Asymmetric Information, Quality, and Regulations

Luca Macedoni*
Aarhus University

December 2021

Abstract

I present a model of international trade that features heterogeneous firms and asymmetric information on the quality of products, which is known to producers but unknown to consumers. The presence of asymmetric information leads to adverse selection whereby high-quality firms exit and only low-quality firms survive. The model shows that adverse selection also affects export participation as only firms with the lowest quality are able to export. For this reason, trade can lead to a reduction in welfare if it causes an average product quality reduction that is too substantial. I study the effects of two instruments: minimum quality standards, which force out firms with the lowest quality, and quality certifications, which allow firms to signal to consumers that their quality is higher than a certain threshold, upon payment of a fixed cost. Both instruments can improve welfare if the increase in prices associated with the higher-quality goods is small enough. Furthermore, I study how the two instruments interact with countries' openness.

Keywords: Asymmetric Information, Product Quality, Minimum Quality Standard, Quality Certification.

JEL Code: F12, F13, L15.

*Address: Department of Economics and Business Economics, Aarhus University, Fuglesangs Allé 4, 8210 Aarhus V. E-mail: lmacedoni@econ.au.dk. Financial support from the Carlsberg Foundation is gratefully acknowledged. I thank Paola Conconi, Allan Sørensen, Ariel Weinberger, and two anonymous referees for suggestions and feedback.

1 Introduction

Asymmetric information on the quality of products often justifies government interventions on regulations, labels, and product standards that have the objective to protect consumers (Leland, 1979; Donnenfeld et al., 1985). Such regulations are a key point of contention in modern trade agreements, as legislators have to balance legitimate concerns for product safety with the protectionist side of such standards (Baldwin et al., 2000; Grossman et al., 2021). While the consumption of a product can provide consumers with information about part of its quality, it is often the case that some quality features cannot be learned upon consumption because it is generally prohibitively expensive to do so. For instance, consumers generally lack the expertise or the equipment required to distinguish between GMO and non-GMO food products. Furthermore, information about the quality of most food products may require information on the actual production processes, such as the environmental and social sustainability of certain practices. A solution to the presence of asymmetric information is the implementation of public and private instruments such as minimum quality standards and quality certifications. The goal of this paper is to study the welfare effects of the two instruments in an international trade context.

Minimum quality standards guarantee that all products in a market are above a certain quality level (Gaigné and Larue, 2016*a*). Quality certifications, communicated to consumers via a proper label, guarantee that a product has a quality above a certain threshold (Bonroy and Constantatos, 2015). While minimum quality standards are generally imposed by a public authority, quality certifications can be also issued by private agencies. In the food industry, minimum quality standards regulate several aspects, from pesticide use (Ferro et al., 2015) to the dry curing of meats.[1] Along these minimum quality standards, institutions like the EU also issue certifications for products that attain a certain quality level, such as certification for organic farming. However, there are also private agencies that provide

[1]For instance, the US require prosciutto to be dry cured for at least 2 years, while the EU allows for a shorter time.

quality certifications such as those for animal welfare (Olper et al., 2014). I find that both instruments can improve welfare. Furthermore, I study how trade can exacerbate the negative effects of asymmetric information and how the two instruments interact with a country's level of trade openness.

The main contribution of the paper is to study the welfare effects of asymmetric information and regulations on product standards in a model of heterogeneous firms à la Melitz (2003). The model is best exemplified by applying it to the the food processing sector, which is rife with minimum quality standards and quality certifications. Furthermore, the sector is constituted by heterogeneous firms that produce differentiated products (see Gaigné and Le Mener (2014) and Gaigné and Larue (2016*b*) for a review of the evidence).

There are three key assumptions to clarify from the start. First, firms differ in terms of their quality, which is modeled as a demand shifter: in the case of perfect information, higher-quality firms have larger sales. Although the trade literature has extensively discussed the determinants of firm-product quality, such as productivity (Feenstra and Romalis, 2014; Gaigné and Larue, 2016*a*; Manova and Zhang, 2017), the goal of this paper is to examine the role of asymmetric information when firms are heterogeneous in quality and, hence, I abstract from the sources of quality heterogeneity and take the quality distribution as given.[2] Furthermore, the assumption accounts for the growing evidence that heterogeneity on the demand side is the main source of firm size heterogeneity (Hottman et al., 2016).

Second, firms with higher quality also pay higher marginal costs, which is a feature present in Feenstra and Romalis (2014) and Gaigné and Larue (2016*a*). This implies that high-quality firms sell products with higher prices. The theoretical literature also considers the presence of a fixed cost of quality (Gaigné and Larue, 2016*a*). For simplicity, the baseline model abstracts from such a fixed cost, and I have verified in an extension that the main result of the study also holds when fixed costs are proportional to product quality.

Introducing asymmetric information in a general equilibrium model with monopolistically

[2]In most papers, there is a one-to-one mapping of productivity into quality (Feenstra and Romalis, 2014).

competitive firms requires an additional key assumption that allows for a simple characterization of the equilibrium, in contrast to the literature in industrial organization and game theory on asymmetric information (see Gavazza and Lizzeri (2021) for a recent review).[3] I assume that in the presence of asymmetric information, varieties are perceived by consumers as being only horizontally differentiated. Hence, consumers do not realize that higher prices signal higher quality.[4] In an important extension in Appendix 5.4.5, I relax this assumption and allow for some imperfect price signaling; by charging higher prices, higher-quality firms can obtain a larger demand shifter than the baseline model. I show that the welfare effects of minimum quality standards and certifications are only affected quantitatively by the presence of a signaling technology.[5]

The presence of asymmetric information leads to the well-known phenomenon of adverse selection (Akerlof, 1970): low-quality firms stay in the market because they sell cheaper products, and high-quality firms exit because their products are more expensive and consumers fail to realize that they are of higher quality.[6] Adverse selection also affects the selection of firms into export markets. In fact, only low-quality firms, i.e., the firms with the least expensive products, are able to export. As trade reallocates production from non-exporters to exporters and exporters are of low-quality, the average domestic quality declines. As a result, trade can actually reduce welfare when the reduction in quality more than offsets the reduction in prices. This is the opposite outcome of the perfect information case, in which trade forces out low-quality firms and welfare always improves.

[3]In my model, any strategic interactions between firms are assumed away as it is standard practice in models of monopolistic competition. This is a convenient feature since strategic interaction among firms can lead to multiple equilibria as discussed in the works of Wolinsky (1983, 1984), Schwartz and Wilde (1985), and Overgaard (1993).

[4]Esponda (2008) introduces a notion of behavioral equilibrium in which consumers fail to account for selection and do not realize that higher prices also imply higher quality. Gavazza and Lizzeri (2021) also argue that an equilibrium under adverse selection requires a potentially unrealistic amount of sophistication on the part of consumers.

[5]Price signaling interacts with the two instruments in different ways. First, price signaling magnifies the welfare benefits of minimum quality standards. Second, price signaling and quality certification are substitutes: the welfare benefits of certifications are diminished in the presence of price signaling.

[6]The presence of horizontal differentiation across varieties partially mitigates the consequences of adverse selection, relative to a case of vertically differentiated homogeneous goods. In fact, consumers are willing to purchase even more expensive products because they exhibit love for variety.

A minimum quality standard forces the lower-quality firms out of the market and allows the entry of higher-quality firms, which is welfare improving. However, the new high-quality firms have higher prices than the exiting low-quality firms, and consumers do not distinguish between the quality of the two. In fact, the budget share of low-quality goods remains higher than the budget share of high-quality goods. As a result, the standard leads to an increase in the average price that can offset the increase in quality and, thus, reduce welfare. The positive effect of the standard dominates if the elasticity of marginal costs with respect to quality is small enough, which leads to a smaller increase in the average price.

