore resembles a prisoners' dilemma for firms: while sticking with niche designs (and not exporting) Pareto dominates switching to board designs and exporting, the strictly dominant strategy for each individual firm is to switch to board design and export (so that each can get access to consumers in both countries).

4.1.2 Specialization to Local Market

In this subsection, instead of symmetry, we assume that country H is more efficient so that $k_H < k_F$. Suppose also that $c \geq \psi$, so under autarky, firms in both countries adopt a board design. We show it is possible that after the trade cost decreases to some low value τ_1, firms in country H would continue to adopt board design and export, whereas firms in country F would switch to producing niche products and sells only locally. For this to occur, it is necessary that U_F increases because of the availability of cheap imports.

As the only products available in country H are those locally produced and has a board design, the consumer-search equation (11) for country H is simply $c = \frac{1}{8}\frac{1}{\bar{\theta}_B - \underline{\theta}_B}\left(\bar{\theta}_B - k_H - U_H\right)^2$. Upon rearranging,

[9] These expressions assume zero trade cost, thus giving the upper bound for the actual consumer welfare and firm's profit.

$U_H = \bar{\theta}_B - k_H - \sqrt{8c\left(\bar{\theta}_B - \underline{\theta}_B\right)}$.

On the other hand, both locally-produced niche products and imported board products are available in country F, so the consumer-search equation for country F is

$$c = \frac{1}{8}\left[\frac{M_F}{M_H + M_F}\frac{1}{\bar{\theta}_N - \underline{\theta}_N}\left(\bar{\theta}_N - k_F - U_F\right)^2 + \frac{M_H}{M_H + M_F}\frac{1}{\bar{\theta}_B - \underline{\theta}_B}\left(\bar{\theta}_B - (k_H + \tau_1) - U_F\right)^2\right]. \tag{21}$$

Denote by U_F^* the solution to equation (21).

Firms in country H find it more profitable to export board products if $\pi_{B,HF} \geq \pi_{B,H}$, or equivalently,

$$\frac{n_F}{M_F\left(\frac{\bar{\theta}_N - k_F - U_F^*}{\bar{\theta}_N - \underline{\theta}_N}\right) + M_H\left(\frac{\bar{\theta}_B - (\tau_1 + k_H) - U_F^*}{\bar{\theta}_B - \underline{\theta}_B}\right)}\frac{\left(\bar{\theta}_B - k_H - \tau_1 - U_F^*\right)^2}{2\left(\bar{\theta}_B - \underline{\theta}_B\right)} \geq \phi_x, \tag{22}$$

Firms in country F find it more profitable to produce niche goods if $\pi_{N,F} \geq \pi_{B,FH}$, or equivalently,

$$\frac{n_F\left(\frac{\left(\bar{\theta}_N - k_F - U_F^*\right)^2}{\bar{\theta}_N - \underline{\theta}_N} - \frac{\left(\bar{\theta}_B - k_F - U_F^*\right)^2}{\bar{\theta}_B - \underline{\theta}_B}\right)}{M_F\left(\frac{\bar{\theta}_N - k_F - U_F^*}{\bar{\theta}_N - \underline{\theta}_N}\right) + M_H\left(\frac{\bar{\theta}_B - (\tau_1 + k_H) - U_F^*}{\bar{\theta}_B - \underline{\theta}_B}\right)} \geq \frac{n_H}{M_H}\frac{\left(k_H - k_F - \tau_1 + \sqrt{8c\left(\bar{\theta}_B - \underline{\theta}_B\right)}\right)^2}{\sqrt{8c\left(\bar{\theta}_B - \underline{\theta}_B\right)}} - 2\phi_x. \tag{23}$$

Moreover, they are willing to produce, rather than shutting down, if

$$k_F \leq \bar{\theta}_N - U_F^*. \tag{24}$$

Proposition 5 *Suppose $c > \psi$, so that under autarky, firms in both countries adopt a board design. If all of inequality (22), (23), and (24) hold, then after the reduction in trade cost to τ_1, firms in country H would continue to adopt board design and export, whereas firms in country F would switch to producing niche products and sells only locally.*

