Quality Standards, International Trade and the Evolution of Industries

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Abstract: We study the impact of public quality standards on industry structure and trade when firms may be able to develop their own private standard with a higher quality than the public standard. To reach our goal, we introduce vertical differentiation in an international trade model based on monopolistic competition in which firms differ in terms of their productivity and select non cooperatively the quality of their product. Firms must incur two fixed export costs when exporting to any given destination: a generic one (i.e., setting up a distribution system) and a destination-specific one to meet the quality standard prevailing in the importing country. Variable costs are also increasing in quality. Not surprisingly, the absolute mass of firms in any given country is decreasing in the domestic standard, but contrary to popular wisdom, the relative mass (market share) of foreign firms is increasing in the domestic standard. A relatively lower (higher) wage (labour endowment) in the exporting country helps foreign firms gain market share in the domestic market. We also show that the ratio of minimum productivity required for foreign firms and for domestic firms to be active in the domestic market is increasing in trade costs, but decreasing in quality. The implication for public policy is that lowering tariffs and increasing quality standards benefit highly productive foreign firms which gain from the quality-induced exit of less productive domestic and foreign firms. Welfare is concave with respect to quality and governments have an incentive to impose standards, but some firms have an incentive to impose higher private standards.

Keywords: quality standards, industry configuration, welfare.
JEL Classification:

1. Introduction

Public and private quality standards have become increasingly common in the aftermath of epizootics, like the Bovine Spongiform Encephalopathy, and well-publicized cases of bacterial contamination, like the 2006 spinach contamination in the United States. Fulponi (2006) reports that major OECD food retailers have responded to such crises by imposing minimum quality standards on an increasingly wide set of food products, even though all interviewed retailers agreed that governments should be responsible for setting minimum standards because of their scientific capacity. Retailers commonly impose standards on upstream suppliers, but Giraud-Héraud et al. (2012) show that more stringent joint private standards need not reduce risk. Interest in the incidence of public quality standard on welfare predates the "mad cow crisis" and other epizootics. In an oligopoly setting, Das and Donnenfeld (1989) and Larue and Lapan (1992) showed that minimum quality limits tend to decrease welfare. In a duopoly setting, Lutz, Lyon and Maxwell (2000) find that the high-quality firm can induce the government to use a weaker public standard that end up reducing welfare by committing to a quality standard before the government regulates. However, less is known about new trade theory and public and private standards, even though recent contributions have allowed for vertical product differentiation.

New trade theory emphasizes that it is individual firms that do the exporting and the importing, not countries. Early models based on monopolistic competition had all firms export to all destinations. This ran counter to the fact that only a fraction of firms in developed and developing economies are involved in international trade (Bernard et al., 2011a, p.2). Melitz (2003) provided a most convincing explanation for the so-called "zero" problem by positing that the productive capacity of firms is distributed according to a Pareto distribution[1] and that only firms that are productive enough can overcome an additional (fixed) cost to export.[2] As in Krugman's (1980) seminal contribution, Melitz's model is one of horizontal product differentiation. There has been much interest recently in the introduction of vertical quality differentiation to explain certain regularity found in international trade data. Kugler and Verhoogen (2012) allow for vertical differentiation in product quality to explain why larger plants tend to specialize in higher quality products and pay higher input prices. In one variant of their extended Melitz's (2003) model, they consider plant productivity and input quality to be complements in generating output quality while in a second variant the technology for product quality is given by a Leontief production function making the level of input quality proportional to a sunk investment in quality. They found evidence that larger, more productive Columbian plants operating in industries in which there is more scope for vertical quality

[1] Redding (2010, p.13) justifies the popularity of the Pareto distribution by noting that a Pareto distributed random variable truncated from below remains Pareto distributed and that a power function of a Pareto random variable is Pareto distributed. This makes the analysis tractable in the case of a CES demand system because revenue is a power function of productivity.

[2] Developments in econometric estimation that address the heterogeneity of firms have been proposed by Helpman, Melitz and Rubinstein (2008).

differentiation (proxied by R&D and advertising intensity) tend to specialize in higher quality products and pay more for their inputs. Crozet, Head and Mayer (2012) argue that firms that export to a larger number of destinations tend to price their goods more dearly. Their analysis revolves around the lesser known interpretation of Melitz's (2003) productivity term as a demand-shifting quality variable as opposed to a cost shifter. Their empirical analysis is based on the Champagne industry because it is one for which a direct measure of product quality exists. Trade liberalization impacts on the behavior of heterogeneous agri-food firms have been analyzed by Chevassus-Lozza, Gaigné and LeMener (2012). They find that larger more productive firms can better take advantage of lower input prices stemming from agricultural trade liberalization. As a result, the number of firms active on export market may fall in response to trade liberalization. They use firm-level French data spanning several agri-food sub-sectors to document the shift in market share on export markets from low to highly productive firms. Trade liberalization does not only make winners and losers between industries as in trade models with sector-specific factors, but there are clearly winners and losers within a given industry and this has nothing to do with Stolper-Samuelson effects.

Our analysis, like the aforementioned ones, proposes an extension to Melitz's (2003) model, but it differs by focussing on public and private quality standards as public policy instruments and strategic profit-enhancing tools for firms. Since vertical differentiation and public standards are typical in the food manufacturing industry, we use it to motivate our analysis. Countries have developed their own set of standards with some guidance from the *Codex Alimentarius* and the World Trade Organization's Sanitary and Phytosanitary Agreement. However, epizooties that have shaken consumer confidence in their country's ability to regulate food supply chains and insure that the food sold in grocery store is safe. As a result, several private firms have invested in the development of their own food standards.

We found results that have interesting policy implications. For instance, the relative mass (market share) of foreign firms is increasing in the level of the standard imposed by an importing country. Furthermore, a relatively lower (higher) wage (labour endowment) in the exporting country helps foreign firms gain market share in the domestic market, but the ratio of minimum productivity required for foreign firms and for domestic firms to be active in the domestic market is increasing in trade costs, but decreasing in quality. The implication for public policy is that lowering tariffs and increasing quality standards benefit highly productive foreign firms which gain from the quality-induced exit of less productive domestic and foreign firms.

2. Model

We rely on a Melitz-like model of international trade in which firms have heterogenous productivity and consumers in *K* countries have identical Spence-Dixit-Stiglitz preferences. We introduce vertical product differentiation in a more general manner than Kugler and Verhoogen (2012). Quality is valued by consumers and the technology is such that quality increases entail increases in fixed and variable costs on firms. We consider a single period of production, but we can easily extend our framework to multiple periods by assuming an exogenous probability about the survival of firms as in Melitz (2003). In what follows, we describe the economy for a given distribution of standards, prices and mass of firms. In the next sections, prices and the mass of firms are determined with respect to different regimes (public versus private) of standards.

A. Preferences and demand

Consumers have identical Cobb-Douglas preferences over differentiated products and a homogeneous aggregate good. We posit a CES sub-utility function for the differentiated products:

$$U = \left(\left[\int_{\Omega_\upsilon} \theta(\upsilon)^\beta q(\upsilon)^{\frac{\varepsilon-1}{\varepsilon}} \mathrm{d}\upsilon \right]^{\frac{\varepsilon}{\varepsilon-1}} \right)^{\kappa} z^{1-\kappa} \quad (1)$$

where q and θ_j is the quantity and quality purchased for each variety, Ω_υ is the set of varieties available in the country, ε is the substitution elasticity between varieties and z the homogenous aggregate good whose price is normalized at 1. This is a generalization of the utility function used in Kugler and Verhoogen (2012) which restricts β to be equal to $(\varepsilon-1)/\varepsilon$. Each country selects its standard $\theta(\upsilon)$. This standard is a scalar that embodies a very large number of standards like pesticide residue limits, veterinary drugs, additives and manufacturing processes. Even if two importing countries have the same score, they are assumed to have different standards. For example, they might have the same average pesticide residue limit, but their limits on a given pesticide might differ. When governments choose standards, these standards apply to all products marketed in the domestic market whether they are manufactured by foreign or by domestic firms. Thus, in this instance there is a single θ_j for each country. However, private standards can discriminate across sources, then more generally we define the standard imposed by country j on exports from country i by θ_{ij}.

The equilibrium demand for a variety produced in country i is given by:

$$q_{ij} = p_{ij}^{-\varepsilon} \theta_{ij}^{\beta\varepsilon} P_j^{\varepsilon-1} L_j \quad (2)$$

where p_{ij} / θ_j is the quality-adjusted price of variety-υ, P_j is the price index in country j and L_j is the part of the total labor force in country *j* allocated to the differentiated product sector (i.e., $L_j \equiv \kappa \bar{L}_j$). Hence, the expenditures for a variety produced in country i is:

$$p_{ij} q_{ij} = \theta_{ij}^{\beta\varepsilon} p_{ij}^{1-\varepsilon} P_j^{\varepsilon-1} L_j \quad (3)$$

with the price index defined as:

$$P_j^{1-\varepsilon} = \sum_k^K \int_\varphi \theta_{kj}^{\beta\varepsilon} \left[p_{kj}(\varphi) \right]^{1-\varepsilon} M_{kj} \mu_{kj}(\varphi) \mathrm{d}\varphi \tag{4}$$

where M_{kj} is the mass of varieties produced in country k and consumed in country j and $\mu_{kj}(\varphi)$ is the *ex post* distribution of productivity conditional on a variety produced in country k and consumed in country j over a subset of $[1,\infty)$. Note that for a given mass of firms and prices, the price index reacts negatively in response to a generalized increase in quality.

B. Technology and profits

The aggregate good z is produced under constant returns to scale, with one unit of labor producing one unit of good z, by competitive firms. Intersectoral labor mobility implies that the wage rate equals 1.

In the differentiated sector, serving country j implies a fixed distribution cost f_{ij} which is specific to each destination with $f_{jj} < f_{ij}$ when $j \neq i$. For simplicity, we assume that $f_{ki} = f_{ii} + f_k$. Firms must also incur two additional costs which are standard-specific. Firms have to pay a fixed cost ϕ_{ij} to cover expenses associated with the implementation of new technology and additional labor training to operate in country *j*. We assume that it is increasing with the level of quality embodied in the standard:

$$\phi_{ij} = \theta_{ij}^{\eta} / \eta \tag{5}$$

where $\eta > 0$.

We also assume that serving country j causes a shift in variable costs because firms have to adapt their product for each country. To meet the standard applied in country j, a firm must hire additional labor units $\delta_j q_{ij} / \varphi$ with q_{ij} the exports, φ the productivity of the firm and $\delta_j \geq 1$ the productivity shifter due to the standard adopted in country j. We assume that the productivity shifter increases with quality θ. For simplicity, we consider $\delta_j = \theta_j^{\alpha}$. Hence, the production costs incurred by a firm producing variety υ located in country i is given by

$$C_i(\upsilon) = \sum_j^K \left(\frac{\theta_{ij}^{\alpha} q_{ij} \tau_{ij}}{\varphi} + \frac{\theta_{ij}^{\eta}}{\eta} + f_{ij} \right) = \sum_j^K \left(c_{ij} q_{ij} + \frac{\theta_{ij}^{\eta}}{\eta} + f_{ij} \right)$$

and the profit of the firm producing variety ω located in country i is given by:

$$\pi_i = \sum_j^K \left[\left(p_{ij} - \theta_{ij}^{\alpha} \frac{\tau_{ij}}{\varphi} \right) q_{ij} - \frac{\theta_{ij}^{\eta}}{\eta} - f_{ij} \right] \tag{6}$$

Firms produce under monopolistic competition. They maximize profit, treating the price index P_j as a constant, but from (2) they are indirectly connected through the price index.

Firms have to pay a sunk entry cost equal to f_e units of labor and do not know *a priori* their productivity. A risk neutral firm enters the market as long as the expected value of entry is higher then the sunk entry cost. The expected profit of a manufacturer prior to entering the market is given by $[1-G(\varphi_{ii})]\overline{\pi}_i$ where $[1-G(\varphi_{ii})]$ is the probability to enter the market and $\overline{\pi}_i$ is the espected profit conditional on succesful entry. We have:[3]

$$\overline{\pi}_i = \sum_j^K \lambda_{ij} \int_{\varphi_{ij}}^{\infty} \pi_{ij} \frac{g(\varphi)}{1-G(\varphi_{ij})} \mathrm{d}\varphi \tag{7}$$

where $\lambda_{ij} = [1-G(\varphi_{ij})]/[1-G(\varphi_{ii})]$ is the probability to serve country j conditional on succesful entry. To simplify the analysis, we specify the distribution of productivity. As in Arkolakis et al. (2008), we assume φ follows a Pareto distribution over $[1,+\infty)$ with shape parameter γ (with $\gamma > \varepsilon - 1$) and with lower productivity bound $\varphi_{\min}$ ($G(\varphi) \equiv 1 - \varphi^{-\gamma} / \varphi_{\min}^{-\gamma}$ and $g(\varphi) = \gamma \varphi_{\min}^{\gamma} \varphi^{-\gamma-1}$). We normalize $\varphi_{\min}$ to *1*.