The welfare effects of certifications depend on the costs associated with obtaining the certification and on the quality threshold guaranteed by the certification. I model the costs of the certification as a fixed cost as in Bonroy and Constantatos (2015). Intuitively, the higher the fixed cost, the lower the welfare benefits of the certification. The threshold, or certification standard, has a twofold effect on welfare. On the one hand, increasing its value increases the average quality of firms with a certification. On the other, this also creates a hollowing out of medium-quality firms and a polarization of quality around the minimum quality and the certification quality. In a closed economy, the optimal threshold tends to minimize the quality polarization, allowing medium-quality firms to certify their products.

The two instruments interact with a country's openness in different ways. Let us first consider the minimum quality standard. I consider the optimal harmonized standard between two countries. Since trade reduces the average quality in the market, the optimal standard is larger with trade relative to the autarky case. However, reductions in trade costs are associated with a *smaller* optimal quality standard. The reason for this lies in an interesting property of standards in a trade context. In fact, a quality standard can create trade because it causes the entry of high-quality firms both in the domestic *and* in the export market.[7] Since reductions in trade costs allow some higher-quality firms to begin exporting, one of the advantages of the minimum quality standard becomes less relevant. This is a conclusion

[7]This occurs even when trade costs are prohibitively large and they generate zero trade flows in the market allocation.

reached also by Macedoni and Weinberger (2019*b*), but in the context of perfect information.

The relationship between quality certification and trade costs is opposite that of minimum quality standards. In fact, since trade forces the exit of some medium-quality firms, the optimal certification standard is lower than the autarky case. Furthermore, the certification standard exhibits a non-monotone, V-shaped relationship with respect to trade costs, which reflects the trade-off previously discussed. At low levels of trade costs, the main benefit of certifications is to promote entry of higher-quality firms. Hence, starting from low trade costs, their further reduction causes a lowering of average quality, which increases the optimal certification threshold. In contrast, starting from high trade costs, a reduction in them causes the certification standard to decline to mitigate the exit of medium-quality firms. These results show that explicitly modeling asymmetric information can reveal heterogeneous effects of policies and, thus, shed light on their effectiveness.

Related Literature. Following the work of Akerlof (1970), early studies examined the welfare effects of minimum quality standards in a sector (Leland, 1979; Shapiro, 1983; Ronnen, 1991; Crampes and Hollander, 1995). This literature showed that, under some parameter values, standards can improve welfare. My paper extends this line of research along two dimensions. First, I consider the effects of standards in the current workhorse trade model of monopolistic competition and firm heterogeneity. Second, I consider the effects of asymmetric information in trade and examine how standards are related to trade costs. This second avenue is motivated by the fact that current "deep" trade agreements also involve product standards which traditionally have been considered just a domestic policy.[8]

The international trade literature has examined the effects of asymmetric information and adverse selection since the 1980s (Mayer, 1984; Bond, 1984; Donnenfeld et al., 1985; Donnenfeld, 1986; Bagwell and Staiger, 1989).[9] Several policies have been suggested to

[8]A related line of research considers the effects of regulations in the presence of heterogeneous consumers. In fact, Shapiro (1983) notices that a quality standard may harm those consumers who prefer low-prices, low-quality goods.

[9]The works of Baldwin et al. (2000), Fischer and Serra (2000), and Atkeson et al. (2014) examine the

reduce such a negative externality. For instance, Bagwell and Staiger (1989) find that an export subsidy can compensate the high-quality firms and allow them to export when adverse selection generates insufficient entry of such firms. The work of Donnenfeld et al. (1985) is, to my knowledge, the first that examines the effects of minimum quality standards when quality is known for domestic production but not for imports. My paper expands such literature as it examines the consequences of asymmetric information in the Melitz (2003) model of heterogeneous firms and monopolistic competition. An additional contribution is the study of quality certifications.

The paper also contributes to the literature that provides rationales for regulations and product standards. Trade models often justify the presence of regulations with ad hoc externalities (Mei, 2017; Parenti and Vannoorenberghe, 2019; Grossman et al., 2021).[10] The assumption of ad hoc externalities has the disadvantage of always justifying the presence of a minimum quality standard. However, confirming the results of the literature (Donnenfeld, 1986; Gaigné and Larue, 2016*a*), I show that when asymmetric information is explicitly modeled, such standards do not always improve welfare. Furthermore, private action is still possible in the presence of market frictions and, thus, assuming an ad hoc externality ignores the strategies heterogeneous firms can follow in response to the externality, such as the quality certifications modeled in this paper.

My model is closely related to the work by Gaigné and Larue (2016*a*, *b*) who also study the effects of quality standards in a Melitz model with heterogeneous firms. The key difference between my paper and that of the two authors is that in their paper, consumers have full information on product quality, while in my baseline model, consumers do not know the quality of firms' products. Hence, my paper extends the previous results by adding the channel of asymmetric information. The paper is also closely related to the review of the effects of certifications and labels by Bonroy and Constantatos (2015). My model comple-

effects of regulations in the context of models of oligopoly.

[10]Another rationale explored in the literature is misallocation of production across heterogeneous firms that charge variable markups (Macedoni and Weinberger, 2019*a*, *b*). I abstract from such channel as I assume constant markups.

ments the authors', as it extends the analysis of certification to a market organization with a continuum of firms, each producing products with different quality levels. While Bonroy and Constantatos (2015) offer a comprehensive analysis of the effects of certification and labeling, my paper focuses solely on their effects in the presence of heterogeneous firms.[11] A further contribution is to examine the effects of trade on the optimal certification standard.[12]

My model shares some similarities with Disdier et al. (2020) as both papers feature a Melitz model of trade with asymmetric information on firm quality. While the focus of my paper is on the welfare effects of minimum quality standards and certifications, the objective in Disdier et al. (2020) is to predict how a minimum quality standard affects export performance. Furthermore, the authors' paper features a signaling technology which allows firms to fully communicate their quality to consumers upon payment of a fixed cost - which distinguishes such technology from the certification technology examined in this paper.

The paper is organized as follows: I begin with a closed economy model in section 2, in which I show the welfare effects of quality standards and quality certifications. Section 3 studies the interaction between asymmetric information, quality standards, quality certification, and countries' openness in a model with two-symmetric countries. Section 4 concludes.

2 Closed Economy Model

I consider a closed economy model in which L consumers enjoy the consumption of varieties of a differentiated good. There is a mass of atomistic firms that are monopolistically competitive. Firms differ in their quality which is modeled as a demand shifter denoted by z. Quality is drawn from a distribution with support $[b, \infty]$, pdf g(z), and CDF G(z).[13]

[11] Bonroy and Constantatos (2015) survey the effects of certification and labels on market structure, showing that the certification can reduce welfare if it exacerbates market distortions due to imperfect competition (Zago and Pick, 2004; Baltzer, 2012). The authors also discuss the effects of alternative cost schemes for quality inspection, as well as the difference between socially optimal standards and industry-set standards.

[12] There is a parallel literature that studies the role of reputation in the presence of asymmetric information on product quality (Grossman and Horn, 1988; Falvey, 1989; Chisik, 2003; Cagé and Rouzet, 2015; Zhao, 2018; Zhong, 2018; Bai et al., 2019). My paper complements this literature as it shows that even in the absence of reputation externalities, minimum quality standards and certifications can improve welfare.

[13] Heterogeneity in quality modeled this way is also a feature of Macedoni and Weinberger (2019*a*, *b*).

Higher-quality firms have higher marginal costs. Firms pay a fixed cost f_E in labor units to enter and discover their quality draw. Labor is the only factor of production, and I normalize the wage to one. Free entry drives expected profits to zero.