The proposition illustrates the possibility that the country with an absolute disadvantage in production can specialize to produce niche products. Below, we discuss when all of inequality (23), (22), and (24) could hold. First note that by equation (21), U_F^* is a weighted average of $\bar{\theta}_N - k_F - \sqrt{8c\left(\bar{\theta}_N - \underline{\theta}_N\right)}$ and $\bar{\theta}_B - (k_H + \tau_1) - \sqrt{8c\left(\bar{\theta}_B - \underline{\theta}_B\right)}$, where the weights depend on the relative number of firms in each country. If M_H is large relative to M_F, then U_F^* can be close to $\bar{\theta}_B - (k_H + \tau_1) - \sqrt{8c\left(\bar{\theta}_B - \underline{\theta}_B\right)}$. Moreover, if $k_H + \tau_1$ is sufficiently smaller than k_F, country F can have $k_F > \Theta - U_F^*$, making the firms in country F willing to switch to niche designs, i.e., inequality (23) holds. On the other hand, provided that the fixed trade cost ϕ_x is sufficiently small and the market in country F is sufficiently large (i.e., n_F is large), firms in country H is willing to export to country F and inequality (22) holds. Finally, inequality (24) holds if $\bar{\theta}_N$ is sufficiently large.

4.2 Uniformly Distributed Costs

Throughout this subsection, we assume that for each $l \in \{H, F\}$, G_l is uniform with support $\left[\underline{k}_l, \bar{k}_l\right]$. In autarky, a firm finds it more profitable to adopt a board design if and only if inequality (17) holds. Thus, $\kappa_l = \Theta - U_l$. Moreover, production is profitable if and only if $k \leq \bar{\theta}_N - U_l$. Thus, $\hat{k}_l = \min\left\{\bar{\theta}_N - U_l, \bar{k}_l\right\}$.

The consumer-search equation (9) can be simplified into

$$c = \frac{1}{24\left(\hat{k}_l - \underline{k}_l\right)} \left\{ \frac{1}{\bar{\theta}_B - \underline{\theta}_B} \left[\left(\bar{\theta}_B - \underline{k}_l - U_l\right)^3 - \left(\bar{\theta}_B - \kappa_l - U_l\right)^3 \right] + \frac{1}{\bar{\theta}_N - \underline{\theta}_N} \left[\left(\bar{\theta}_N - \kappa_l - U_l\right)^3 - \left(\bar{\theta}_N - \hat{k}_l - U_l\right)^3 \right] \right\}. \tag{25}$$

Similarly, the probability of stopping at a random firm, equation (2), can be simplified into

$$\rho_l = \frac{1}{4} \frac{1}{\hat{k}_l - \underline{k}_l} \left\{ \frac{1}{\bar{\theta}_B - \underline{\theta}_B} \left[\left(\bar{\theta}_B - \underline{k}_l - U_l\right)^2 - \left(\bar{\theta}_B - \kappa_l - U_l\right)^2 \right] + \frac{1}{\bar{\theta}_N - \underline{\theta}_N} \left[\left(\bar{\theta}_N - \kappa_l - U_l\right)^2 - \left(\bar{\theta}_N - \hat{k}_l - U_l\right)^2 \right] \right\}.$$

4.2.1 Open Economy

The mass of firms present in country $l \in \{H, F\}$ is $M_l G_l\left(\hat{k}_l\right) + M_{l'} G_{l'}\left(k^x_{l'}\right)$. These firms can be classified into the following three types, depending on their chosen design and country of origin.

- Local firms that produce board-design products;
- Foreign firms that produce board-design products;
- Local firms that produce niche-design products.

The proposition below states that given the uniform-distribution assumptions, the firms' export and design decisions have a simple cutoff structure.