3 Public standards and industrial structure

In order to disentangle the various effects at work, it is convenient to start our analysis by considering public standards which from the firms' standpoint can be treated as parameters, i.e. $\theta_{ij} = \theta_j$ regardless of the country of origin. We assume that all firms selling to country j must incur expenses to meet the public standard θ_j. In the absence of private standards, the fixed cost to meet the standard in country j is the same for all firms regardless of country of origin and $\phi_{ij} = \phi_j$. We can then modify (2) and define a firm's output under public standards as: $q_{ij} = \theta_j^{\beta\varepsilon} p_{ij}^{-\varepsilon} P_j^{\varepsilon-1} L_j$. Conditional on the public standard, profit maximization yields the following equilibrium price:

$$p_{ij}^* = \frac{\varepsilon}{\varepsilon - 1} \frac{\tau_{ij}}{\varphi} \theta_j^{\alpha} \tag{8}$$

which implies the usual constant mark-up relation: $(p_{ij}^* - c_{ij}) / p_{ij}^* = 1/\varepsilon$. The price is increasing in the quality standard, but decreasing in the productivity of firms. Even though there is no vertical quality differentiation, prices differ across firms because of

[3] We do not use the expectation operator to simplify the notation.

horizontal quality differentiation. The volume produced by firms is increasing in the productivity of the firm. To see this, consider two firms with productivity $\varphi_1 > \varphi_2$ then it can be shown from (8) and (2) that $\frac{q_1}{q_2} = \left(\frac{\varphi_1}{\varphi_2}\right)^{\varepsilon}$. Thus, more productive firms produce more than less productive ones. Profit can then be written as:

$$\pi_{ij} = \frac{\varphi^{\varepsilon-1}}{\varepsilon}\left(\frac{\varepsilon\tau_{ij}}{\varepsilon-1}\right)^{1-\varepsilon}\theta_j^{\Lambda}P_j^{\varepsilon-1}L_j - \left(\phi_j + f_{ij}\right) \tag{9}$$

with

$$\Lambda \equiv \beta\varepsilon - \alpha\left(\varepsilon-1\right) \tag{10}$$

Because $\varepsilon - 1 > 0$, the profit of a incumbent firm based in country *i* is increasing in φ, its productivity level. When the minimum productivity increases, the level of competition decreases and the demand faced by the remaining firms is larger.

A. Entry and mass of firms

A firm serves country j if and only if $\pi_{ij}^{*} > 0$. From the constant mark-up relation, the weakly positive profit condition can be expressed as $p_{ij}^{*}q_{ij}^{*} > \varepsilon(\phi_j + f_j)$ or, equivalently, in terms of a minimum productivity threshold φ_{ij} for market j given by

$$\varphi_{ij}^{\varepsilon-1} \equiv \theta_j^{-\Lambda}\left(\frac{\varepsilon\tau_{ij}}{\varepsilon-1}\right)^{\varepsilon-1}\frac{\varepsilon(\phi_j + f_{ij})}{L_j P_j^{\varepsilon-1}} \tag{11}$$

Setting $f_{ij} = 0$ and $\tau_{ij} = 1$ when $j = i$, we can define the minimum productivity of firms from country i to operate in their own market:

$$\varphi_{ii}^{\varepsilon-1} = \theta_i^{-\Lambda}\left(\frac{\varepsilon}{\varepsilon-1}\right)^{\varepsilon-1}\frac{\varepsilon(\phi_i + f_{ii})}{L_i P_i^{\varepsilon-1}} \tag{12}$$

and derive the ratio of minimum productivities required for foreign and domestic firms to operate in the domestic market:

$$\frac{\varphi_{ki}}{\varphi_{ii}} = \tau_{ki}\left(1 + \frac{f_k}{\phi_i + f_{ii}}\right)^{\frac{1}{\varepsilon-1}} \tag{13}$$

Note that the ratio of minimum productivities is decreasing in the standard-related fixed cost: $\partial\left(\varphi_{ki}/\varphi_{ii}\right)/\partial\phi_i < 0$.

By using the labor market clearing in country i (see Appendix B.2) the mass of firms producing in country i is given by:

$$M_i = \frac{L_i(\varepsilon - 1)}{\varphi_{ii}^{\gamma} f_e \gamma \varepsilon} \tag{14}$$

Similar expressions can be found in the litterature (e.g., equation (4) in Arkolakis et al., 2008). The notable difference in our expression is that ϕ_i impacts the mass of firms through φ_{ii} as noted in (12) which is conditioned by exogenous variables and the price index P_i. From appendix B.3, the price index can be expressed only in terms of exogenous variables and when we plug this expression in (12), we obtain the equilibrium minimum productivity of domestic firms to be active in the domestic market:

$$\varphi_{ii}^{\gamma} = \frac{\varepsilon - 1}{\gamma - (\varepsilon - 1)} \frac{\phi_i + f_{ii}}{f_e} \frac{1}{L_i} \sum_k \frac{L_k}{\tau_{ki}^{\gamma}} \left(1 + \frac{f_k}{\phi_i + f_{ii}}\right)^{\frac{-\gamma+\varepsilon-1}{\varepsilon-1}}$$

It is easy to show that increases in the fixed cost required to meet the domestic standard cause the minimum productivity to increase: $\partial \varphi_{ii} / \partial \phi_i > 0$.

The mass of foreign firms producing country in j and serving country i is given by:

$$M_{ki} = \frac{M_j \varphi_{kk}^{\gamma}}{\varphi_{ki}^{\gamma}} = \frac{L_k(\varepsilon - 1)}{\varphi_{ki}^{\gamma} f_e \gamma \varepsilon} \tag{15}$$

with

$$\varphi_{ki}^{\gamma} = \frac{\varepsilon - 1}{\gamma - (\varepsilon - 1)} \frac{(\phi_i + f_{ii})}{f_e} \frac{\tau_{ki}^{\gamma}}{L_i} \left(1 + \frac{f_k}{\phi_i + f_{ii}}\right)^{\frac{\gamma}{\varepsilon-1}} \sum_k \frac{L_k}{\tau_{ki}^{\gamma}} \left(1 + \frac{f_k}{\phi_i + f_{ii}}\right)^{1+\frac{-\gamma}{\varepsilon-1}} \tag{16}$$

where we have used (11) and the price index in appendix B.3. The share of foreign firms serving the domestic country is:

$$\frac{M_{ki}}{M_i} = \tau_{ki}^{-\gamma} \left(\frac{L_k}{L_i}\right) \left(1 + \frac{f_k}{\phi_i + f_{ii}}\right)^{\frac{-\gamma}{\varepsilon-1}}.$$

PROPOSITION 1: *Foreign firms have a larger market share when trade costs are low and the fixed cost* ϕ_i *required to meet the public standard is high.*

The intuition behind this result is that the relative advantage of domestic firms in terms of fixed costs, $\frac{\phi_i + f_{ii} + f_k}{\phi_i + f_{ii}}$, is decreasing with the national standard ϕ_i.

B. Market shares and profits

The sales in country i are given by (3) with $\theta_{ij} = \theta_j$ or equivalently by:

$$p_{ii}q_{ii} = \varepsilon\varphi^{\varepsilon-1}\left\{\frac{\gamma-(\varepsilon-1)}{\varepsilon-1} f_e L_i \left[\sum_k L_k \tau_{ki}^{-\gamma}(\phi_i + f_{ki})^{\frac{-\gamma+\varepsilon-1}{\varepsilon-1}}\right]^{-1}\right\}^{\frac{\varepsilon-1}{\gamma}}$$

where $p_{ii}q_{ii}$ increases with ϕ_i as well as $\partial^2 p_{ii}q_{ii} / \partial\phi_i\partial\varphi > 0$ and $\partial^2 p_{ii}q_{ii} / \partial\phi_i\partial f_{ki} > 0$. By increasing ϕ_i, a higher θ_i increases the sales of surviving domestic firms. The rise of domestic sales is higher the more productive the surviving firms. Because the total market size is constant, $\sum_k \int_{\varphi_{ki}}^{\infty} p(\varphi)q(\varphi)\mu_{ki}(\varphi)\,\mathrm{d}\varphi = L_i$, there is a reallocation of demand from less to more productive firms.

As shown in Appendix B.4, $\pi_{ki} = \varphi^{\varepsilon-1}\varphi_{ki}^{1-\varepsilon}\phi_i - \phi_i$ and it is straightforward to see that:

$$\frac{d\pi_{ki}}{d\phi_i} = \frac{\varphi^{\varepsilon-1}}{\varphi_{ki}^{\varepsilon-1}}\left[1-(\varepsilon-1)\varphi_{ki}^{\varepsilon-1}\phi_i \frac{\partial\varphi_{ki}}{\partial\phi_i}\right]-1,$$

where the term in brackets is positive, as all surviving firms enjoy higher sales when ϕ_i increases, but is lower than 1. For surviving firms with a productivity close to the minimum threshold, $\partial\pi_{ii} / \partial\phi_i < 0$, because the rise in operating profits is not sufficient to cover the increase in fixed costs associated with the higher standard while for highly productive firms, their profit raise with higher fixed costs ϕ_i. Hence:

PROPOSITION 2: *An increase in the public standard forces the exit of some foreign and domestic firms and reduces (increases) the profit of the least (most) productive surviving firms.*

To summarize, a stricter national standard makes winners and losers. The most productive firms gain from having fewer rivals to compete with. Figure 1 illustrates the result. The increase in the national standard raises the minimum productivity level required for a firm to survive. Accordingly, some firms are forced out. The level of profit of a firm is increasing with its productivity, but more so under a stricter/higher standard. As a result, not all surviving firms are better off after the introduction of a stricter standard. Firms with productivity $\varphi \in [\varphi_{ki}, \hat{\varphi}_{ki})$ unambiguously lose under a stricter national standard while more productive firms with $\varphi > \hat{\varphi}_{ki}$ enjoy higher profits.

[Insert Figure 1 about here]

C. The impact of an increase in the public standard on welfare

Individual welfare is given by the real wage which boils down to $V_i = P_i^{-1}$:

$$V_i = \theta_i^{\frac{\Lambda}{(\varepsilon-1)\gamma}} \left(\frac{L_i^{\frac{\gamma-(\varepsilon-1)}{(\varepsilon-1)\gamma}} \varepsilon^{-\frac{\varepsilon}{\varepsilon-1}} (\varepsilon-1)^{\frac{1+\gamma}{\gamma}}}{[\gamma-(\varepsilon-1)]^{\frac{1}{\gamma}} f_e^{\frac{1}{\gamma}}} \right) \left(\sum_k L_k \tau_{ki}^{-\gamma} \left(\frac{\theta_i^\eta}{\eta} + f_{ki} \right)^{\frac{-\gamma+\varepsilon-1}{\varepsilon-1}} \right)^{\frac{1}{\gamma}} \quad (17)$$

Maximizing welfare with respect to the public standard :

$$\frac{\mathrm{d}V_i}{\mathrm{d}\theta_i} = \frac{\Lambda}{(\varepsilon-1)\gamma} \frac{V_i}{\theta_i} - \left(\frac{\gamma-(\varepsilon-1)}{(\varepsilon-1)\gamma} \right) \left(\frac{V_i \sum_k L_k \tau_{ki}^{-\gamma} (\theta_i^\eta / \eta + f_{ki})^{\frac{-\gamma}{\varepsilon-1}}}{\sum_k L_k \tau_{ki}^{-\gamma} (\theta_i^\eta / \eta + f_{ki})^{1-\frac{\gamma}{\varepsilon-1}}} \right) \theta_i^{\eta-1} \quad (18)$$

Common elements can be factored out and it can be shown that (18) is zero when $F_i = 0$:

$$F_i \equiv \frac{\Lambda}{[\gamma-(\varepsilon-1)]\eta} \sum_k L_k \tau_{ki}^{-\gamma} \left(1 + f_{ki}\eta / \theta_i^\eta\right)^{1-\frac{\gamma}{\varepsilon-1}} - \sum_k L_k \tau_{ki}^{-\gamma} \left(1 + f_{ki}\eta / \theta_i^\eta\right)^{\frac{-\gamma}{\varepsilon-1}}$$

Because $sign\{\partial F_i / \partial \phi_i\} = -sign\{\partial F_i / \partial f_{ki}\}$, we can infer :

$$\frac{\partial \theta_i}{\partial f_{ki}} = \frac{\partial \theta_i}{\partial \phi_i} \frac{\partial \phi_i}{\partial f_{ki}} = \frac{\partial \theta_i}{\partial \phi_i} \left(-\frac{\partial F_i}{\partial f_{ki}} / \frac{\partial F_i}{\partial \phi_i} \right) > 0$$

Thus, countries with higher levels of fixed distribution costs f_{ki} can set higher standards, where:

$$\frac{\partial F_i}{\partial \phi_i} = \frac{\gamma}{\varepsilon-1} \frac{f_{ki}}{\phi_i^2} \left\{ \frac{[\beta\varepsilon - \alpha(\varepsilon-1)]}{\gamma\eta} \sum_k L_k \tau_{ki}^{-\gamma} w_k^{\frac{-\gamma\varepsilon+\varepsilon-1}{\varepsilon-1}} \left(1 + \frac{f_{ki}}{\phi_i}\right)^{-\frac{\gamma}{\varepsilon-1}} - \frac{f_{ki}}{\phi_i^2} \sum_k L_k \tau_{ki}^{-\gamma} w_k^{\frac{-\gamma\varepsilon+\varepsilon-1}{\varepsilon-1}} \left(1 + \frac{f_{ki}}{\phi_i}\right)^{\frac{-\gamma}{\varepsilon-1}-1} \right\}$$

4. Private standards

We now consider that firms can choose freely their standard for each market. In other words, θ_{ij} is determined non cooperatively by each firm. As we will see below, although each firm operates under monopolistic competition, their standard is related to the standard of their rivals. As a result, the pricing decision of firms interacts with their vertical differentiation strategy.