2.1 Benchmark

As a benchmark, this section briefly outlines a model with perfect information. Consumers have CES utility with a quality shifter as in Kugler and Verhoogen (2012), Hallak and Sivadasan (2013), Feenstra and Romalis (2014), and Gaigné and Larue (2016*a*):

$$U = \left[\int_{\omega \in \Omega} (z(\omega) q(\omega))^{\frac{\sigma-1}{\sigma}} d\omega \right]^{\frac{\sigma}{\sigma-1}} \tag{1}$$

where $q(\omega)$ is the quantity consumed of variety ω and $\sigma > 1$ is the elasticity of substitution. The inverse demand function for variety ω is:

$$q(\omega) = \frac{z(\omega)^{\sigma-1} p(\omega)^{-\sigma}}{P_{pi}^{1-\sigma}} \tag{2}$$

where $P_{pi} = \left[\int_{\omega \in \Omega} \left(\frac{p(\omega)}{z(\omega)} \right)^{1-\sigma} d\omega \right]^{\frac{1}{1-\sigma}}$ is the price index in the benchmark model and $\frac{p(\omega)}{z(\omega)}$ is the quality-adjusted price. Notice that $U = P_{pi}^{-1}$.

Since firms differ in their quality z, I substitute the argument ω above with z.[14] The marginal cost increases in quality and equals z^{α}, with $\alpha \in (0, 1)$. The restriction on the parameter α guarantees that higher-quality firms enjoy higher revenues because the quality-adjusted price is declining in quality. Firms pay a fixed cost of production f in labor units.[15]

[14] An alternative framework is that of Hallak and Sivadasan (2013), in which firms differ both in terms of quality and productivity. While the qualitative results of standards would be similar, the quantitative effect would differ as the authors' model features a distribution of firms of different sizes at the same quality level.

[15] In Appendix 5.4.7, I consider a model extension in which quality increases the fixed costs of firms. I show that this assumption only affects the results quantitatively. For instance, minimum quality standards can still improve welfare and, furthermore, the presence of fixed costs related to quality magnify the benefits of the standard. When high-quality firms pay higher fixed costs, there is a tougher selection on them with asymmetric information. Hence, instruments that mitigate the information distortion have larger welfare implications.

Profit maximization yields the standard pricing equation:

$$p(z) = \frac{\sigma}{\sigma - 1} z^{\alpha} \tag{3}$$

Firm profits are increasing in quality and equal:

$$\pi(z) = \frac{L(\sigma - 1)^{\sigma - 1}}{\sigma^{\sigma} P_{pi}^{1-\sigma}} z^{(\sigma-1)(1-\alpha)} - f \tag{4}$$

Setting profits to zero yields the market quality cutoff z_{pi}^{*}:

$$z_{pi}^{*} = \left(\frac{\sigma^{\sigma} P_{pi}^{1-\sigma} f}{L(\sigma - 1)^{\sigma - 1}} \right)^{\frac{1}{(\sigma-1)(1-\alpha)}} \tag{5}$$

Only firms with $z > z_{pi}^{*}$ survive in the market allocation.

2.2 Information Asymmetries

Let us now consider the case in which the information on product quality is only known to firms and not to consumers. While firms offer vertically differentiated varieties where higher-priced goods have higher-quality, consumers only observe horizontally differentiated varieties with varying prices. Since the model is static, consumers cannot adjust their behavior even if they learn the quality of products upon consumption. For this reason, the model is mostly representative of environments in which the identification of the quality of the product is prohibitively expensive because it, for instance, requires investigation over the production processes (i.e., working conditions, emissions, organic farming, etc...). In these cases, government regulations are typically advocated for.

As consumers do not distinguish the quality draws across firms, their demand depends on the average quality in the market (Akerlof, 1970). The inverse demand shifter for each variety is the same and is equal to the average inverse demand shifter in the market $\bar{z}_{ia}$:

$$\bar{z}_{ia} = \left[\int_{\omega \in \Omega} z^{\frac{\sigma-1}{\sigma}} \mu(z) dz \right]^{\frac{\sigma}{\sigma-1}} \tag{6}$$

where $z^{\frac{(\sigma-1)}{\sigma}}$ is the inverse demand shifter under perfect information for variety z, $\mu(z)$ is the pdf of the quality distribution, conditional on being supplied in the market, namely that firms with quality z are active. The ex-ante utility of the representative consumer is then:

$$U_{ex-ante} = \left[\int_{\omega \in \Omega} (\bar{z}_{ia} q(\omega))^{\frac{\sigma-1}{\sigma}} d\omega \right]^{\frac{\sigma}{\sigma-1}} \tag{7}$$

The inverse demand function for variety ω is:

$$q(\omega) = \frac{p(\omega)^{-\sigma}}{P_{ia}^{1-\sigma}} \tag{8}$$

where $P_{ia} = \left[\int_{\omega \in \Omega} p(\omega)^{1-\sigma} d\omega \right]^{\frac{1}{1-\sigma}}$ is the price index under information asymmetries. Notice that the average quality $\bar{z}_{ia}$ does not enter the demand function. A higher average quality shifts up the demand for all goods equally and, consequently, has no effect on the demand for a single good. The ex-post utility is:

$$U_{ex-post} = \left[\int_{\omega \in \Omega} (z(\omega) q(\omega))^{\frac{\sigma-1}{\sigma}} d\omega \right]^{\frac{\sigma}{\sigma-1}} = P_{ia}^{\sigma-1} \left[\int_{\omega \in \Omega} z(\omega)^{\frac{\sigma-1}{\sigma}} p(\omega)^{1-\sigma} d\omega \right]^{\frac{\sigma}{\sigma-1}} \tag{9}$$

and takes into account the actual quality of products. The difference between the ex-ante utility and the ex-post utility captures the negative externality that the asymmetric information generates.

The solution to the firm's problem is analogous to the benchmark model as prices equal a constant markup over the marginal cost (3), which is increasing in z. However, higher z does not increase the demand for firm z's products, since consumers do not have information on product quality. As a result, high-quality firms are equivalent to high-cost firms. This is summarized in the fact that profits are declining in quality:

$$\pi(z) = \frac{L(\sigma-1)^{\sigma-1}}{\sigma^{\sigma} P_{ia}^{1-\sigma}} z^{-(\sigma-1)\alpha} - f \tag{10}$$

which is in stark contrast with the profit equation (4) under perfect information. Setting the profits equal to zero determines an upper cutoff for quality z_{ia}^*:

$$z_{ia}^* = \left(\frac{L(\sigma-1)^{\sigma-1}}{\sigma^{\sigma} P_{ia}^{1-\sigma} f} \right)^{\frac{1}{(\sigma-1)\alpha}} \tag{11}$$

Hence, only firms with $z \in [b, z_{ia}^*]$ survive in the market. This is the well-known phenomenon of adverse selection, whereby the presence of information asymmetries leads to the exit of high-quality firms in favor of low-quality firms. In fact, in the case of perfect information, the market selects out low-quality firms and only firms with high enough quality, above the cutoff z_{pi}^*, survive in the market.

The equilibrium cutoff is pinned down by the zero expected profit condition:

$$f J(b, z_{ia}^*) = f_E \tag{12}$$

where:

$$J(\underline{z}, z^*) = \int_{\underline{z}}^{z^*} \left(\left(\frac{z^*}{z} \right)^{(\sigma-1)\alpha} - 1 \right) g(z) dz \tag{13}$$

With the equilibrium value of the cutoff, we can derive the other general equilibrium variables of the model: the mass of entrants, the price index, and the ex-post utility of the representative consumer. I leave these derivations to Appendix 5.1.1.

2.3 Minimum Quality Standards

The government chooses a value of $z_{min} \geq b$, such that only firms with quality $z > z_{min}$ are allowed to stay in the market. I abstract from the costs associated with the quality inspections and the enforcement of this policy which would inevitably reduce its welfare benefits.[16] The zero-profit condition becomes:

$$fJ(z_{min}, z^*_{min}) = f_E \tag{14}$$

A minimum quality standard allows a more lenient selection on higher-quality firms. In fact, by comparing (14) with (12), $J(z_{min}, z^*_{min}) = J(b, z^*_{ia})$. $J(z_{min}, z^*_{min})$, defined in (13), is declining in z_{min} and increasing in z^*_{min}. Because $z_{min} \geq b$, $z^*_{min} \geq z^*_{ia}$, with strict inequality if $z_{min} > b$. This means that the quality cutoff is higher under a minimum quality standard than in the market allocation.