Proposition 6 *Suppose the distribution of consumers' tastes and firms' production costs are uniform. Then for each country $l \in \{H, F\}$, there exists cutoffs k^x_l, κ_l, and $\hat{k}_l$ with $k^x_l \leq \kappa_l \leq \hat{k}_l$ such that*

1. *if $k \leq k^x_l$, then the firm adopts a board design and exports;*
2. *if $k \in (k^x_l, \kappa_l]$, then then firm adopts a board design and sells only locally;*
3. *if $k \in (\kappa_l, \hat{k}_l]$, then the firm adopts a niche design and sells only locally.*

Proof. Fix a consumers' payoff in country l at some U_l. Denote by $\tilde{M}_l$ the mass of firms present in country l. The profit of a country-l firm with cost k depends on its export and design decision as follows:

- adopting board design and selling only locally, which gives a profit of $\pi_{B,l} = \frac{n_l}{\rho_l \tilde{M}_l} \frac{\left(\bar{\theta}_B - k - U_l\right)^2}{4\left(\bar{\theta}_B - \underline{\theta}_B\right)}$.
- adopting board design and exporting, which gives a profit of $\pi_{B,k,ll'} = \frac{n_l}{\rho_l \tilde{M}_l} \frac{\left(\bar{\theta}_B - k - U_l\right)^2}{4\left(\bar{\theta}_B - \underline{\theta}_B\right)} + \frac{n_{l'}}{\rho_{l'} \tilde{M}_{l'}} \frac{\left(\bar{\theta}_B - \tau - k - U_{l'}\right)^2}{4\left(\bar{\theta}_B - \underline{\theta}_B\right)} - \phi_x$.
- adopting a niche design and selling only locally, which gives a profit of $\pi_{N,l} = \frac{n_l}{\rho_l \tilde{M}_l} \frac{\left(\bar{\theta}_N - k - U_l\right)^2}{4\left(\bar{\theta}_N - \underline{\theta}_N\right)}$.

Denote by $\tilde{k}_l^x$ the solution in k to the equation $\frac{n_{l'}}{\rho_{l'} \tilde{M}_{l'}} \frac{\left(\bar{\theta}_B - \tau - k - U_{l'}\right)^2}{4\left(\bar{\theta}_B - \underline{\theta}_B\right)} = \phi_x$. Thus, if a firm adopts a board design, it exports if and only if $k \leq \tilde{k}_l^x$. Moreover, denote by $\tilde{\kappa}_l \equiv \Theta - U_l$. It is immediate to verify that $\pi_{B,l} \geq \pi_{N,l}$ if and only if $k \leq \tilde{\kappa}_l$.

If $\tilde{k}_l^x \leq \tilde{\kappa}_l$, then it is immediate that the proposition holds. More specifically, if $\tilde{k}_l^x > \bar{k}_l$, then it must be that $k_l^x = \kappa_l = \bar{k}_l$, so that all firms adopt board designs and export. If $\tilde{k}_l^x \leq \bar{k}_l \leq \tilde{\kappa}_l$, then $k_l^x = \tilde{k}_l^x$, and $\kappa_l = \hat{k}_l = \bar{k}_l$. That is, all firms adopt board designs, but only the efficient firms export. Finally, if $\tilde{k}_l^x \leq \tilde{\kappa}_l \leq \bar{k}_l$, then $k_l^x = \tilde{k}_l^x$, $\kappa_l = \tilde{\kappa}_l$, and $\hat{k}_l = \min\left\{\bar{k}_l, \bar{\theta}_N - U_l\right\}$.

Next suppose $\tilde{k}_l^x > \tilde{\kappa}_l$. We need to show that there is a cutoff $\kappa_l \in \left(\tilde{\kappa}_l, \tilde{k}_l^x\right)$ such that $\pi_{B,k,ll'} \geq \pi_{N,l}$ if and only if $k \leq \kappa_l$. To this end, observe that

$$\pi_{B,k,ll'} - \pi_{N,l} = \frac{n_{l'}}{\rho_{l'} \tilde{M}_{l'}} \frac{\left(\bar{\theta}_B - \tau - k - U_{l'}\right)^2}{4\left(\bar{\theta}_B - \underline{\theta}_B\right)} - \frac{n_l}{\rho_l \tilde{M}_l} \left(\frac{\left(\bar{\theta}_N - k - U_l\right)^2}{4\left(\bar{\theta}_N - \underline{\theta}_N\right)} - \frac{\left(\bar{\theta}_B - k - U_l\right)^2}{4\left(\bar{\theta}_B - \underline{\theta}_B\right)} \right) - \phi_x$$