A. The firms' setting of standards and prices

With private standards, there is discrimination across exporting countries and generally

$\phi_{kj} \neq \phi_{ij}$ whether the exporting firms from countries *k* and *i* have the same productivity or not. The private standard θ_{ij} is endogenous and using (5) we can express the profit of a firm in country *i* as:

$$\pi_i(\upsilon) = \sum_j^K \left[\left(p_{ij} - \theta_{ij}^{\alpha} \frac{\tau_{ij}}{\varphi} \right) q_{ij} - \left(\frac{\theta_{ij}^{\eta}}{\eta} + f_{ij} \right) \right] \quad (19)$$

where the quantity is given by (2). Firms optimize on price and their private standard. From the first order condition with respect to price, we can show that:

$$p_{ij}^{*} = \frac{\varepsilon}{\varepsilon - 1} \frac{\tau_{ij}}{\varphi} \theta_{ij}^{\alpha} \quad (20)$$

As in the case of the public standard, the price is equal to a constant mark-up times a marginal cost which now depends not only on the firm's productivity but also on its own standard. From $\partial \pi_i / \partial \theta_{ij} = 0$, we find :

$$\Lambda \frac{p_{ij} q_{ij}}{\varepsilon} - \theta_{ij}^{\eta} = 0 \quad (21)$$

It can be shown that the second order condition requires that $\eta > \Lambda$. By rising its standard, a firm increases its operating profits (sales minus costs associated with the level of production) as long as Λ>0, but its fixed costs associated with the quality of product shifts upward. Note that $\theta \to \theta_{\min}$ if $\Lambda < 0$. This latter condition means that if quality is not sufficiently valued by consumers or the elasticity of marginal costs to a change in quality is too high relative to the mark-up, then firms adopt the minimum quality. When the inequality is reversed, an interior solution is possible. Under these circumstances, the profit from market *j* evaluated at the equilibrium prices and quality is:

$$\pi_{ij} = \frac{\eta - \Lambda}{\eta \Lambda} \theta_{ij}^{\eta} - f_{ij} = \frac{\eta - \Lambda}{\eta} \frac{p_{ij} q_{ij}}{\varepsilon} - f_{ij} \quad (22)$$

which is positive given that $\eta > \Lambda$. As expected, (22) is increasing with the quality standard. By plugging (20) into (3), we obtain the sales of a φ-firm from each market (or operating profits up to a constant) :

$$p_{ij} q_{ij} = \theta_{ij}^{\Lambda} \varphi^{\varepsilon - 1} \left(\frac{\varepsilon}{\varepsilon - 1} \tau_{ij} \right)^{1-\varepsilon} P_j^{\varepsilon - 1} L_j \quad (23)$$

which are increasing with market size and the firm's standard and productivity, but decreasing with trade costs. However, the level of standard is related to the productivity of the firm. Indeed, (23) and (21) generate the standard set by a φ-firm:

$$\theta_{ij} = \left[\frac{\Lambda}{\varepsilon} \left(\frac{\varepsilon}{\varepsilon - 1} \right)^{1-\varepsilon} \tau_{ij}^{\ 1-\varepsilon} \varphi^{\varepsilon - 1} P_j^{\varepsilon - 1} L_j \right]^{\frac{1}{\eta - \Lambda}}. \quad (24)$$

Hence, the level of standard of a firm increases with its productivity and market size but depends also on the standards detemined by its rivals through the price index which is now given by:

$$P_j^{1-\varepsilon} = \sum_k^K \left(\frac{\varepsilon}{\varepsilon - 1} \frac{\tau_{kj}}{\varphi} \right)^{1-\varepsilon} \int_\varphi \theta_{kj}^{\Lambda} \varphi^{\varepsilon-1} M_{kj} \mu_{kj}(\varphi) \mathrm{d}\varphi \tag{25}$$

More precisely, when the average standard of rivals increases, the price index declines inducing a lower demand, *ceteris paribus*. This is a competition effect, known also as a market crowding effect (Baldwin et al., 2003) because the markup over the marginal cost never changes. Under these circumstances, all firms are prompted to shift downward their standard to reduce fixed costs assciated with quality because sales and, in turn, operating profit (22) decrease. This response is more pronounced for more productive firms.

B. Productivity cutoff, minimum quality, the distributions of quality and firm size

We determine the minimum quality for a given productivity cutoff (or a given mass of firm). Because the relationship between quality and productivity is positive, a firm with higher productivity adopts a higher quality standard. Therefore, the firm which is indifferent between producing and exiting (the firm with $\pi_{ij} = 0$) chooses the following minimum standard:

$$\underline{\theta}_{ij}^{\eta} = \frac{\eta \Lambda}{\eta - \Lambda} f_{ij} \tag{26}$$

where Λ is defined as in (10). We can now expressed the price index as a function of the minimum quality and productivity cutoffs (defined as $\underline{\varphi}_{ij}$). The sales (see (22)) of the marginal firm having a profit equal to zero on market *j* ($\pi(\underline{\varphi}_{ij}) = 0$) are such that:

$$P_j^{\varepsilon-1} = \frac{\eta}{\eta - \Lambda} \frac{\varepsilon f_{ij}}{L_j} \left(\frac{\varepsilon \tau_{ij}}{\varepsilon - 1} \right)^{\varepsilon-1} \underline{\theta}_{ij}^{-\Lambda} \underline{\varphi}_{ij}^{1-\varepsilon} = \frac{\varepsilon}{\Lambda L_j} \left(\frac{\varepsilon \tau_{ij}}{\varepsilon - 1} \right)^{\varepsilon-1} \left(\frac{\eta \Lambda f_{ij}}{\eta - \Lambda} \right)^{\frac{\eta-\Lambda}{\eta}} \underline{\varphi}_{ij}^{1-\varepsilon}. \tag{27}$$

Hence, higher minimum quality implies a fall in the price index for a given productivity cutoff. Plugging (27) into (24) we get the optimal standards of firms with productivity above the minimum cutoff $\left(\varphi > \underline{\varphi}_{ij} \right)$:

$$\theta_{ij} = \left[\left(\frac{\eta \Lambda}{\eta - \Lambda} \right) f_{ij} \left(\frac{\varphi}{\underline{\varphi}_{ij}} \right)^{\varepsilon-1} \underline{\theta}_{ij}^{-\Lambda} \right]^{\frac{1}{\eta-\Lambda}} = \left(\frac{\eta \Lambda f_{ij}}{\eta - \Lambda} \right)^{\frac{1}{\eta}} \left(\frac{\varphi}{\underline{\varphi}_{ij}} \right)^{\frac{\varepsilon-1}{\eta-\Lambda}} \tag{28}$$

For two firms with productivities $\varphi > \varphi' > \underline{\varphi}_{ij}$, it follows that the spread in their quality increases with the spread between their productivities because $\frac{\theta_{ij}}{\theta_{ij}'} = \left(\frac{\varphi}{\varphi'} \right)^{\frac{\varepsilon-1}{\eta-\Lambda}}$. The quality supplied by a firm increases with its productivity and fixed cost. High fixed costs make it harder to export and as a result more productive firm do not have to bid up quality to get their share of the market.

From (28) and (23), we can infer that an increase in the minimum quality has a negative effect on sales, through the firm's quality choice and price index. However, the gains in terms of profits associated with an increasing minimum quality are higher for the more productive firms. This can be seen by combining (23), (27), (28) and (22) to obtain the following expression for profit:

$$\pi_{ij} = f_{ij}\left(\frac{\varphi}{\underline{\varphi}_{ij}}\right)^{\frac{\eta(\varepsilon-1)}{\eta-\Lambda}} - f_{ij} \tag{29}$$

Profits increase unambiguously with the firm's productivity even though the fixed costs related to the level of quality increases. The gain accruing to more productive firms is even larger when consumers value more quality, that is when β and hence Λ are larger. Inserting (28) into (20), we obtain the equilibrium price under the private standard regime:

$$p_{ij} = \left(\frac{\varepsilon\tau_{ij}}{\varepsilon-1}\right)\left(\frac{\eta\Lambda f_{ij}}{\eta-\Lambda}\right)^{\frac{\alpha}{\eta}} \varphi^{\frac{\beta\varepsilon-\eta}{\eta-\Lambda}} \underline{\varphi}_{ij}^{\frac{\alpha(1-\varepsilon)}{\eta-\Lambda}} \tag{30}$$

The price is increasing (decreasing) in productivity if $\beta\varepsilon > (<) \eta$. Similarly, the operating scale is not necessarely affected postively by the firm's productivity. To get additional insight, we derive the volume produced by a firm by dividing revenue, (23), by the price, (20), and by using (28):

$$q_{ij} = \left(\frac{1}{\underline{\varphi}_{ij}}\right)^{\frac{(\varepsilon-1)(\Lambda-\alpha)}{\eta-\Lambda}} \varphi^{\frac{(\eta-\beta)\varepsilon}{\eta-\Lambda}} \left(\frac{\varepsilon\tau_{ij}}{\varepsilon-1}\right)^{-\varepsilon} P_j^{\varepsilon-1} L_j \tag{31}$$

More productive firms produce more when the minimum private standard is higher only if $\eta > \max\{\beta, \beta\varepsilon - \alpha(\varepsilon-1)\}$. From the second order condition of the firms' profit maximization, we already had established that : $\eta > \Lambda \equiv \beta\varepsilon - \alpha(\varepsilon-1)$. However, $\eta \in \{\beta\varepsilon - \alpha(\varepsilon-1), \beta\}$ cannot be ruled out and in this domain more productive firms end up producing less. The fixed cost parameter being smaller and the marginal cost of quality α being higher, a highly productive firm end up producing a lesser volume. This is illustrated in Figure 2 where the region to the left of the Λ-line defines the region of admissible η, β values. The effect of higher productivity on a firm's output and price is sensitive to the speed at which fixed cost is increasing in quality (i.e, η) relative to the appreciation of vertical quality differentiation by consumers (i.e., β). At low values of β, $\beta > \Lambda$ and $\frac{\partial q_{ij}}{\partial \varphi} \underset{<}{\geq} 0$ as $\eta \underset{<}{\geq} \beta$. Kugler and and Verhoogen (2012, p.325) reaches a similar ambiguous conclusion using a model with a less general utility function and different assumptions on technology. This contrasts with our result under the public standard and standard results in Melitz-like models without vertical product differentiation. On the other hand, the quantity of labor used by a firm is increasing in its productivity, as shown in appendix B.5. It also worth noting that more productive firms end up setting lower prices when η is high.

[Insert Figure 2 about here]

Figure 3 illustrates the choices made by two firms where the vertical axis is price and the horizontal one is quality. The p-curve corresponds to the first order condition with respect to price. The lower p-curve is associated with a higher productivity firm. The θ -curve represents the first order condition with respect to quality. The intersection of the two curves determine the equilbrium choices for the two firms. The high productivity firm selects a higher quality level and a higher price relative to the low productivity firm, an outcome reminiscent of the Kugler and Verhoogen (2012).