The welfare effects of the minimum standard can be summarized as:

Proposition 1. *A minimum quality standard has an ambiguous effect on welfare and its welfare benefits decline with the elasticity of marginal costs with respect to quality.*

As the there are no closed form expressions for the quality cutoff z^*_{ia}, the welfare effects of minimum quality standards cannot be characterized analytically in a tractable manner. Hence, I rely on numerical methods to substantiate Proposition 1. For convenience, I assume that quality is Pareto distributed with shape parameter κ and shift parameter b.[17]. I restrict the parameter space so that $\kappa > (\sigma - 1)(1 - \alpha)$. I leave the derivations to Appendix 5.2. It is convenient to write the optimal level of the minimum quality standard as relative to the lower bound of the quality distribution b, namely z_{min}/b. If this ratio equals one, the minimum quality standard is ineffective.[18]

By increasing the lower and upper bound of quality allowed in the market, both the average quality and the average price increase. The increase in the average quality is welfare

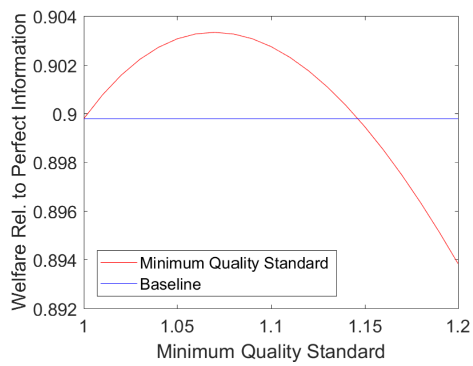
[16] Although the theoretical implication of inspection and enforcement costs are trivial since they unambiguously reduce the welfare benefits of quality standards, their quantitative implications are crucial to decide on the implementation of a standard. Furthermore, absent any inspection and enforcement costs, it would be optimal for governments to apply exact quality scores to products and, thus, eliminate the negative consequences of asymmetric information. Only the presence of large inspection and enforcement costs prevents governments from implementing this policy.

[17] The assumption that the underlying distribution of firm characteristics is Pareto is a common one in the trade literature and follows Helpman et al. (2004) and Chaney (2008).

[18] In the numerical exercise shown in the main text, I normalize b to one so that both minimum quality standard z_{min} and the certification standard are expressed as relative to b.

improving, but such an effect can be more than offset by the increase in prices. In fact, the minimum quality standard does not alter the relative consumption across varieties: consumers continue to purchase higher volumes of cheap, low-quality varieties relative to the expensive, high-quality ones. Whether or not welfare improves with the minimum quality standard depends on whether the average quality effect dominates the price effect. Figure 1 shows that a minimum quality standard can increase welfare under some values for the parameters of the model. For low levels of the standard, the benefits from higher average quality outweigh the costs associated with higher average prices.

Figure 1: Minimum Quality Standard and Welfare



The figure plot the value of the utility of the representative consumer under the baseline scenario of asymmetric information and under the case of a minimum quality standard. Both values are normalized by the utility attained under perfect information. The main parameters used are: $\alpha = 0.3$, $\kappa = 4$, $\sigma = 4$ and $L = b = f = f_E = 1$.

The key parameter that controls the welfare effects of the standard is α, which is the marginal cost elasticity with respect to quality. The larger the value of α, the lower the welfare benefits of the standard, which can even be welfare reducing. Figure 4 in the appendix shows the relationship between welfare and the minimum quality standard for alternative values for α. Higher α implies a higher increase in prices due to the entry of high-quality (and high-price) firms. Figure 5 in the appendix shows that the higher α, the higher the increase in P_{ia} after the imposition of the standard. The figure also shows that the standard increases the mass of entrants, but such a positive effects declines with α.

Finally, I consider the effects of changes in the lower bound of the quality distribution b. Higher b implies a quality distribution which is shifted towards higher values. However,

b only has a level effect on the productivity distribution: it does not affect how changes in minimum quality standard affect welfare. As a result, although for higher levels of b the optimal minimum quality standard z_{min} is higher, the optimal level of z_{min}/b is independent of b. Details are in the Appendix 5.4.6.[19]

2.4 Quality Certifications

In this section, I examine the welfare effects of quality certifications. Firms with high enough quality can pay an extra fixed cost K that guarantees that the quality level of the product is above a certain threshold z_g, and such information is successfully conveyed to consumers with a proper label. The fixed cost represents, for instance, the costs required for the inspections from a government agency or a private one.[20] This way of modeling the quality certification is in line with the survey by Bonroy and Constantatos (2015), although I abstract from per-unit costs of inspection.[21]

The utility of the representative consumer becomes:

$$U_{ex-ante} = \left[\int_{\omega \in \Omega_{ia}} (\bar{z}_{ia} q(\omega))^{\frac{\sigma-1}{\sigma}} d\omega + \int_{\omega \in \Omega_{ct}} (\bar{z}_{ct} q(\omega))^{\frac{\sigma-1}{\sigma}} d\omega \right]^{\frac{\sigma}{\sigma-1}} \tag{15}$$

where Ω_{ia} is the set of varieties produced without the certification and Ω_{ct} with the certification. The shifters $\bar{z}_{ia}$ and $\bar{z}_{ct}$ represent the average quality, conditional on products being in the sets Ω_{ia} and Ω_{ct}, and are defined by (6).

In this case, the firm z faces two alternative demand functions depending on whether the fixed cost K is paid:

$$q(\omega) = \frac{\bar{z}_{ia}^{\sigma-1} p(\omega)^{-\sigma}}{P_{ct}^{1-\sigma}} \qquad \omega \in \Omega_{ia} \tag{16}$$

[19] I also show that changes in the level of b do not affect the welfare effects of quality certifications, which I discuss in the next section.

[20] To obtain the certification for organic farming, US firms cannot use prohibited materials for three years. This constitutes another example of the fixed cost K required to obtain the certification.

[21] Here I consider the simplifying case in which the certification only offers one quality threshold, although there are examples in which certifications cover multiple quality thresholds, such as for energy efficiency. See Bonroy and Constantatos (2015) for a discussion of the optimal number of thresholds.

$$q(\omega) = \frac{\bar{z}_{ct}^{\sigma-1} p(\omega)^{-\sigma}}{P_{ct}^{1-\sigma}} \qquad \omega \in \Omega_{ct} \tag{17}$$

where the price index is $P_{ct} = \left[\int_{\omega\in\Omega_{ia}} \bar{z}_{ia}^{\sigma-1} p(\omega)^{1-\sigma} d\omega + \int_{\omega\in\Omega_{ct}} \bar{z}_{ct}^{\sigma-1} p(\omega)^{1-\sigma} d\omega\right]^{\frac{1}{1-\sigma}}$. Since here there are two sets of varieties, the terms $\bar{z}_{ia}$ and $\bar{z}_{ct}$ do not cancel out in the demand functions, in contrast to the previous section.