is convex in the interval $\left(\tilde{\kappa}_l, \tilde{k}_l^x\right)$, positive for k sufficiently close to $\tilde{\kappa}_l$ and negative for k sufficiently close to $\tilde{k}_l^x$. Therefore, in this case, $k_l^x = \kappa_l$, and firms with $k \leq k_l^x$ adopt board designs and export, whereas firms with $k \geq k_l^x$ adopt niche designs and sell only locally. Finally, $\hat{k}_l = \min\left\{\max\left\{\bar{\theta}_N - U_l, k_l^x\right\}, \bar{k}_l\right\}$. ■

Using the proposition, the consumer-search equation (11) can be simplified into

$$\begin{aligned} c &= \frac{1}{24} \left(M_{l'} \frac{k_{l'}^x - \underline{k}_{l'}}{\bar{k}_{l'} - \underline{k}_{l'}} + M_l \frac{\hat{k}_l - \underline{k}_l}{\bar{k}_l - \underline{k}_l} \right)^{-1} \\ &\times \left[\begin{array}{c} \frac{M_l}{\bar{k}_l - \underline{k}_l} \frac{1}{\bar{\theta}_B - \underline{\theta}_B} \left[\left(\bar{\theta}_B - \underline{k}_l - U_l\right)^3 - \left(\bar{\theta}_B - \kappa_l - U_l\right)^3 \right] \\ + \frac{M_l}{\bar{k}_l - \underline{k}_l} \frac{1}{\bar{\theta}_N - \underline{\theta}_N} \left[\left(\bar{\theta}_N - \kappa_l - U_l\right)^3 - \left(\bar{\theta}_N - \hat{k}_l - U_l\right)^3 \right] \\ + \frac{M_{l'}}{\bar{k}_{l'} - \underline{k}_{l'}} \frac{1}{\bar{\theta}_B - \underline{\theta}_B} \left[\left(\bar{\theta}_B - \underline{k}_{l'} - \tau - U_l\right)^3 - \left(\bar{\theta}_B - k_{l'}^x - \tau - U_l\right)^3 \right] \end{array} \right]. \end{aligned} \tag{26}$$

The probability of stopping at a random firm is

$$\rho_l = \frac{1}{4}\left(M_{l'}\frac{k^x_{l'} - \underline{k}_{l'}}{\bar{k}_{l'} - \underline{k}_{l'}} + M_l \frac{\hat{k}_l - \underline{k}_l}{\bar{k}_l - \underline{k}_l}\right)^{-1} \times \left[\begin{array}{c} \frac{M_l}{\bar{k}_l - \underline{k}_l}\frac{1}{\bar{\theta}_B - \underline{\theta}_B}\left[\left(\bar{\theta}_B - \underline{k}_l - U_l\right)^2 - \left(\bar{\theta}_B - \kappa_l - U_l\right)^2\right] \\ +\frac{M_l}{\bar{k}_l - \underline{k}_l}\frac{1}{\bar{\theta}_N - \underline{\theta}_N}\left[\left(\bar{\theta}_N - \kappa_l - U_l\right)^2 - \left(\bar{\theta}_N - \hat{k}_l - U_l\right)^2\right] \\ +\frac{M_{l'}}{\bar{k}_{l'} - \underline{k}_{l'}}\frac{1}{\bar{\theta}_B - \underline{\theta}_B}\left[\left(\bar{\theta}_B - \underline{k}_{l'} - \tau - U_{l'}\right)^2 - \left(\bar{\theta}_B - k^x_{l'} - \tau - U_{l'}\right)^2\right] \end{array}\right].$$

The equilibrium of the open-economy setting is characterized by $\left(U_l, k^x_l, \kappa_l, \hat{k}_l\right)_{l\in\{H,F\}}$, where the firms' cutoffs in export decision k^x_l, design choice κ_l, and production decision $\hat{k}_l$, are determined as in Proposition 6, and consumer's payoff U_l satisfies equation (26). Explicitly solving for the equilibrium is complicated as it involves solving a system of cubic equations. In the subsection below, we provide some numerical simulations of the model, which illustrates the welfare effect of trade liberalization discussed in the previous subsection.