[Insert Figure 3 about here]

C. Entry and mass of firms

The mass of firms is calculated in Appendices C.1 and C.2 and it is given by:

$$M_i = \frac{L_i\left(\varepsilon-1\right)}{\varphi_{ii}^{\gamma} f_e \gamma\varepsilon} \frac{\eta}{\eta-\Lambda} \frac{\eta\varepsilon}{\Lambda+\eta\varepsilon} \quad (32)$$

Note that:

$$\underline{\varphi}_{ij}^{\gamma} = \left(\frac{\varepsilon-1}{f_e}\right)\left(\frac{\varepsilon\eta}{\Lambda+\eta\varepsilon}\right)\left(\frac{\eta}{\eta-\Lambda}\right)^2 \left(f_{ij}^{\frac{(\eta-\Lambda)\gamma}{\eta(\varepsilon-1)}} \frac{\tau_{ij}^{\gamma}}{L_j}\right)\left(\sum_{k}^{K} \frac{L_k}{\tau_{kj}^{\gamma}} f_{kj}^{1-\frac{(\eta-\Lambda)\gamma}{\eta(\varepsilon-1)}}\right) \quad (33)$$

where we have used (24) and the price index defined in Appendix C.3 (see equation (C.3.1)). In addition, the ratio of foreign firms serving the domestic market to the mass of domestic firms is given by

$$\frac{M_{ki}}{M_i} = \frac{\underline{\varphi}_{ii}^{\gamma}}{\underline{\varphi}_{ki}^{\gamma}} \frac{L_k}{L_i} = \frac{L_k}{\tau_{ki}^{\gamma} L_i}\left(\frac{\underline{\theta}_{ii}}{\underline{\theta}_{ki}}\right)^{\frac{(\eta-\Lambda)\gamma}{\varepsilon-1}} = \frac{L_k}{\tau_{ki}^{\gamma} L_i}\left(\frac{f_{ii}}{f_{ki}}\right)^{\frac{(\eta-\Lambda)\gamma}{\varepsilon-1}}.$$

The share of foreign rivals serving the domestic market is positively related to the level of minimum quality supplied by the least productive domestic firm.

PROPOSITION 2: *When the fixed cost advantage of domestic firms gets smaller, the market share of foreign firms increases faster when the fixed cost parameter increases rapidly with quality, horizontal product differentiation is strong, vertical differentiation is weak and the distribution of productivities is less concentrated around the minimum.*

From (33), we can see that an increase in market size decreases the minimum productivity required for firms to survive. An increase in market size would allow low-quality firms to enter the market, but from (28), the lower minimum productivity would induce firms already in the market to boost their quality. However, the overall effect on the average quality supplied is positive:

$$\tilde{\theta}_{ij} = \left(\frac{\eta\Lambda}{\eta - \Lambda} f_{ij} \right)^{\frac{1}{\eta}} \left(\frac{\gamma(\eta - \Lambda)}{\gamma(\eta - \Lambda) - \varepsilon + 1} \right) \underline{\varphi}_{ij}^{-\gamma} \tag{34}$$

Thus, the downward pressure on quality stemming from the entry of low-quality firms following an increase in market size is more than offset by the increase in the quality of existing firms.

5. Public versus private standards

Let us assume now that each country may introduce a standard which sets a minimum quality ($\theta_{\min} = \theta_j$) while firms can implement their own standard as long as $\theta_{ij} \geq \theta_j$. Three cases arise: (i) $\max(\theta_{ij}) < \theta_j$; (ii) $\underline{\theta}_{ij} > \theta_j$; (iii) $\underline{\theta}_{ij} < \theta_j < \max(\theta_{ij})$. If cases (i) and (ii) occurs then the results in sections 3 and 4 apply respectively. Case (iii) is the more interesting configuration under which some firms are constrained to adopt the public standard while the more productive firms set their own standard. Under this configuration, the private standard is given by (24). In this section, we focus on case (iii). Firms that are constrained by the public quality standard will be refered to a c-firms and variables specific to these firms will have a “c” superscript.

A. The impact of a higher public standard on quality and prices

The profit of a public-standard firm and a private-standard firm are given by (9) and (17) respectively where the price index is now defined as

$$P_j^{\varepsilon-1} = \theta_j^{-\Lambda} \left(\frac{\varepsilon\tau_{ij}}{\varepsilon - 1} \right)^{\varepsilon-1} \frac{\varepsilon(\theta_j^{\eta} / \eta + f_{ij})}{L_j} \bar{\varphi}_{ij}^{1-\varepsilon} \tag{35}$$

with $\bar{\varphi}_{ij}$ the minimum productivity to serve profitably country *j* when a fraction of firms adopts a private standard. The effect of the public standard is ambiguous at first glance. However, from (26) and the assumed ranking between the minimum private standard and the public standard tell us that $\underline{\theta}_{ij} = \left(\frac{\eta\Lambda}{\eta - \Lambda} f_{ij} \right)^{\frac{1}{\eta}} < \theta_j$. For a given $\bar{\varphi}_{ij}$, an increase in the public standard raises the price index, as long as $\underline{\theta}_{ij} < \theta_j$. Similarly, there is a positive relation between the two standards:

$$\theta_{ij} = \left[\Lambda \theta_j^{-\Lambda} \left(\frac{\theta_j^\eta}{\eta} + f_{ij} \right) \left(\frac{\varphi}{\overline{\varphi}_{ij}} \right)^{\varepsilon - 1} \right]^{\frac{1}{\eta - \Lambda}}. \tag{36}$$

We investigate the effect an increase in the public on the quantities produced by constrained and non-constrained firms, assuming that the minimum productivity is unchanged. For the constrained firms, $p_{ij}^c q_{ij}^c = \theta_j^{\Lambda} L_j P^{\varepsilon-1} \left(\frac{\varepsilon \tau_{ij}}{\varepsilon - 1} \right) \varphi^{\varepsilon - 1}$, and substituting for the price index using (35), we have $p_{ij}^c q_{ij}^c = \varepsilon \left(\frac{\theta_j^\eta}{\eta} + f_{ij} \right) \left(\frac{\varphi}{\overline{\varphi}_{ij}} \right)^{\varepsilon - 1}$ which when divided by the equilibrium price (8) yields: $q_{ij}^c = \left(\frac{\varepsilon - 1}{\tau_{ij}} \right) \left(\frac{\varphi^\varepsilon}{\overline{\varphi}_{ij}^{\,\varepsilon - 1}} \right) \theta_j^{-\alpha} \left(\frac{\theta_j^\eta}{\eta} + f_{ij} \right)$. This quantity is decreasing if $\alpha > \eta$ or if $\alpha < \eta$ decreasing and $\frac{\theta_j^\eta}{\eta} < \frac{\alpha f_{ij}}{\eta - \alpha}$. For the non-constrained firms, their sales are: $p_{ij} q_{ij} = \frac{\varepsilon}{\Lambda} \left(\Lambda \theta_j^{-\Lambda} \left(\frac{\theta_j^\eta}{\eta} + f_{ij} \right) \left(\frac{\varphi}{\overline{\varphi}_{ij}} \right)^{\varepsilon - 1} \right)^{\frac{\eta}{\eta - \Lambda}}$ and from (20) and (36) their price is: $p_{ij} = \left(\frac{\varepsilon \tau_{ij}}{\varepsilon - 1} \right) \left(\Lambda \theta_j^{-\Lambda} \left(\frac{\theta_j^\eta}{\eta} + f_{ij} \right) \overline{\varphi}_{ij}^{\,1-\varepsilon} \right)^{\frac{\alpha}{\eta - \Lambda}} \varphi^{\frac{(\varepsilon - 1)\alpha}{\eta - \Lambda} - 1}$. Accordingly, their quantity turn out to be $q_{ij} = \left(\frac{\varepsilon - 1}{\Lambda \tau_{ij}} \right) \left(\Lambda \theta_j^{-\Lambda} \left(\frac{\theta_j^\eta}{\eta} + f_{ij} \right) \overline{\varphi}_{ij}^{\,1-\varepsilon} \right)^{\frac{\eta - \alpha}{\eta - \Lambda}} \varphi^{\frac{\varepsilon(\eta - \beta)}{\eta - \Lambda}}$. This quantity is decreasing (increasing) in the public standard if $\alpha > (<) \eta$. Thus, the quantity response of non-constrained firms depends on the relative speed at which variable and fixed cost increase with quality. When fixed costs increase rapidly, all things equal a larger volume is required to break even and this explains why the quantity may increase when the public standard is tightened.

Figure 4a shows the price and quality choices of two firms with different productivities. In the initial situation, there is no binding public standard restricting the firms' choices and the firms' price and quality choices are determined by the intersection of the curves depicting their first order conditions in the price-quality space. The more productive firm chooses a higher quality and a higher price at e_0 while the less productive firm's choices are given by e_0^c. When the public standard is increased, the standard binds on the lower productivity firm as its optimal quality falls short of the public standard θ_i. As a result, it is forced to adopt the public standard and it ends up setting a higher price at e_1^c than it would if it was unconstrained. The more productive firm's response to the higher public standard is unconstrained and is depicted by higher quality and price at e_1. Figure 4b illustrates the same effect as both firms increase their price in response to the increase in the public standard. However, in this case the highly productive firms sells at a lower price than the less productive firm before and after the increase in the public standard. To summarize:

PROPOSITION 3: *After an exogenous increase in the public standard θ_j, firms that still use a private standard use a higher quality standard. The volume produced by firms constrained and unconstrained by the public standard can increase or decrease when the latter is increased.*

PROOF: From (36), $\frac{\partial \theta_{ij}}{\partial \theta_j} = \theta_j^{-\Lambda-1}\left(\frac{\Lambda(\eta-\Lambda)}{\eta}\right)\left(\theta_j^{\eta} - \frac{\eta\Lambda}{\eta-\Lambda} f_{ij}\right) > 0$ as long as the public strandard binds for lower productivity (i.e., $\underline{\theta}_{ij} = \left(\frac{\eta\Lambda}{\eta-\Lambda} f_{ij}\right)^{\frac{1}{\eta}} < \theta_j$). As shown above, $\alpha < \eta$ is sufficient for the quantity sold by unconstrained firms to increase, but this condition is only necessary for the case of constrained firms. We showed that another condition, $\frac{\theta_j^{\eta}}{\eta} > \frac{\alpha f_{ij}}{\eta - \alpha}$ is required for the quantity of constrained firm to increase in response to an increase in the public standard. **QED**

When the public standard offered in a given industry is increased, firms with a private standard choose a higher quality to differentiate themselves from firms adopting the public standard. The latter are constrained in the quality space and as such their profit is suboptimal in relation to the firms that are productive enough to have their higher private standards. The fact that the quantity and quality of a product sold by a given firm can move in the same direction constrasts with results obtained from oligopoly models with endogenous quality. In these models, quantity and quality are substitutes because of their effect on the marginal cost of firms (see fig.1 in Das and Donnenfeld, 1989).

B. The selection of private-standard and public-standard firms

The profit of firms adopting the public standard to serve country *j* is given by

$$\pi_{ij}^{c} = \left(\frac{\theta_j^{\eta}}{\eta} + f_{ij}\right)\left(\frac{\varphi}{\overline{\varphi}_{ij}}\right)^{\varepsilon-1} - \left(\frac{\theta_j^{\eta}}{\eta} + f_{ij}\right) \qquad (37)$$

whereas the profit of a firm that sets its own quality standard above the public standard to serve country *j* is:

$$\pi_{ij} = \frac{\eta-\Lambda}{\eta\Lambda}\left[\Lambda\theta_j^{-\Lambda}\left(\frac{\theta_j^{\eta}}{\eta}+f_{ij}\right)\right]^{\frac{\eta}{\eta-\Lambda}}\left(\frac{\varphi}{\bar{\varphi}_{ij}}\right)^{\frac{(\varepsilon-1)\eta}{\eta-\Lambda}} - f_{ij} \qquad (38)$$

where (38) and (29) are equal when $\theta_j = \underline{\theta}_{ij}$. and π_{ij} increases with $\theta_j \geq \underline{\theta}_{ij}$. There exists a firm with a productivity $\hat{\varphi}_{ij}$ which is indifferent between selecting its own standard and adopting the public standard such that $\theta_{ij} = \theta_j$ or, equivalently,

$$\hat{\varphi}_{ij} = \theta_j^{\frac{\eta}{\varepsilon-1}}\Lambda^{\frac{-1}{\varepsilon-1}}\left(\frac{\theta_j^{\eta}}{\eta}+f_{ij}\right)^{\frac{-1}{\varepsilon-1}}\bar{\varphi}_{ij} \qquad (39)$$

As expected, if $\theta_j = \underline{\theta}_{ij}$ then $\hat{\varphi}_{ij} = \bar{\varphi}_{ij}$ and $\frac{\partial\hat{\varphi}}{\partial\theta_j} > 0$ for a given $\bar{\varphi}_{ij}$. The implication is that an increase in the public standard entails a higher minimum productivity on the part of firms that choose a private standard, the other active firms being forced to adopt the public standard. The latter, defined by (31) in terms of the minimum productivity for a firm to be active, can be defined in terms of the minimum productivity to adopt a private standard: $\theta_{ij} = \theta_j\left(\varphi / \hat{\varphi}_{ij}\right)^{\frac{\varepsilon-1}{\eta-\Lambda}}$. For a given mass of firms, there is a reallocation of firms as some private standard firms switch to the public standard when the latter is increased. The effect of the increase in the public standard tends to increase the prices chosen by individual firms.

Figure 5 illustrates the relationship between the price and the productivities of individual firms, for a given mass of firms. Depending on the sign of $\beta\varepsilon - \eta$, the price of firms using private standards can increase or decrease with productivity.