The pricing equation is the same as (3) and profits are:

$$\pi_{ia}(z) = \frac{L(\sigma-1)^{\sigma-1} \bar{z}_{ia}^{\sigma-1}}{\sigma^\sigma P_{ct}^{1-\sigma}} z^{-(\sigma-1)\alpha} - f \qquad \text{if } z \in \Omega_{ia} \tag{18}$$

$$\pi_{ct}(z) = \frac{L(\sigma-1)^{\sigma-1} \bar{z}_{ct}^{\sigma-1}}{\sigma^\sigma P_{ct}^{1-\sigma}} z^{-(\sigma-1)\alpha} - f - K \qquad \text{if } z \in \Omega_{ct} \tag{19}$$

Setting the two profit functions (18) and (19) to zero yields the quality cutoffs:

$$(z_{ia}^*)^{(\sigma-1)\alpha} = \frac{L(\sigma-1)^{\sigma-1} \bar{z}_{ia}^{\sigma-1}}{\sigma^\sigma P_{ct}^{1-\sigma} f} \tag{20}$$

$$(z_{ct}^*)^{(\sigma-1)\alpha} = \frac{L(\sigma-1)^{\sigma-1} \bar{z}_{ct}^{\sigma-1}}{\sigma^\sigma P_{ct}^{1-\sigma} (f+K)} \tag{21}$$

However, in this case, the sorting of firms is not entirely determined by the two cutoffs. Consider the case in which $\pi_{ct}(z_g) > \pi_{ia}(z_g)$ and $z_{ct}^* > z_{ia}^*$.[22] This means that obtaining the certification is profitable for a firm with quality equal to z_g and for higher levels of quality than z_g the certification is always preferred.

In this case, there are two possible sorting patterns that depend on the level of z_g, which is chosen by the certification agency. If $z_g > z_{ia}^*$, there are two distinct sets of firms: firms with $z \in [b, z_{ia}^*]$ are without certification, and firms with $z \in [z_g, z_{ct}^*]$ are with certification. The certification allows some high-quality firms to enter the market since firms with $z \in [z_g, z_{ct}^*]$ were not producing in the market allocation. This occurs at the expense of some medium-quality firms that are forced out of the market. In fact, I prove, in Appendix 5.3, that z_{ia}^* declines with the certification. The certification, thus, causes a hollowing out of medium-

[22] In Appendix 5.3, I show the derivations and discuss all sorting cases.

quality firms and the polarization of quality in the market. The quality polarization does not occur if $z_g < z^*_{ia}$. In this case, the set of firms that do not have the certification is $z \in [b, z_g]$ and the set of firms that do have the certification is $z \in [z_g, z^*_{ct}]$.

As for the case of a minimum quality standard, I rely on numerical methods, assuming that quality is Pareto distributed, to illustrate the welfare effects of quality certifications:

Proposition 2. *Quality certification can improve welfare for appropriate choices of certification standard z_g and fixed certification cost K.*

The certification allows some high-quality firms to enter, which raises average quality. However, this is achieved with the payment of a fixed cost, which is, on the other hand, welfare reducing. Furthermore, the entry of new firms squeezes the set of firms without certification, forcing those with the higher quality out of the market.

Figure 2 shows a hump-shaped relationship between the minimum quality certification z_g and welfare. Hence, for some values of z_g and K, the certification can improve welfare. The optimal level of z_g balances the benefits of promoting entry of higher-quality firms with the negative effect of forcing out the medium-quality firms with no certification. The optimal z_g tends to avoid an increase in quality polarization, so that the optimal set of firms without certification is $[b, z_g]$, and the optimal set of firms with certification is $[z_g, z^*_{ct}]$. Figure 2 also shows that the positive effect of certifications depends on having a sufficiently low K.[23]

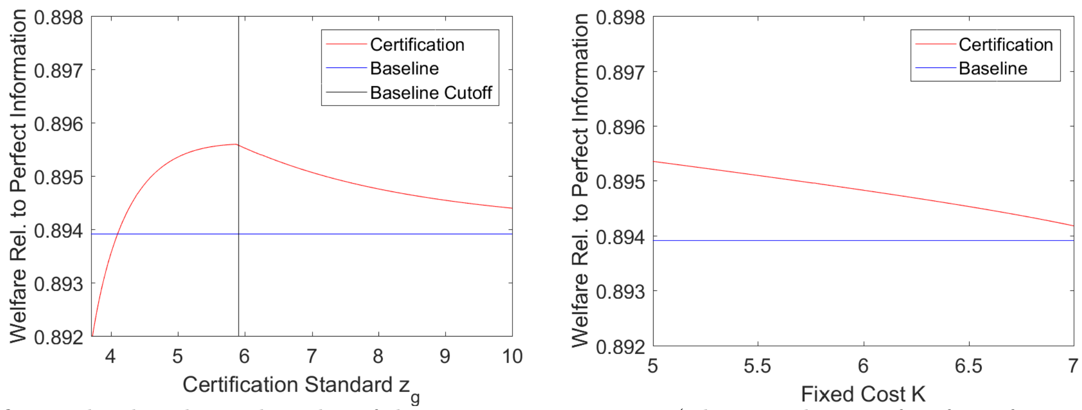
3 Two Country Model

In this section, I study the relationship between asymmetric information and trade, and show how minimum quality standards and certifications interact with trade costs. I consider a model with two symmetric countries, in which exporting requires a variable iceberg trade cost

[23] Figure 6 in the appendix shows the relationship between the welfare effects of the certification and α. Higher values of α magnify the benefits of the certification as they limit the entry of the most expensive firms. The effects of a minimum quality standard in the presence of certification are qualitatively similar to the case discussed in section 2.3.

Figure 2: Certification and Welfare

(a) Certification Standard z_g (b) Fixed Cost K



The figures plot the value in the utility of the representative consumer (relative to the case of perfect information without the option of certification) for alternative parameter values described in the figures. The main parameters used are: $\kappa = 4$, $b = f = f_E = 1$, $\alpha = 0.3$, and $\sigma = 2.5$. When varying K, $z_g = 5$. When varying z_g, $K = 5$.

$\tau > 1$ as well as a fixed cost f which is identical to the fixed cost for domestic production.[24]

3.1 Information Asymmetries and Trade

I assume that consumers do not distinguish between the average quality sold in the domestic economy and the average quality of exporters. For this reason, both domestic varieties and foreign varieties exhibit the same inverse demand shifter which is the average inverse demand shifter in the market $\bar{z}_{ia}$ computed in an analogous way to the closed economy model $\bar{z}_{ia} = \left[\int_{\omega\in\Omega} z^{\frac{\sigma-1}{\sigma}} \mu(z)dz\right]^{\frac{\sigma}{\sigma-1}}$. This assumption allows for the closest comparison between the closed economy model and the two country model. Such an assumption seems reasonable in the case of two symmetric countries: consumers need to know which firms select into exporting in order to distinguish between the average quality across sources.

The expression for the ex-ante and ex-post utility of consumers is analogous to the closed economy case, and so is the solution to the consumer problem. Similarly, prices equal a constant markup over the marginal cost, which is increasing in z. I denote the destination with subscript $j = D, X$ for domestic and export markets. As in the closed economy model,

[24] Allowing heterogeneity between fixed costs for export and for domestic sales does not alter the results.

profits are declining in quality:

$$\pi_j(z) = \frac{L(\sigma-1)^{\sigma-1}}{\sigma^\sigma P_{ia}^{1-\sigma}} \tau_j^{1-\sigma} z^{-(\sigma-1)\alpha} - f \tag{22}$$

where $\tau_D = 1$ and $\tau_X = \tau$. Setting the profits equal to zero yields the cutoff $z^*_{j,ia}$:

$$z^*_{j,ia} = \left(\frac{L(\sigma-1)^{\sigma-1}\tau_j^{1-\sigma}}{\sigma^\sigma P_{ia}^{1-\sigma} f} \right)^{\frac{1}{(\sigma-1)\alpha}} \tag{23}$$

Hence, only firms with $z \in [b, z^*_{j,ia}]$ survive in market j. The export cutoff is declining in the trade costs: only firms with the lowest quality can export, as they have low enough prices. The higher the trade costs, the lower the average quality exported. This is in stark contrast to the benchmark case of perfect information where only high-quality firms can export.[25]

Furthermore, if trade costs are large enough, no firms export. In particular, if $z^*_{X,ia} < b$, the export cutoff is so low that no firm is able to make a positive profit by exporting. This provides an additional explanation to the puzzle of zero trade flows between countries (Baldwin and Harrigan, 2011).[26] The presence of zero exports from a country to a destination can be due to the presence of asymmetric information: when a destination lacks information about the quality of products coming from a certain origin and trade costs are large but finite, zero trade flows can occur.