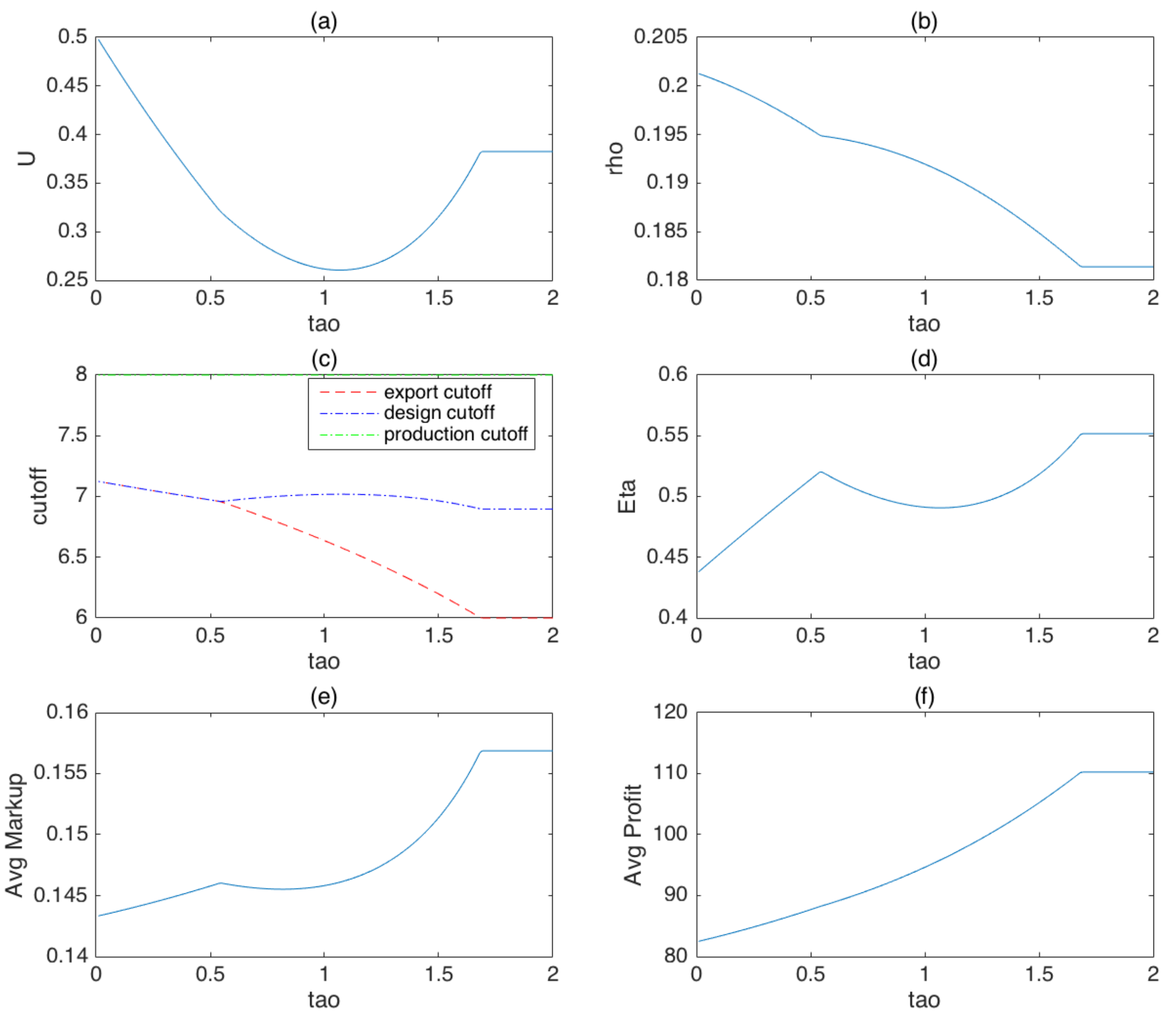
4.2.2 Numerical Simulation

In the numerical simulation below, we assume the two countries are completely symmetric. Specifically, we set $c = 0.1$, $\underline{k}_l = 6$, $\bar{k} = 8$, $\phi_x = 30$, $n_l = 10000$, $M_l = 100$, $\bar{\theta}_N = 10$, $\underline{\theta}_N = 0$, $\bar{\theta}_B = 9$, and $\underline{\theta}_B = 5$.