C. Entry and exit when the public standard is increased

Expected profits are now the sum of expected profits of firms adopting the public standard and expected profits of firms developping their own standard weighted by their probability of occurrence respectively, so that

$$[1-G(\bar{\varphi}_{ii})]\bar{\pi}_i = \sum_{j}^{K}\left[\int_{\bar{\varphi}_{ij}}^{\hat{\varphi}_{ij}} \pi_{ij}^{c}(\theta_j)g(\varphi)\mathrm{d}\varphi + \int_{\hat{\varphi}_{ij}}^{\infty} \pi_{ij}(\theta_{ij})g(\varphi)\mathrm{d}\varphi\right] \qquad (40)$$

In the case where some firms are constrained by the public standard, $\bar{\varphi}_{ij} < \hat{\varphi}_{ij}$, the effect on the average quality associated with the introduction of a public standard is ambiguous. On the one side, it raises the quality of all products for a given mass of firms (direct effect). Higher minimum quality strenghens competition among firms forcing them to improve the quality of their products. On the other side, the less productive incumbent firms exit the market with the introduction of a public standard (an indirect direct through a rise in $\bar{\varphi}_{ij}$) reducing the mass of firms and making the competition less fierce.

D. The impact of a higher public standard on welfare

Welfare is given by the purchasing power of workers: $w_i L_i P_i^{-1}$ with

$$P_i = \theta_i^{\frac{-\Lambda}{\varepsilon-1}} \left(\frac{\varepsilon}{\varepsilon - 1} \right) \left[\frac{\varepsilon(\theta_i^{\eta} / \eta + f_{ij})}{L_i} \right]^{\frac{1}{\varepsilon-1}} \bar{\varphi}_{ii}^{-\gamma}$$

where $\frac{\mathrm{d}P_i}{\mathrm{d}\theta_i} = \frac{1}{\varepsilon - 1} \frac{P_i}{\theta_i} \left[-\Lambda + \theta_i^{\eta} \left(\frac{\theta_i^{\eta}}{\eta} + f_{ij} \right)^{-1} - (\varepsilon - 1) \frac{\theta_{ii}}{\bar{\varphi}_{ii}} \frac{\mathrm{d}\bar{\varphi}_{ii}}{\mathrm{d}\theta_i} \right]$

The impact of a higher public standard is generally ambigous as it depends on $\frac{\mathrm{d}\bar{\varphi}_{ii}}{\mathrm{d}\theta_i}$.

6. Concluding remarks

Public standards play an important role in agriculture. They must be set at high enough levels to insure that food is safe, but not too high to ration consumers and force the exit of too many firms. There is a widespread perception that setting high public standards help small domestic firms compete against firms. We show that high public standards benefits most to highly productive foreign firms. Recently, many firms have developed their own private standards. In the absence of public standards, firms will adopt private standards and when the fixed cost advantage of domestic firms gets smaller, foreign firms gain market share and more so when fixed costs increase rapidly with quality and horizontal (vertical) product differentiation is strong (weak). When public and private standards coexist, lower productivity firms adopt the lower public standard while high productivity firms set their own higher standards. An exogenous increase in the public standard θ_j induce firms that still use a private standard to use a higher one. Interestingly, the volume produced by firms constrained and unconstrained by the public standard can increase or decrease when the latter is increased. Standards can have unsuspecting effects and governments must be careful in setting them.

Appendix A. Quality and demand

Maximizing $U=\left[\int_{\Omega_\upsilon}\theta(\upsilon)^{\beta}q(\upsilon)^{\frac{\varepsilon-1}{\varepsilon}}\mathrm{d}\upsilon\right]^{\frac{\varepsilon}{\varepsilon-1}}$ subject to the budget constraint $R=\int_{\Omega_\upsilon}pq\,\mathrm{d}\upsilon$ leads to the following demand and expenditures equations:

$$q(\upsilon)=\theta^{\beta\varepsilon}\left[\int_{\Omega_\upsilon}\theta^{\beta}q(\upsilon)^{\frac{\varepsilon-1}{\varepsilon}}\mathrm{d}\upsilon\right]^{\frac{\varepsilon}{\varepsilon-1}}p(\upsilon)^{-\varepsilon}/\lambda^{\varepsilon}$$

$$p(\upsilon)q(\upsilon)=\theta^{\beta\varepsilon}\left[\int_{\Omega_\upsilon}\theta^{\beta}q(\upsilon)^{\frac{\varepsilon-1}{\varepsilon}}\mathrm{d}\upsilon\right]^{\frac{\varepsilon}{\varepsilon-1}}p(\upsilon)^{1-\varepsilon}/\lambda^{\varepsilon}$$

Plugging the above in the budget constraint and isolating the marginal utility of income:

$$R\equiv\int_{\Omega_\upsilon}p(\upsilon)q(\upsilon)\mathrm{d}\upsilon=\left[\int_{\Omega_\upsilon}\theta^{\beta}q(\upsilon)^{\frac{\varepsilon-1}{\varepsilon}}\mathrm{d}\upsilon\right]^{\frac{\varepsilon}{\varepsilon-1}}\int_{\Omega_\upsilon}\theta^{\beta\varepsilon}p(\upsilon)^{1-\varepsilon}\mathrm{d}\upsilon/\lambda^{\varepsilon}$$

$$\lambda^{\varepsilon}=\left[\int_{\Omega_\upsilon}\theta^{\beta}q(\upsilon)^{\frac{\varepsilon-1}{\varepsilon}}\mathrm{d}\upsilon\right]^{\frac{\varepsilon}{\varepsilon-1}}\int_{\Omega_\upsilon}\theta^{\beta\varepsilon}p(\upsilon)^{1-\varepsilon}\mathrm{d}\upsilon/R$$

Plugging the above expression back in the expenditure equation, we get (3):

$$p(\upsilon)q(\upsilon)=\theta^{\beta\varepsilon}R\left(\int_{\Omega_\upsilon}\theta^{\beta\varepsilon}p(\upsilon)^{1-\varepsilon}\mathrm{d}\upsilon\right)p(\upsilon)^{1-\varepsilon}.$$

Appendix B. Industrial structure and prices under a public standard

1. Expected profits.

Because φ follows a Pareto distribution over $[1,+\infty)$ with shape parameter γ (with $\gamma > \varepsilon - 1$) and with lower productivity bound $\varphi_{\min} = 1$ ($G(\varphi) = \varphi^{-\gamma}$ and $g(\varphi) = \gamma\varphi^{-\gamma-1}$) and inserting (11) into (9) and then in (7), we obtain:

$$\overline{\pi}_i = \sum_j \varphi_{ii}^{\gamma} \int_{\varphi_{ij}}^{\infty} \left[\left(\frac{\varphi^{\varepsilon-1}}{\varphi_{ij}^{\varepsilon-1}} - 1 \right)(\phi_j + f_j) \right] \gamma\varphi^{-\gamma-1} \mathrm{d}\varphi$$

$$= \frac{\varepsilon - 1}{\gamma - (\varepsilon - 1)} \varphi_{ii}^{\gamma} \sum_j \varphi_{ij}^{-\gamma} \left(\phi_j + f_{ij} \right)$$

Because expected profit, conditional on sucessful entry, must equal the sunk entry cost, $[1 - G(\varphi_{ii})]\overline{\pi}_i = f_e$, we can rearrange to solve for the sunk entry cost:

$$\frac{\varepsilon - 1}{\gamma - (\varepsilon - 1)} \sum_j \varphi_{ij}^{-\gamma} (\phi_j + f_{ij}) = f_e \qquad \text{(B.1.1)}$$

From the above expression, the level of minimum productivity of firms selling in the market must increase when the fixed cost that must be incurred to meet the public standard is augmented: $\partial\varphi_{ij} / \partial\phi_j > 0$.

2. Labor market clearing and the mass of firms.

By using the labor market clearing condition in country i, we have

$$L_i = \sum_j M_i \varphi_{ii}^{\gamma} \int_{\varphi_{ij}}^{\infty} \frac{\theta_j^{\alpha} q(\varphi) \tau_{ij}}{\varphi} g(\varphi) \mathrm{d}\varphi + M_e f_e + \sum_j M_i \varphi_{ii}^{\gamma} \varphi_{ij}^{-\gamma} (\phi_j + f_{ij}) \qquad \text{(B.2.1)}$$

with the mass of entering firms M_e being equal to the mass of firms in country *i*, M_i, times the reciprocal of the probability of entry, $M_e = M_i \varphi_{ii}^{\gamma}$ and where τ_{ij} is an iceberg trade cost parameter. Variable labor requirement can be expressed as:

$$\int_{\varphi_{ij}}^{\infty} \frac{\theta_j^{\alpha} q(\varphi) \tau_{ij}}{\varphi} g(\varphi) \mathrm{d}\varphi = \int_{\varphi_{ij}}^{\infty} \frac{\theta_j^{\alpha} \tau_{ij} p(\varphi)^{-\varepsilon} \theta_j^{\beta\varepsilon} P^{\varepsilon-1} L_j}{\varphi} g(\varphi) \mathrm{d}\varphi$$

$$= \int_{\varphi_{ij}}^{\infty} \frac{\theta_j^{\alpha} \tau_{ij} p_{ij}(\varphi)^{-\varepsilon} \varepsilon(\phi_j + f_{ij})}{\varphi\, p(\varphi_{ij})^{1-\varepsilon}} g(\varphi) \mathrm{d}\varphi$$

$$= \int_{\varphi_{ij}}^{\infty} \frac{\theta_j^{\alpha} \tau_{ij} \theta_j^{-\alpha\varepsilon} \varphi^{\varepsilon-1} (\varepsilon - 1)(\phi_j + f_{ij})}{\theta_j^{\alpha(1-\varepsilon)} \varphi_{ij}^{\varepsilon-1}} g(\varphi) \mathrm{d}\varphi$$

$$= \frac{\gamma(\varepsilon-1)}{\gamma-(\varepsilon-1)} \sum_j \varphi_{ij}^{-\gamma} (\phi_j + f_{ij}) \qquad \text{(B.2.2)}$$

Plugging (B.1.1) and (B2.2) into (B.2.1) yields (14):

$$M_i = \frac{L_i(\varepsilon-1)}{\varphi_{ii}^{\gamma} f_e \gamma \varepsilon}$$

3. Price index

From (4), $\mu_{ki}(\varphi) = \lambda_{ki} / [1-G(\varphi_{ki})]$ and $g(\varphi)$, the price index can be expressed as follows:

$$P_i^{1-\varepsilon} = \frac{\theta_i^{\beta\varepsilon-\alpha(\varepsilon-1)}\gamma}{\gamma-(\varepsilon-1)} \sum_k \frac{M_k}{\varphi_{kk}^{-\gamma}} \left(\frac{\varepsilon}{\varepsilon-1} w_k \tau_{ki} \right)^{1-\varepsilon} \varphi_{ki}^{-\gamma+\varepsilon-1}$$

with $\partial P_i / \partial \theta_i > 0$ because $\beta\varepsilon > \alpha(\varepsilon-1)$. Using (14) and (11), the reciprocal of the price index, which is the level of welfare, can be expressed as:

$$P_i^{-1} = \frac{\theta_i^{\frac{\Lambda}{\varepsilon-1}} L_i^{\frac{\gamma-(\varepsilon-1)}{\gamma(\varepsilon-1)}} \varepsilon^{-\frac{\varepsilon}{\varepsilon-1}} (\varepsilon-1)^{\frac{1+\gamma}{\gamma}}}{[\gamma-(\varepsilon-1)]^{\frac{1}{\gamma}} f_e^{\frac{1}{\gamma}}} \left(\sum_k L_k \tau_{ki}^{-\gamma} \left(\frac{\theta_i^{\eta}}{\eta} + f_{ki}\right)^{\frac{-\gamma+\varepsilon-1}{\varepsilon-1}} \right)^{\frac{1}{\gamma}}$$

4. Profits

$$\pi_{ii} = \frac{p_{ii}(\varphi) q_{ii}(\varphi)}{\varepsilon} - (\phi_i + f_{ii}) = \frac{p_{ii}(\varphi) q_{ii}(\varphi)}{p_{ii}(\varphi_{ii}) q_{ii}(\varphi_{ii})} \frac{p_{ii}(\varphi_{ii}) q_{ii}(\varphi_{ii})}{\varepsilon} - (\phi_i + f_{ii})$$

Because $\pi_{ij}(\varphi_{ij}) = 0$, then $\frac{p_{ii}(\varphi_{ii}) q_{ii}(\varphi_{ii})}{\varepsilon} = \phi_i + f_{ii}$, and from (3) with $\phi_{ij} = \phi_j$ and (8), then: $\pi_{ii} = \varphi^{\varepsilon-1} \varphi_{ii}^{1-\varepsilon} (\phi_i + f_{ii}) - (\phi_i + f_{ii}) \geq 0$. An increase in the minimum productivity to be active in the domestic market reduces the profit of surviving domestic firms in the domestic market.