We can express the export quality cutoff as a function of the domestic quality cutoff:

$$z^*_{X,ia} = z^*_{D,ia} \tau^{-\frac{1}{\alpha}} \tag{24}$$

The equilibrium cutoffs are determined by substituting (24) into the zero expected profit

[25] I consider a model with perfect information and trade in Appendix 5.4.1.

[26] In a standard model with perfect information, monopolistic competition, and heterogeneous firms, the presence of zero trade flows is rationalized with infinite trade costs or by setting an upper bound to the productivity distribution.

condition, which is given by:

$$f\left[J(b, z^*_{D,ia}) + J(b, z^*_{X,ia})\right] = f_E \tag{25}$$

When a country opens to trade, the average quality in the economy declines. In fact, by comparing (25) to (12), $J(b, z^*_{D,ia}) < J(b, z^*_{ia})$. Since Since $\frac{\partial J}{\partial z^*} > 0$, we can conclude that $z^*_{D,ia} < z^*_{ia}$. As in a standard model with perfect information, trade reallocates production from small non-exporting firms towards large exporting firms. While in the case of perfect competition, the reallocation is from low-quality to high-quality firms, in the case of asymmetric information, trade reallocates production from high-quality firms to low-quality firms. I leave the derivations of the other equilibrium variables to Appendix 5.4.2.

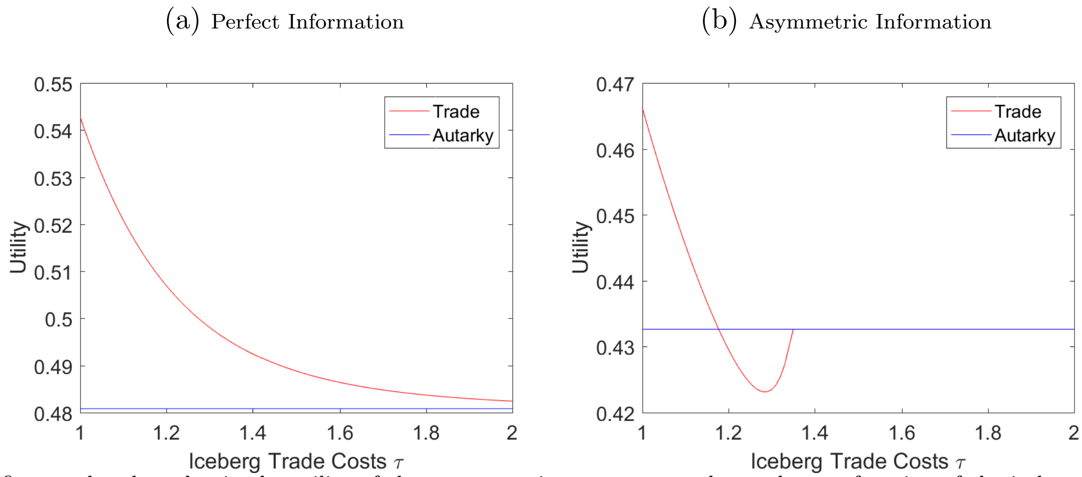
Under perfect information, trade always improves welfare relative to autarky, and reductions in trade costs always improve welfare. Panel (a) of Figure 3 illustrates this result. As trade increases the average quality, the utility of the representative consumer increases. In contrast, the effects of trade on welfare can be summarized by the following proposition:

Proposition 3. *In the presence of asymmetric information, trade has an ambiguous effect on welfare.*

I rely on numerical methods to illustrate the result since the presence of asymmetric information causes the analytical results to be highly intractable. On the one hand, trade reduces prices, as the surviving firms are low-quality, low-price producers. On the other hand, as stated in Proposition **??**, trade reduces the average quality. At low levels of trade costs, the first effect dominates and trade improves welfare (see Panel (b) of Figure 3). At relatively higher values of trade costs, trade reduces welfare as the loss in quality dominates the efficiency gains.[27]

[27]Notice that at values of trade costs τ greater than 1.4 in the Figure, the economy reverts back to autarky as explained in the main text.

Figure 3: Trade and Welfare



The figures plot the value in the utility of the representative consumer under trade as a function of the iceberg trade cost τ and under autarky, for the case of perfect information and the case of asymmetric information. Quality is assumed to be Pareto distributed with shape parameter $\kappa = 4$ and shift parameter $b = 1$. The main parameters used are: $L = f = f_E = 1$, $\sigma = 2.5$, and $\alpha = 0.3$.

3.2 Trade and Minimum Quality Standards

The governments of each country impose a harmonized minimum quality standard z_{min} such that only firms with $z > z_{min}$ are allowed to stay in the market. For simplicity, I assume that the standard is harmonized: both countries choose the same level of the standard to maximize the ex-post utility of consumers.[28] The quality cutoffs for the domestic and export markets are defined by (23) and (24). The standard affects the zero expected profit condition:

$$f\left[J(z_{min}, z^*_{D,ia}) + J(z_{min}, z^*_{X,ia})\right] = f_E \tag{26}$$

Since J is declining in z_{min}, the imposition of a minimum quality standard allows for some higher-quality firms to start producing and exporting as both cutoffs $z^*_{D,ia}$ and $z^*_{X,ia}$ increase. As we previously discussed, if trade costs are large enough, the export cutoff $z^*_{X,ia}$ could be lower than b, and for this reason, exports are zero. The positive effect of z_{min} on the cutoff $z^*_{X,ia}$ is such that the standard has an effect of *trade creation*. By allowing the production of firms that have higher-quality and are more expensive, the standards facilitate exports and,

[28] The objective is to study how the standards interact with trade openness. Political economy considerations are beyond the purpose of this paper.

thus, can allow for positive trade flows across two countries.[29]

The relationship between trade and the optimal minimum quality standard can be summarized by the following proposition:

Proposition 4. *The optimal standard under trade is larger than the standard in autarky. Furthermore, the optimal standard increases with trade costs.*

I use numerical methods to illustrate the proposition in Figure 9 of the appendix. This result is due to the fact that under trade, the average quality is lower than in autarky. As only low-quality firms are able to export, labor is reallocated from high-quality firms to low-quality firms, exacerbating the distortion solved by the minimum quality standard. Hence, trade calls for a higher optimal standard. Even though the standard is higher under trade than in autarky, a reduction in trade costs is associated with a reduction in the optimal level of the standard. One of the benefits of the minimum quality standard is to promote the exports of some higher-quality firms. This benefit becomes less important when trade costs fall, since this allows some high-quality firms to begin exporting. Thus, the optimal standard declines.

3.3 Trade and Quality Certifications

In this section, I consider the effects of certifications in the context of trade. I restrict the attention to the case in which only domestic firms can apply for the certification. Hence, home firms can apply to the home certification and foreign firms can apply to the (identical) foreign certification. This is reflective of environments in which there are implicit barriers for exporters, which could be due to lack of knowledge of the certification agency of the destination or other impediments (see, for instance, Iodice (2020)).

Leaving the derivations to Appendix 5.4.4, the relationship between quality certifications and trade are summarized in the following proposition:

[29] In Figure 9 of the appendix, I plot the optimal level of the minimum quality standard under trade and find that trade occurs even at levels of trade costs, such that in the original market allocation no exports were concluded (see Panel (b) of Figure 3 for $\tau > 1.4$).