Figure 1 shows how our endogenous variables in the equilibrium change with the unit export cost τ. Panel (c) shows that when the export cost is high, there is no trade between the countries, as the export cutoff is constant at $\underline{k}_l$. As the export cost decreases, somewhere around 1.6, the most efficient firms begin to export. Interestingly, consumer welfare first goes down as firms start exporting and then goes up with further trade liberalization. This non-monotonic behavior of consumer welfare to trade liberalization is due to the two counteracting effects during this process. On one hand, the share of imported board-design products available in the market increases as more and more firms export in response to a reduction in trade cost τ. These board-design products are quite expensive to import because of the trade cost. Their increasing abundance in the market thus lowers consumer welfare U. On the other hand, the reduction in trade cost τ directly translates into a decrease in the price of exported board-design products, which implies an increase in consumer welfare U. The magnitude of the latter effect gets stronger and stronger as τ decreases because the number of exported goods is larger at a low value of τ. As a result, the former effect dominates at the earlier stage of trade liberalization, whereas the latter effect dominates during later stage of trade liberalization.

The non-monotonic behavior of U has interesting effect on firms' product design choice. A smaller value of U favors the production of board designs, as shown in (17). Intuitively, a smaller value of U implies

Figure 1: Numerical Simulation with Uniform Distributions



that for each consumer visit, there is a higher likelihood that the consumer would make a purchase, as his outside option is not desirable. This in turn implies that each firm effectively faces a larger demand, favoring the adoption of a board design that takes the most advantage of it. As a result, as U decreases at early stage of trade liberalization, a larger fraction of firms choose board designs. The preference for board-design products is reversed when consumer welfare U starts to increase when τ is somewhere around 1.1, as shown by the hump-shape product-design cutoff in Panel (c). This hump-shaped relationship ends when export cutoff and design cutoff meet. As trade is further liberalized, board designs get more attractive due to the profit from the foreign market, and all firms with board designs export.

It can be seen from Panel (d) of Figure 1, the fraction of firms in each country choosing niche product design is non-monotone in trade cost. As τ goes down, the fraction of niche-design firms first decreases, and then increases with further trade liberalization. At a sufficiently low trade cost, the export cutoff and design cutoff meet, and fewer firms adopt niche design as trade is further liberalized. Interestingly, the average markup also exhibits a similar pattern: as τ goes down, it first decreases, then increases when there are more and more niche-design products, and finally decreases after the two cutoffs meet.

Our simulation results show that trade liberalization could have a negative impact on welfare if the selection effect (more efficient firms export) is smaller than the composition effect (share of niche-design products decreases) at certain stages of trade liberalization. Moreover, the effects of trade liberalization on consumer welfare and average markup could be non-monotonic. It is possible that for some stages of trade liberalization, it has an anti-competitive effect (markup increases) due to an increase in the share of niche-design products in the market.

5 Concluding Remark

In this paper, we propose a simple model that incorporate firms' product-design choice into an international trade setting. Our main message is that a comprehensive evaluation of the welfare effect of trade liberalization must take firms' product-design decisions into account. Our analysis reveals a number of novel effects of trade liberalization that have previously been overlooked by the literature. To illustrate these effects most transparently, we have abstracted away from a lot of potentially relevant considerations, and future research could enrich our analysis by incorporating these considerations. For example, one can enrich our model by allowing firms to export niche products abroad. While our possibility results remain robust as long as the absolute disadvantage of supplying niche products in foreign markets is sufficiently large, such an extension can yield other predictions consistent with empirical studies. Another promising direction for future research is to consider how the expansion of shopping platforms, such as Amazon and Taobao, into overseas markets affect individual firms' choice in product design and consequently consumer welfare. Finally, the industrial organization literature has used models of location competition (such as Hotelling and Salop) to study product differentiation. It will be interesting to see whether such a modelling approach would lead to other novel insights additional to those discussed in this paper.

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