Appendix C. Industrial structure and prices under private standards

1. Expected profit

We determine the productivity cutoff which depends on the minimum quality. Entry takes place as long as expected profit (the firms need to enter to observe their productivity draw),

$$\overline{\pi}_i = \sum_j^K \underline{\varphi}_{ii}^{\gamma} \int_{\varphi_{ij}}^{\infty} \left\{ f_{ij} \left(\frac{\varphi}{\underline{\varphi}_{ij}} \right)^{\frac{\eta(\varepsilon-1)}{\eta-\Lambda}} - f_{ij} \right\} \gamma \varphi^{-\gamma-1} \mathrm{d}\varphi = \underline{\varphi}_{ii}^{\gamma} \frac{\eta(\varepsilon-1)}{\gamma(\eta-\Lambda)-\eta(\varepsilon-1)} \sum_j^K \underline{\varphi}_{ij}^{-\gamma} f_{ij}$$

Is sufficient to cover the sunk entry cost f_e. Considering that the probability of entry is $\underline{\varphi}_{ii}^{-\gamma}$, we find:

$$f_e = \frac{\eta(\varepsilon-1)}{\gamma(\eta-\Lambda)-\eta(\varepsilon-1)} \sum_j^K \underline{\varphi}_{ij}^{-\gamma} f_{ij} \tag{C.1.1}$$

An increase in the consumers' appreciation of quality, β, implies higher expected revenues for firms entering the market which requires the sunk entry cost f_e to increase to stop entry all else being equal.

2. Mass of firms

By using the labor market clearing condition in country i, we have

$$L_i = \ell_i + M_e f_e + \sum_j M_i \varphi_{ii}^{\gamma} \varphi_{ij}^{-\gamma} f_{ij} \tag{C.2.1}$$

where ℓ_i is the requirement in variable labor in country *i* and it can be expressed as:

$$\ell_i = \sum_j^K \int_{\varphi_{ij}}^{\infty} M_{ij} \left[\frac{\theta_{ij}^{\alpha} q(\varphi) \tau_{ij}}{\varphi} + \frac{\theta_{ij}^{\eta}}{\eta} \right] g(\varphi) \mathrm{d}\varphi = \sum_j^K \int_{\varphi_{ij}}^{\infty} M_{ij} \left[\frac{(\varepsilon-1) p_{ij} q_{ij}}{\varepsilon w_i} + \frac{\Lambda p_{ij} q_{ij}}{\varepsilon \eta} \right] g(\varphi) \mathrm{d}\varphi \tag{C.2.2}$$

where we used (20) and (21). From (29), we can express $p_{ij} q_{ij} / \varepsilon$ as:

$$\frac{p_{ij} q_{ij}}{\varepsilon} = f_{ij} \left(\frac{\varphi}{\underline{\varphi}_{ij}} \right)^{\frac{\eta(\varepsilon-1)}{\eta-\Lambda}}$$

Plugging the above in (C.2.2), noting that $g(\varphi) = \gamma \varphi^{-\gamma-1}$, we find:

$$\ell_i = \sum_j^K \int_{\varphi_{ij}}^{\infty} M_{ij} f_{ij} \left(\frac{\varphi}{\underline{\varphi}_{ij}}\right)^{\frac{\eta(\varepsilon-1)}{\eta-\Lambda}} \left[\varepsilon - 1 + \frac{\Lambda}{\eta}\right] \gamma \varphi^{-\gamma-1} \mathrm{d}\varphi$$

$$= M_i \underline{\varphi}_{ii}^{\gamma} \frac{\gamma(\eta-\Lambda)}{\gamma(\eta-\Lambda)-\eta(\varepsilon-1)} \left[\frac{\varepsilon-1}{w_i} + \frac{\Lambda}{\eta}\right] \sum_j^K f_{ij} \underline{\varphi}_{ij}^{-\gamma} \text{ (C.2.3)}$$

$$= M_i \underline{\varphi}_{ii}^{\gamma} \frac{\gamma(\eta-\Lambda)}{\eta} \left[1 + \frac{\Lambda}{\eta(\varepsilon-1)}\right] f_e$$

Plugging and (C.2.3) in (C.2.1) implies

$$L_i = M_i \varphi_{ii}^{\gamma} f_e \left\{ \frac{\gamma(\eta-\Lambda)}{\eta} \left[1 + \frac{\Lambda}{\eta(\varepsilon-1)}\right] + 1 + \frac{\gamma(\eta-\Lambda)-\eta(\varepsilon-1)}{\eta(\varepsilon-1)} \right\}$$

$$= M_i \varphi_{ii}^{\gamma} f_e \left\{ \frac{\gamma(\eta-\Lambda)}{\eta} \frac{\Lambda}{\eta(\varepsilon-1)} + \frac{\gamma(\eta-\Lambda)\varepsilon}{\eta(\varepsilon-1)} \right\}$$

$$= M_i \varphi_{ii}^{\gamma} f_e \gamma \frac{\varepsilon}{\varepsilon-1} \frac{\eta-\Lambda}{\eta} \left(\frac{\Lambda}{\eta\varepsilon} + 1\right)$$

so that

$$M_i = \left(\frac{L_i(\varepsilon-1)}{\varphi_{ii}^{\gamma} f_e \gamma \varepsilon}\right) \left(\frac{\eta}{\eta-\Lambda}\right) \left(\frac{\eta\varepsilon}{\Lambda+\eta\varepsilon}\right).$$

3. Price index

From (4), $\mu_{ki}(\varphi) = \lambda_{ki} / [1 - G(\varphi_{ki})]$ and $g(\varphi)$, and noting that the mass of exporting firms from country *k* active in country *i* is equal to the mass of firms in country *k* divided by the probability of being active in country *k*, $\varphi_{kk}^{-\gamma}$, times the probabilty of surviving in country *i*, $\varphi_{ki}^{-\gamma}$ ($M_{kj}\mu_{kj} = \frac{M_k \varphi_{ki}^{-\gamma}}{\varphi_{kk}^{-\gamma}}$). The price index can be expressed as follows:

$$
\begin{aligned}
P_j^{1-\varepsilon} &= \sum_k^K \int_\varphi \theta_{kj}^{\beta\varepsilon} \left[p_{kj}(\varphi) \right]^{1-\varepsilon} \frac{M_k \varphi_{kj}^{-\gamma}}{\underline{\varphi}_{kk}^{-\gamma}} g(\varphi) \mathrm{d}\varphi \\
&= \left(\frac{\varepsilon}{\varepsilon-1} \right)^{-\varepsilon} \frac{\eta}{f_e \gamma(\eta-\Lambda)} \sum_k^K \frac{\eta\varepsilon L_k}{\Lambda+\eta\varepsilon} \int_\varphi \theta_{kj}^{\Lambda} \varphi^{\varepsilon-1} \tau_{kj}{}^{1-\varepsilon} \underline{\varphi}_{kj}^{-\gamma} \gamma \varphi^{-\gamma-1} \mathrm{d}\varphi \\
&= \left(\frac{\varepsilon}{\varepsilon-1} \right)^{-\varepsilon} \frac{\eta}{f_e \gamma(\eta-\Lambda)} \sum_k^K \frac{\eta\varepsilon L_k}{\Lambda+\eta\varepsilon} \int_\varphi \left[\left(\frac{\eta\Lambda}{\eta-\Lambda w_k} \right) f_{kj} \left(\frac{\varphi}{\underline{\varphi}_{kj}} \right)^{\varepsilon-1} \underline{\theta}_{kj}{}^{-\Lambda} \right]^{\frac{1}{\eta-\Lambda}} \varphi^{\varepsilon-1} \left(w_k \tau_{kj} \right)^{1-\varepsilon} \underline{\varphi}_{kj}^{-\gamma} \gamma \varphi^{-\gamma-1} \mathrm{d}\varphi \\
&= \left(\frac{\varepsilon}{\varepsilon-1} \right)^{-\varepsilon} \frac{\eta}{f_e \gamma(\eta-\Lambda)} \sum_k^K \frac{\eta\varepsilon L_k}{\Lambda+\eta\varepsilon} \left[\left(\frac{\eta\Lambda}{\eta-\Lambda w_k} \right) f_{kj} \underline{\theta}_{kj}{}^{-\Lambda} \right]^{\frac{1}{\eta-\Lambda}} \tau_{kj}{}^{1-\varepsilon} \int_\varphi \left[\left(\frac{\varphi}{\underline{\varphi}_{kj}} \right)^{\varepsilon-1} \right]^{\frac{1}{\eta-\Lambda}} \varphi^{\varepsilon-1} \underline{\varphi}_{kj}^{-\gamma} \gamma \varphi^{-\gamma-1} \mathrm{d}\varphi \\
&= \left(\frac{\varepsilon}{\varepsilon-1} \right)^{-\varepsilon} \frac{\eta}{f_e (\eta-\Lambda)} \sum_k^K \frac{\eta\varepsilon L_k}{\Lambda+\eta\varepsilon} \left[\left(\frac{\eta\Lambda}{\eta-\Lambda w_k} \right) f_{kj} \underline{\theta}_{kj}{}^{-\Lambda} \right]^{\frac{1}{\eta-\Lambda}} \tau_{kj}{}^{1-\varepsilon} \underline{\varphi}_{kj}^{-\gamma+\varepsilon-1}
\end{aligned}
$$

In addition, (24) implies that

$$
\underline{\varphi}_{kj}^{-\gamma+\varepsilon-1} = P_j^{\gamma-(\varepsilon-1)} \left(\frac{\varepsilon}{\Lambda} \right)^{\frac{-\gamma+\varepsilon-1}{\varepsilon-1}} \underline{\theta}_{kj}^{\frac{(\eta-\Lambda)(-\gamma+\varepsilon-1)}{\varepsilon-1}} \left(\frac{\varepsilon}{\varepsilon-1} \tau_{kj} \right)^{-\gamma+\varepsilon-1} L_j{}^{\frac{\gamma-(\varepsilon-1)}{\varepsilon-1}}
$$

so that

$$
P_j^{1-\varepsilon} = \left(\frac{\varepsilon}{\varepsilon-1} \right)^{-\varepsilon} \frac{\eta \left(w_j L_j \right)^{\frac{\gamma-(\varepsilon-1)}{\varepsilon-1}}}{f_e(\eta-\Lambda)} \sum_k^K \frac{\eta\varepsilon L_k}{\Lambda w_k+\eta\varepsilon} \left[\frac{\eta\Lambda w_k f_{kj}}{\eta-\Lambda w_k} \underline{\theta}_{kj}{}^{-\Lambda} \right]^{\frac{1}{\eta-\Lambda}} \left(w_k \tau_{kj} \right)^{1-\varepsilon} \left(\frac{\varepsilon}{\Lambda} \right)^{\frac{-\gamma+\varepsilon-1}{\varepsilon-1}} \underline{\theta}_{kj}^{\frac{(\eta-\Lambda)(-\gamma+\varepsilon-1)}{\varepsilon-1}} \left(\frac{\varepsilon}{\varepsilon-1} w_k \tau_{kj} \right)^{-\gamma+\varepsilon}
$$

$$
P_j^{-\gamma} = \left(\frac{\varepsilon}{\varepsilon-1} \right)^{-(\gamma+1)} \frac{\eta \left(w_j L_j \right)^{\frac{\gamma-(\varepsilon-1)}{\varepsilon-1}}}{f_e(\eta-\Lambda)} \sum_k^K \frac{\eta\varepsilon L_k}{\Lambda w_k+\eta\varepsilon} \left[\frac{\eta\Lambda w_k f_{kj}}{\eta-\Lambda w_k} \right]^{\frac{1}{\eta-\Lambda}} \left(\frac{\varepsilon}{\Lambda} \right)^{\frac{-\gamma+\varepsilon-1}{\varepsilon-1}} \underline{\theta}_{kj}^{\frac{(\eta-\Lambda)(-\gamma+\varepsilon-1)}{\varepsilon-1}-\frac{\Lambda}{\eta-\Lambda}} \left(w_k \tau_{kj} \right)^{-\gamma}
$$

$$
P_j^{\varepsilon-1} = \left(\frac{\varepsilon}{\varepsilon-1} \right)^{\frac{(\gamma+1)(\varepsilon-1)}{\gamma}} \left[\frac{\eta \left(w_j L_j \right)^{\frac{\gamma-(\varepsilon-1)}{\varepsilon-1}}}{f_e(\eta-\Lambda)} \sum_k^K \frac{\eta\varepsilon L_k}{\Lambda w_k+\eta\varepsilon} \left[\frac{\eta\Lambda w_k f_{kj}}{\eta-\Lambda w_k} \right]^{\frac{1}{\eta-\Lambda}} \left(\frac{\varepsilon}{\Lambda} \right)^{\frac{-\gamma+\varepsilon-1}{\varepsilon-1}} \underline{\theta}_{kj}^{\frac{(\eta-\Lambda)(-\gamma+\varepsilon-1)}{\varepsilon-1}-\frac{\Lambda}{\eta-\Lambda}} \left(w_k \tau_{kj} \right)^{-\gamma} \right]^{\frac{-(\varepsilon-1)}{\gamma}}
$$