Proposition 5. *The optimal level of the quality certification is lower with trade than in autarky, and it exhibits a V-shaped relationship with respect to trade costs.*

I illustrate the proposition using numerical methods in Figure 10 of the appendix, I plot the optimal level of z_g, relative to its corresponding value in autarky, against the level of trade costs τ. Recall that the optimal z_g is low enough to incentivize medium-quality firms to distinguish themselves from low-quality firms by paying the fixed cost of certification. As trade forces some medium-quality firms out of the market, the optimal z_g declines as well to a lower value than autarky.

Let us now discuss the fact that the optimal z_g exhibits a V-shaped relationship with respect to trade costs. Starting from high levels of trade costs, a reduction in trade costs also reduces the optimal z_g. This is due to the fact that lower τ forces some medium-quality firms out of the market, and the optimal certification allows medium-quality firms to pay for the fixed cost of certification. In contrast, starting from low levels of trade costs, a further reduction in them increases the optimal z_g. This is because, at low levels of trade costs, only low-quality firms are able to survive in the market allocation. As a result, the objective of the certification standard z_g is to promote entry of higher-quality firms, which is possible only with higher values of the standard.

4 Conclusions

This paper presents a model of heterogeneous firms in which product quality is known to producers and unknown to consumers. By the well-known adverse selection mechanism, low-quality firms are the only firms able to sell their products in the market allocation. In addition to that, I show that adverse selection affects export selection, as only low-quality firms are able to export.

The paper shows that two common instruments can partially address the negative externality: minimum quality standards force out of the market the low-quality firms, and quality certifications allow the entry of high-quality firms. Although the two instruments can improve welfare in autarky and under trade, their effects differ depending on the level of trade costs. Lower trade costs call for lower minimum quality standards, but they can increase or decrease the optimal level of the certification threshold. These results have a clear implication for policy makers, as in modern trade agreement reductions in trade costs are often accompanied by changes in the restrictiveness of product regulations and standards.

References

Akerlof, G. A. (1970), 'The market for "lemons": Quality uncertainty and the market mechanism', *The Quarterly Journal of Economics* **84**(3), 488–500.

Atkeson, A., Hellwig, C. and Ordoñez, G. (2014), ' Optimal Regulation in the Presence of Reputation Concerns', *The Quarterly Journal of Economics* **130**(1), 415–464.

Bagwell, K. and Staiger, R. W. (1989), 'The role of export subsidies when product quality is unknown', *Journal of International Economics* **27**(1), 69–89.

Bai, J., Gazze, L. and Wang, Y. (2019), 'Collective Reputation in Trade: Evidence from the Chinese Dairy Industry', *NBER Working Paper* (26283).

Baldwin, R. E., McLaren, J. and Panagariya, A. (2000), 'Regulatory protectionism, developing nations, and a two-tier world trade system [with comments and discussion]', *Brookings Trade Forum* pp. 237–293.

Baldwin, R. and Harrigan, J. (2011), 'Zeros, Quality, and Space: Trade Theory and Trade Evidence', *American Economic Journal: Microeconomics* **3**(2), 60–88.

Baltzer, K. (2012), 'Standards vs. labels with imperfect competition and asymmetric information', *Economics Letters* **114**(1), 61–63.

Bond, E. W. (1984), 'International trade with uncertain product quality', *Southern Economic Journal* **51**(1), 196–207.

Bonroy, O. and Constantatos, C. (2015), 'On the economics of labels: How their introduction affects the functioning of markets and the welfare of all participants', *American Journal of Agricultural Economics* **97**(1), 239–259.

Cagé, J. and Rouzet, D. (2015), 'Improving "national brands": Reputation for quality and export promotion strategies', *Journal of International Economics* **95**(2), 274–290.

Chaney, T. (2008), 'Distorted Gravity: The Intensive and Extensive Margins of International Trade', *American Economic Review* **98**(4), 1707–21.

Chisik, R. (2003), 'Export industry policy and reputational comparative advantage', *Journal of International Economics* **59**(2), 423–451.

Crampes, C. and Hollander, A. (1995), 'How Many Karats Is Gold: Welfare Effects of Easing a Denomination Standard', *Journal of Regulatory Economics* **7**(2), 131–143.

Disdier, A.-C., Gaigné, C. and Herghelegiu, C. (2020), Do Standards Improve the Quality of Traded Products?, Ecares working paper 2018-38.

Donnenfeld, S. (1986), 'Intra-industry trade and imperfect information about product quality', *European Economic Review* **30**(2), 401–417.

Donnenfeld, S., Weber, S. and Ben-Zion, U. (1985), 'Import controls under imperfect information', *Journal of International Economics* **19**(3), 341–354.

Esponda, I. (2008), 'Behavioral equilibrium in economies with adverse selection', *American Economic Review* **98**(4), 1269–91.

Falvey, R. E. (1989), 'Trade, quality reputations and commercial policy', *International Economic Review* **30**(3), 607–622.

Feenstra, R. C. and Romalis, J. (2014), 'International prices and endogenous quality', *The Quarterly Journal of Economics* **129**(2), 477–527.

Ferro, E., Otsuki, T. and Wilson, J. S. (2015), 'The effect of product standards on agricultural exports', *Food Policy* **50**(C), 68–79.

Fischer, R. and Serra, P. (2000), 'Standards and protection', *Journal of International Economics* **52**(2), 377–400.

Gaigné, C. and Larue, B. (2016*a*), 'Quality Standards, Industry Structure, and Welfare in a Global Economy', *American Journal of Agricultural Economics* **98**, 1432–1449.

Gaigné, C. and Larue, B. (2016*b*), 'Public quality standards and the food industry's structure in a global economy', *Review of Agricultural, Food and Environmental Studies* **97**.

Gaigné, C. and Le Mener, L. (2014), 'Agricultural prices, selection, and the evolution of the food industry', *American Journal of Agricultural Economics* **96**(3), 884–902.

Gavazza, A. and Lizzeri, A. (2021), 'Frictions in product markets', *NBER Working Paper* (29259).

Grossman, G. M. and Horn, H. (1988), 'Infant-industry protection reconsidered: The case of informational barriers to entry', *The Quarterly Journal of Economics* **103**(4), 767–787.

Grossman, G. M., McCalman, P. and Staiger, R. W. (2021), 'The "new" economics of trade agreements: From trade liberalization to regulatory convergence?', *Econometrica* **89**(1), 215–249.

Hallak, J. C. and Sivadasan, J. (2013), 'Product and process productivity: Implications for quality choice and conditional exporter premia', *Journal of International Economics* **91**(1), 53–67.

Helpman, E., Melitz, M. J. and Yeaple, S. R. (2004), 'Export Versus FDI with Heterogeneous Firms', *American Economic Review* **94**(1), 300–316.

Hottman, C., Redding, S. J. and Weinstein, D. E. (2016), 'Quantifying the sources of firm heterogeneity', *The Quarterly Journal of Economics* .

Iodice, I. (2020), 'The Sound of Silence. Non-transparent technical regulations as obstacles to trade.', *Mimeo* .

Jones, P. and Hudson, J. (1996), 'Signalling product quality: When is price relevant?', *Journal of Economic Behavior & Organization* **30**(2), 257–266.

Kugler, M. and Verhoogen, E. (2012), 'Price, plant size, and product quality', *The Review of Economic Studies* **79**, 307–339.

Leland, H. E. (1979), 'Quacks, lemons, and licensing: A theory of minimum quality standards', *Journal of Political Economy* **87**(6), 1328–1346.

Macedoni, L. and Weinberger, A. (2019*a*), Quality Heterogeneity and Misallocation: The Welfare Benefits of Raising your Standards, Working paper.

Macedoni, L. and Weinberger, A. (2019*b*), Quality Misallocation, Trade, and Regulations, Working paper.

Manova, K. and Zhang, Z. (2017), 'Multi-Product Firms and Product Quality', *Journal of International Economics* **109**, 116–137.

Mayer, W. (1984), 'The infant-export industry argument', *The Canadian Journal of Economics / Revue canadienne d'Economique* **17**(2), 249–269.