(C.3.1)

$$\underline{\varphi}_{ij}^{\gamma} = \left(\frac{\eta \Lambda w_i f_{ij}}{\eta - \Lambda w_i} \right)^{\frac{\gamma}{\varepsilon - 1}} \left(w_i \tau_{ij} \right)^{\gamma} \underline{\theta}_{ij}^{\frac{\Lambda \gamma}{1-\varepsilon}} \frac{\eta \left(\varepsilon - 1 \right) \varepsilon}{f_e (\eta - \Lambda) \Lambda w_j L_j} \sum_k^K \frac{\eta L_k}{\Lambda w_k + \eta \varepsilon} \left[\frac{\eta \Lambda w_k f_{kj}}{\eta - \Lambda w_k} \right]^{\frac{1}{\eta - \Lambda}} \underline{\theta}_{kj}^{\frac{-(\eta - \Lambda)(\gamma - \varepsilon + 1)}{\varepsilon - 1} - \frac{\Lambda}{\eta - \Lambda}} \left(w_k \tau_{kj} \right)^{-\gamma}$$

$$= \left(\frac{\eta \Lambda w_i f_{ij}}{\eta - \Lambda w_i} \right)^{\frac{\gamma}{\varepsilon - 1} \frac{\eta - \Lambda}{\eta}} \left(w_i \tau_{ij} \right)^{\gamma} \frac{\eta \left(\varepsilon - 1 \right) \varepsilon}{f_e (\eta - \Lambda) \Lambda w_j L_j} \sum_k^K \frac{\eta L_k}{\Lambda w_k + \eta \varepsilon} \left[\frac{\eta \Lambda w_k f_{kj}}{\eta - \Lambda w_k} \right]^{\frac{-(\eta - \Lambda)(\gamma - \varepsilon + 1)}{(\varepsilon - 1)\eta} + \frac{1}{\eta}} \left(w_k \tau_{kj} \right)^{-\gamma}$$

Appendix D. Industrial structure and prices under mixed configuration

1. Expected profit

By inserting (37) and (38) into (40), the expected profit is given by:

$$\underline{\varphi}_{ii}^{-\gamma}\overline{\pi}_i = \sum_j^K \left[\frac{\gamma}{\gamma-(\varepsilon-1)}\left(\underline{\varphi}_{ij}^{-\gamma} - \hat{\varphi}_{ij}^{-\gamma}\frac{\hat{\varphi}_{ij}^{\varepsilon-1}}{\underline{\varphi}_{ij}^{\varepsilon-1}}\right) - \left(\underline{\varphi}_{ij}^{-\gamma} - \hat{\varphi}_{ij}^{-\gamma}\right)\right]_i \left(\frac{\theta_j^{\eta}}{\eta} + f_{ij}\right)$$

$$+\sum_j^K \frac{\gamma(\eta-\Lambda)}{\gamma(\eta-\Lambda)-(\varepsilon-1)\eta}\hat{\varphi}_{ij}^{-\gamma}\left(\frac{\hat{\varphi}_{ij}}{\underline{\varphi}_{ij}}\right)^{\frac{(\varepsilon-1)\eta}{\eta-\Lambda}}\frac{\eta-\Lambda}{\eta\Lambda}\left[\Lambda\theta_j^{-\Lambda}\left(\frac{\theta_j^{\eta}}{\eta}+f_{ij}\right)\right]^{\frac{\eta}{\eta-\Lambda}} - \hat{\varphi}_{ij}^{-\gamma} f_{ij}$$

Because $\Lambda\left(\frac{\theta_j^{\eta}}{\eta}+f_{ij}\right) = \theta_j^{\eta}\left(\frac{\hat{\varphi}}{\underline{\varphi}_{ij}}\right)^{-(\varepsilon-1)}$, we get

$$\underline{\varphi}_{ii}^{-\gamma}\overline{\pi}_i = \sum_j^K \left[\frac{\gamma}{\gamma-(\varepsilon-1)}\left(\overline{\varphi}_{ij}^{-\gamma} - \hat{\varphi}_{ij}^{-\gamma}\Lambda^{-1}\left(\frac{\theta_j^{\eta}}{\eta}+f_{ij}\right)^{-1}\theta_j^{\eta}\right) - \left(\overline{\varphi}_{ij}^{-\gamma} - \hat{\varphi}_{ij}^{-\gamma}\right)\right]\left(\frac{\theta_j^{\eta}}{\eta}+f_{ij}\right)$$

$$+\sum_j^K \frac{\gamma(\eta-\Lambda)}{\gamma(\eta-\Lambda)-(\varepsilon-1)\eta}\hat{\varphi}_{ij}^{-\gamma}\frac{\eta-\Lambda}{\eta\Lambda}\theta_j^{\eta} - \hat{\varphi}_{ij}^{-\gamma} f_{ij}$$

or, equivalently,

$$\underline{\varphi}_{ii}^{-\gamma}\overline{\pi}_i = \sum_j^K \left[\frac{\gamma}{\gamma-(\varepsilon-1)}\left(\overline{\varphi}_{ij}^{-\gamma}\left(\frac{\theta_j^{\eta}}{\eta}+f_{ij}\right) - \hat{\varphi}_{ij}^{-\gamma}\Lambda^{-1}\theta_j^{\eta}\right) - \left(\underline{\varphi}_{ij}^{-\gamma} - \hat{\varphi}_{ij}^{-\gamma}\right)\left(\frac{\theta_j^{\eta}}{\eta}+f_{ij}\right)\right]$$

$$+\sum_j^K \frac{\gamma(\eta-\Lambda)}{\gamma(\eta-\Lambda)-(\varepsilon-1)\eta}\hat{\varphi}_{ij}^{-\gamma}\frac{\eta-\Lambda}{\eta\Lambda}\theta_j^{\eta} - \hat{\varphi}_{ij}^{-\gamma} f_{ij}$$

$$= \sum_j^K \frac{\varepsilon-1}{\gamma-(\varepsilon-1)}\underline{\varphi}_{ij}^{-\gamma}\left(\frac{\theta_j^{\eta}}{\eta}+f_{ij}\right) + \sum_j^K \hat{\varphi}_{ij}^{-\gamma}\left(\frac{\theta_j^{\eta}}{\eta}\right) + \sum_j^K \hat{\varphi}_{ij}^{-\gamma}\frac{\theta_j^{\eta}}{\Lambda}\left[\frac{\gamma(\eta-\Lambda)}{\gamma(\eta-\Lambda)-(\varepsilon-1)\eta}\frac{\eta-\Lambda}{\eta} - \frac{\gamma}{\gamma-(\varepsilon-1)} + \frac{\Lambda}{\eta}\right]$$

$$= \sum_j^K \frac{\varepsilon-1}{\gamma-(\varepsilon-1)}\underline{\varphi}_{ij}^{-\gamma}\left(\frac{\theta_j^{\eta}}{\eta}+f_{ij}\right) + \sum_j^K \hat{\varphi}_{ij}^{-\gamma}\theta_j^{\eta}\frac{\varepsilon-1}{\gamma(\eta-\Lambda)-(\varepsilon-1)\eta}\frac{\varepsilon-1}{\gamma-(\varepsilon-1)}$$

$$= \sum_j^K \frac{\varepsilon-1}{\gamma-(\varepsilon-1)}\underline{\varphi}_{ij}^{-\gamma}\left(\frac{\theta_j^{\eta}}{\eta}+f_{ij}\right) + \sum_j^K \theta_j^{\frac{-\gamma\eta}{\varepsilon-1}}\Lambda^{\frac{\gamma}{\varepsilon-1}}\left(\frac{\theta_j^{\eta}}{\eta}+f_{ij}\right)^{\frac{\gamma}{\varepsilon-1}}\underline{\varphi}_{ij}^{-\gamma}\theta_j^{\eta}\frac{\varepsilon-1}{\gamma(\eta-\Lambda)-(\varepsilon-1)\eta}\frac{\varepsilon-1}{\gamma-(\varepsilon-1)}$$

Hence, $\underline{\varphi}_{ii}^{-\gamma}\overline{\pi}_i = f_e$ implies

$$f_e = \sum_j^K \frac{\varepsilon-1}{\gamma-(\varepsilon-1)}\underline{\varphi}_{ij}^{-\gamma}\left(\frac{\theta_j^\eta}{\eta}+f_{ij}\right)\left[1+\Lambda^{\frac{\gamma}{\varepsilon-1}}\left(\frac{\theta_j^\eta}{\eta}+f_{ij}\right)^{\frac{\gamma-(\varepsilon-1)}{\varepsilon-1}}\theta_j^{\frac{-\eta[\gamma-(\varepsilon-1)]}{\varepsilon-1}}\frac{\varepsilon-1}{\gamma(\eta-\Lambda)-(\varepsilon-1)\eta}\right]$$

$$Z \equiv \left(\frac{\theta_j^\eta}{\eta}+f_{ij}\right)+\Lambda^{\frac{\gamma}{\varepsilon-1}}\left(\frac{\theta_j^\eta}{\eta}+f_{ij}\right)^{\frac{\gamma}{\varepsilon-1}}\theta_j^{\frac{-\eta[\gamma-(\varepsilon-1)]}{\varepsilon-1}}\frac{\varepsilon-1}{\gamma(\eta-\Lambda)-(\varepsilon-1)\eta}$$

$$\frac{dZ}{d\theta_j} = \frac{\theta_j^\eta}{\theta_j}+\Lambda^{\frac{\gamma}{\varepsilon-1}}\frac{\varepsilon-1}{\gamma(\eta-\Lambda)-(\varepsilon-1)\eta}\left(\frac{\theta_j^\eta}{\eta}+f_{ij}\right)^{\frac{\gamma}{\varepsilon-1}}\theta_j^{\frac{-\eta[\gamma-(\varepsilon-1)]}{\varepsilon-1}}\left(\frac{1}{\theta_j(\varepsilon-1)}\right)\left[\gamma\theta_j^\eta\left(\frac{\theta_j^\eta}{\eta}+f_{ij}\right)^{-1}-\eta[\gamma-(\varepsilon-1)]\right]$$

2. Mass of firms

By using the labor market clearing condition in country i, we have

$$L_i = \ell_i^A+\ell_i^B+M_i\varphi_{ii}^\gamma f_e+\sum_j M_i\varphi_{ii}^\gamma\varphi_{ij}^{-\gamma} f_{ij}$$

Where ℓ_i^A (ℓ_i^B) is the mass of workers allocated to the production in the public-standard (private-standard) firms with

$$\ell_i^A = \int_{\bar{\varphi}_{ij}}^{\hat{\varphi}_{ij}} M_{ij}^A\left[\frac{\theta_j^\alpha q_{ij}(\varphi)\tau_{ij}}{\varphi}+\frac{\theta_j^\eta}{\eta}\right]g(\varphi)\mathrm{d}\varphi = \int_{\bar{\varphi}_{ij}}^{\hat{\varphi}_{ij}} M_{ij}^A\left[\frac{\varepsilon-1}{\varepsilon}p_{ij}q_{ij}+\frac{\theta_j^\eta}{\eta}\right]g(\varphi)\mathrm{d}\varphi$$

$$= \int_{\bar{\varphi}_{ij}}^{\hat{\varphi}_{ij}} M_{ij}^A\left[(\varepsilon-1)\left(\frac{\theta_j^\eta}{\eta}+f_{ij}\right)\left(\frac{\varphi}{\bar{\varphi}_{ij}}\right)^{\varepsilon-1}+\frac{\theta_j^\eta}{\eta}\right]g(\varphi)\mathrm{d}\varphi$$

$$\ell_i^B = \sum_j^K\int_{\hat{\varphi}_{ij}}^{\infty} M_{ij}^B\left[\frac{\theta_{ij}^\alpha q_{ij}(\varphi)\tau_{ij}}{\varphi}+\frac{\theta_{ij}^\eta}{\eta}\right]g(\varphi)\mathrm{d}\varphi$$

$$= \sum_j^K\int_{\hat{\varphi}_{ij}}^{\infty} M_{ij}^B\left(\frac{\varepsilon-1}{w_i}+\frac{\Lambda}{\eta}\right)\left(\frac{\eta-\Lambda}{\eta}\right)\Lambda^{\frac{\Lambda}{\eta-\Lambda}}\theta_j^{\frac{-\eta\Lambda}{\eta-\Lambda}}\left(\frac{\theta_j^\eta}{\eta}+f_{ij}\right)^{\frac{\eta}{\eta-\Lambda}}\left(\frac{\varphi}{\bar{\varphi}_{ij}}\right)^{\frac{(\varepsilon-1)\eta}{\eta-\Lambda}} g(\varphi)\mathrm{d}\varphi$$

Because $g(\varphi) = \gamma\varphi^{-\gamma-1}$,

$$\ell_i^A = M_i \bar{\varphi}_{ii}^{\gamma} \frac{\gamma(\varepsilon-1)}{\gamma-(\varepsilon-1)} \sum_j \left(\frac{\theta_j^{\eta}}{\eta} + f_{ij} \right) \bar{\varphi}_{ij}^{1-\varepsilon} \left(\bar{\varphi}_{ij}^{-\gamma+\varepsilon-1} - \hat{\varphi}_{ij}^{-\gamma+\varepsilon-1} \right) + M_i \bar{\varphi}_{ii}^{\gamma} \sum_j \left(\bar{\varphi}_{ij}^{-\gamma} - \hat{\varphi}_{ij}^{-\gamma} \right) \frac{\theta_j^{\eta}}{\eta}$$

$$\ell_i^B = M_i \bar{\varphi}_{ii}^{\gamma} \left(\frac{\varepsilon-1}{w_i} + \frac{\Lambda}{\eta} \right) \left(\frac{\eta-\Lambda}{\eta} \right) \Lambda^{\frac{\Lambda}{\eta-\Lambda}} \frac{\gamma(\eta-\Lambda)}{\gamma(\eta-\Lambda)-(\varepsilon-1)\eta} \sum_j^K \theta_j^{\frac{-\eta\Lambda}{\eta-\Lambda}} \left(\frac{\theta_j^{\eta}}{\eta} + f_{ij} \right)^{\frac{\eta}{\eta-\Lambda}} \hat{\varphi}_{ij}^{-\gamma} \left(\frac{\hat{\varphi}_{ij}}{\bar{\varphi}_{ij}} \right)^{\frac{(\varepsilon-1)\eta}{\eta-\Lambda}}$$

Because

$$\hat{\varphi}_{ij} = \theta_j^{\frac{\eta}{\varepsilon-1}} \Lambda^{\frac{-1}{\varepsilon-1}} \left(\frac{\theta_j^{\eta}}{\eta} + f_{ij} \right)^{\frac{-1}{\varepsilon-1}} \bar{\varphi}_{ij}$$

$$\ell_i^A = M_i \bar{\varphi}_{ii}^{\gamma} \frac{\gamma(\varepsilon-1)}{\gamma-(\varepsilon-1)} \sum_j \left(\frac{\theta_j^{\eta}}{\eta} + f_{ij} \right) \bar{\varphi}_{ij}^{-\gamma} \left(1 - \theta_j^{\frac{\eta(-\gamma+\varepsilon-1)}{\varepsilon-1}} \Lambda^{\frac{\gamma-(\varepsilon-1)}{\varepsilon-1}} \left(\frac{\theta_j^{\eta}}{\eta} + f_{ij} \right)^{\frac{\gamma-(\varepsilon-1)}{\varepsilon-1}} \right) + M_i \bar{\varphi}_{ii}^{\gamma} \sum_j \left(\bar{\varphi}_{ij}^{-\gamma} - \hat{\varphi}_{ij}^{-\gamma} \right) \frac{\theta_j^{\eta}}{\eta}$$

$$\ell_i^B = M_i \bar{\varphi}_{ii}^{\gamma} \left(\frac{\varepsilon-1}{w_i} + \frac{\Lambda}{\eta} \right) \left(\frac{\eta-\Lambda}{\eta} \right) \Lambda^{-1} \frac{\gamma(\eta-\Lambda)}{\gamma(\eta-\Lambda)-(\varepsilon-1)\eta} \sum_j^K \theta_j^{\eta} \hat{\varphi}_{ij}^{-\gamma}$$

Because $L_i = \ell_i^A + \ell_i^B + M_i \varphi_{ii}^{\gamma} f_e + \sum_j M_i \varphi_{ii}^{\gamma} \bar{\varphi}_{ij}^{-\gamma} f_{ij}$, we get

$$L_i M_i^{-1} \bar{\varphi}_{ii}^{-\gamma} = \frac{\gamma(\varepsilon-1)}{\gamma-(\varepsilon-1)} \sum_j \bar{\varphi}_{ij}^{-\gamma} \left(\left(\frac{\theta_j^{\eta}}{\eta} + f_{ij} \right) - \theta_j^{\frac{\eta(-\gamma+\varepsilon-1)}{\varepsilon-1}} \Lambda^{\frac{\gamma-(\varepsilon-1)}{\varepsilon-1}} \left(\frac{\theta_j^{\eta}}{\eta} + f_{ij} \right)^{\frac{\gamma}{\varepsilon-1}} \right) + \sum_j \bar{\varphi}_{ij}^{-\gamma} \left(\frac{\theta_j^{\eta}}{\eta} + f_{ij} \right)$$

$$+ \left[\left(\frac{\varepsilon-1}{w_i} + \frac{\Lambda}{\eta} \right) \left(\frac{\eta-\Lambda}{\eta} \right) \frac{\gamma(\eta-\Lambda)}{\gamma(\eta-\Lambda)-(\varepsilon-1)\eta} - \frac{\Lambda}{\eta} \right] \sum_j^K \theta_j^{\frac{-(\gamma-\varepsilon+1)\eta}{\varepsilon-1}} \Lambda^{\frac{\gamma-(\varepsilon-1)}{\varepsilon-1}} \left(\frac{\theta_j^{\eta}}{\eta} + f_{ij} \right)^{\frac{\gamma}{\varepsilon-1}} \bar{\varphi}_{ij}^{-\gamma} + f_e$$

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Figure 1. Profits under a stricter public standard

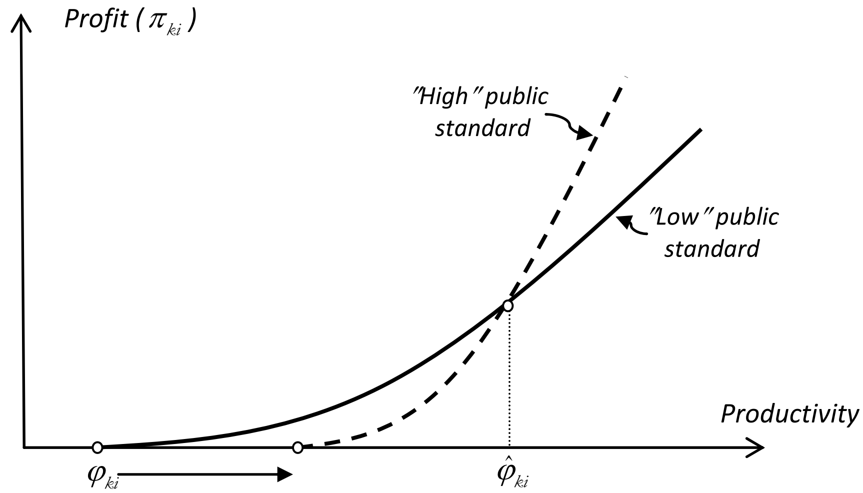

Figure 2. Productivity, price and production without a public standard in (η,β)-space

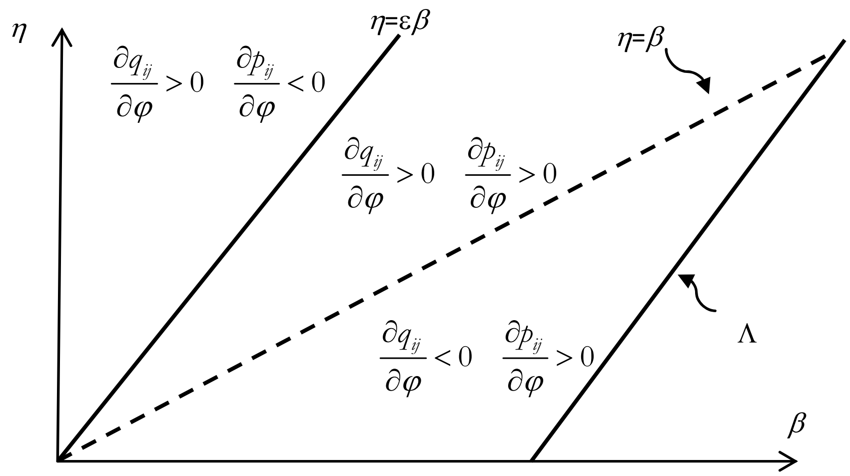

Figure 3. Price and quality without a public standard ($\beta\varepsilon > \eta$)

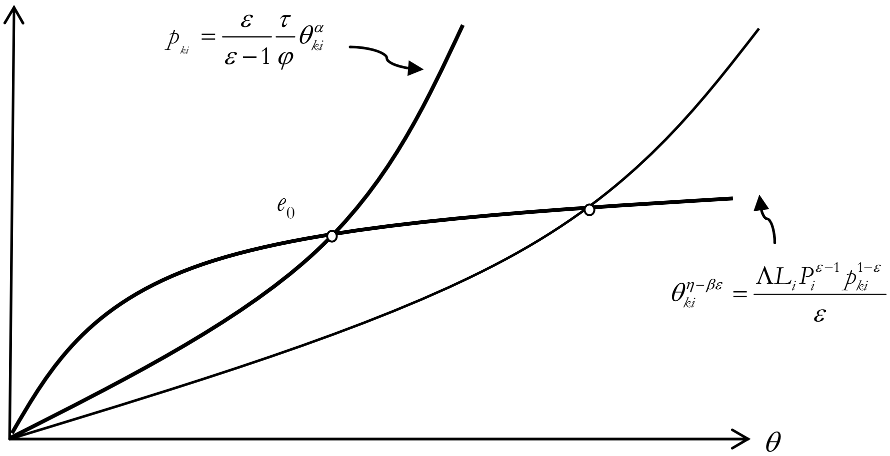

Figure 4a. Price and quality with a public standard ($\beta\varepsilon > \eta$)

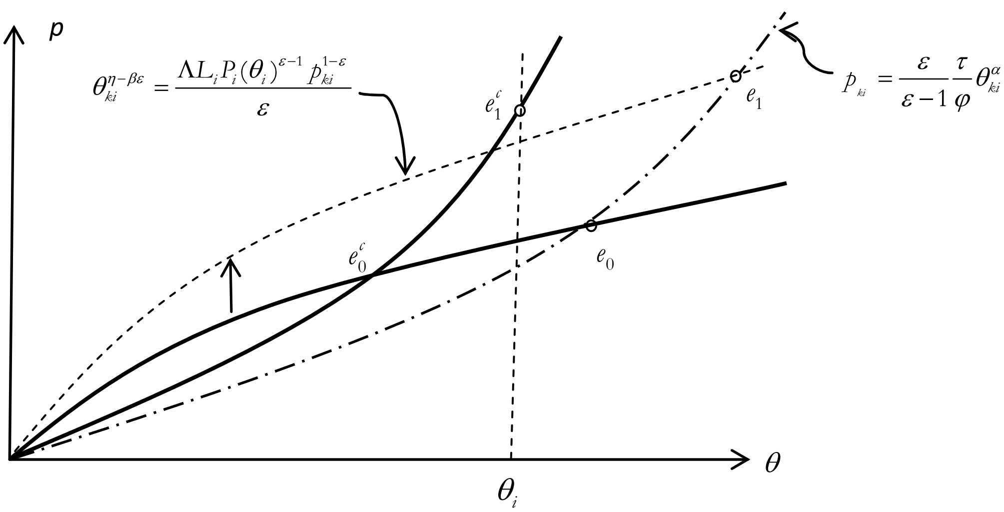

Figure 4b. Price and quality with a public standard ($\beta\varepsilon < \eta$)

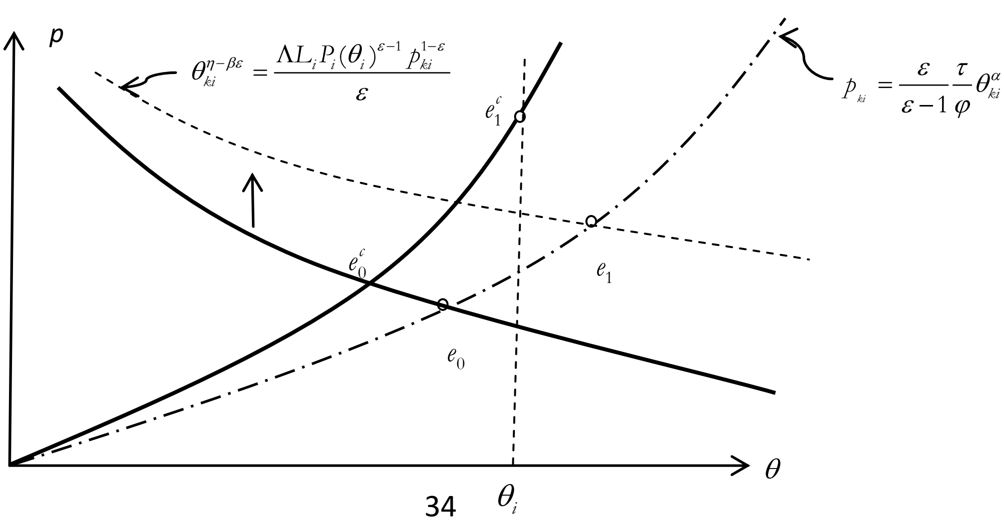

Figure 5. Price with respect to productivity