Mei, Y. (2017), 'Regulatory Protection and the Role of International Cooperation', *Mimeo* .

Melitz, M. J. (2003), 'The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity', *Econometrica* **71**(6), 1695–1725.

Olper, A., Curzi, D. and Pacca, L. (2014), 'Do food standards affect the quality of eu imports?', *Economics Letters* **122**(2), 233–237.

Overgaard, P. B. (1993), 'Price as a signal of quality: A discussion of equilibrium concepts in signalling games', *European Journal of Political Economy* **9**(4), 483–504.

Parenti, M. and Vannoorenberghe, G. (2019), A simple theory of deep trade integration, Working paper.

Ronnen, U. (1991), 'Minimum quality standards, fixed costs, and competition', *The RAND Journal of Economics* **22**(4), 490–504.

Schwartz, A. and Wilde, L. L. (1985), 'Product Quality and Imperfect Information', *Review of Economic Studies* **52**(2), 251–262.

Shapiro, C. (1983), 'Premiums for high quality products as returns to reputations', *The Quarterly Journal of Economics* **98**(4), 659–679.

Wolinsky, A. (1983), 'Prices as signals of product quality', *The Review of Economic Studies* **50**(4), 647–658.

Wolinsky, A. (1984), 'Product differentiation with imperfect information', *The Review of Economic Studies* **51**(1), 53–61.

Zago, A. M. and Pick, D. (2004), 'Labeling Policies in Food Markets: Private Incentives, Public Intervention, and Welfare Effects', *Journal of Agricultural and Resource Economics* **29**(1), 150–165.

Zhao, Y. (2018), 'Your (country's) reputation precedes you: Information asymmetry, externalities and the quality of exports', *Mimeo* .

Zhong, J. (2018), 'Reputation of quality in international trade: Evidence from consumer product recalls', *Mimeo* .

5 Appendix

5.1 Closed Economy

5.1.1 Information Asymmetries

In this section, I derive the ex-post utility of consumers and other equilibrium objects in the case of the closed economy model with asymmetric information. In contrast to the benchmark case, to evaluate the ex-post utility requires the derivation of the mass of entrants M. To derive that, let us consider the market clearing condition. First, firm revenues equal:

$$r(z) = \sigma f \left(\frac{z^*_{ia}}{z}\right)^{(\sigma-1)\alpha} \tag{27}$$

Market clearing implies that the mass of firms equals:

$$M = \frac{L}{f\sigma R(b, z^*_{ia})} \tag{28}$$

where $R(b, z^*_{ia})$ is proportional to the expected revenues, and is defined as:

$$R(\underline{z}, z^*) = \int_{\underline{z}}^{z^*} \left(\frac{z^*}{z}\right)^{(\sigma-1)\alpha} g(z)dz \tag{29}$$

From the cutoff condition (11), the price index equals:

$$P_{ia}^{\sigma-1} = \frac{f\sigma^{\sigma}}{L(\sigma-1)^{\sigma-1}}(z^*_{ia})^{(\sigma-1)\alpha} \tag{30}$$

Hence, the ex-post utility (9) becomes:

$$U_{ex-post} = \frac{f\sigma^{\sigma}}{L(\sigma-1)^{\sigma-1}}(z^*_{ia})^{(\sigma-1)\alpha}\left[M\int_b^{z^*_{ia}} z^{\frac{\sigma-1}{\sigma}} p(z)^{1-\sigma}(z)dz\right]^{\frac{\sigma}{\sigma-1}} = \tag{31}$$

$$= \frac{L^{\frac{1}{\sigma-1}}(\sigma-1)}{\sigma^{\frac{\sigma}{\sigma-1}} f^{\frac{1}{\sigma-1}}}(z^*_{ia})^{(\sigma-1)\alpha}\left[\frac{\tilde{U}(b, z^*_{ia})}{R(b, z^*_{ia})}\right]^{\frac{\sigma}{\sigma-1}} \tag{32}$$

where

$$\tilde{U}(\underline{z}, z^*) = \int_{\underline{z}}^{z^*} z^{\frac{(\sigma-1)}{\sigma}(1-\alpha\sigma)} g(z) dz \tag{33}$$

Notice that the average quality $\bar{z}_{ia}$ does not enter the welfare equation since it does not affect the demand for an individual variety, as previously discussed. Furthermore, in the ex-post utility, quantity of each variety is weighted by the variety specific quality instead of the average quality.

5.2 Minimum Quality Standard

In this section, I show the derivations for the effects of minimum quality standards in the closed economy model. The ex-post utility of the representative consumer can be written as:

$$U_{ex-post} = \frac{L^{\frac{1}{\sigma-1}}(\sigma-1)}{\sigma^{\frac{\sigma}{\sigma-1}} f^{\frac{1}{\sigma-1}}} (z^*_{min})^{(\sigma-1)\alpha} \left[\frac{\tilde{U}(z_{min}, z^*_{min})}{R(z_{min}, z^*_{min})}\right]^{\frac{\sigma}{\sigma-1}} \tag{34}$$

where z^*_{min} is the quality cutoff under a minimum quality standard. Under a Pareto distribution for quality, with shape parameter κ and shift parameter b, the functions $J(\underline{z}, z^*)$, $R(\underline{z}, z^*)$, and $\tilde{U}(\underline{z}, z^*)$, defined in (13), (29), and (33) become:

$$J(\underline{z}, z^*) = \left(\frac{b}{\underline{z}}\right)^{\kappa} \left[\frac{\kappa}{\kappa+(\sigma-1)\alpha}\left(\frac{z^*}{\underline{z}}\right)^{(\sigma-1)\alpha} + \frac{(\sigma-1)\alpha}{\kappa+(\sigma-1)\alpha}\left(\frac{z^*}{\underline{z}}\right)^{-\kappa} - 1\right] \tag{35}$$

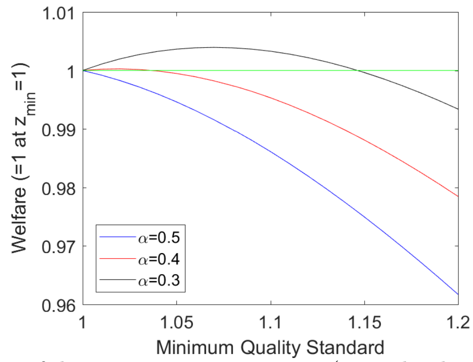
$$R(\underline{z}, z^*) = \left(\frac{b}{\underline{z}}\right)^{\kappa} \frac{\kappa}{\kappa+(\sigma-1)\alpha}\left[\left(\frac{z^*}{\underline{z}}\right)^{(\sigma-1)\alpha} - \left(\frac{z^*}{\underline{z}}\right)^{-\kappa}\right] \tag{36}$$

$$\tilde{U}(\underline{z}, z^*) = \frac{\kappa b^{\kappa}}{\kappa - \frac{(\sigma-1)}{\sigma}(1-\alpha\sigma)} \left[\underline{z}^{-\kappa+\frac{(\sigma-1)}{\sigma}(1-\alpha\sigma)} - (z^*)^{-\kappa+\frac{(\sigma-1)}{\sigma}(1-\alpha\sigma)}\right] \tag{37}$$

First, for a given z_{min} and the parameters, I find the equilibrium cutoff z^*_{min} by solving the free entry condition (12). Second, given z^*_{min}, I can compute $U_{ex-post}$ (34).

Under perfect information, the utility equals: $\left[\frac{(\sigma-1)^{\sigma-1}L}{\sigma^{\sigma} f}\right]^{\frac{1}{\sigma-1}} b^{1-\alpha} \left[\frac{f(\sigma-1)(1-\alpha)}{f_E(\kappa-(\sigma-1)(1-\alpha))}\right]^{\frac{1-\alpha}{\kappa}}$.

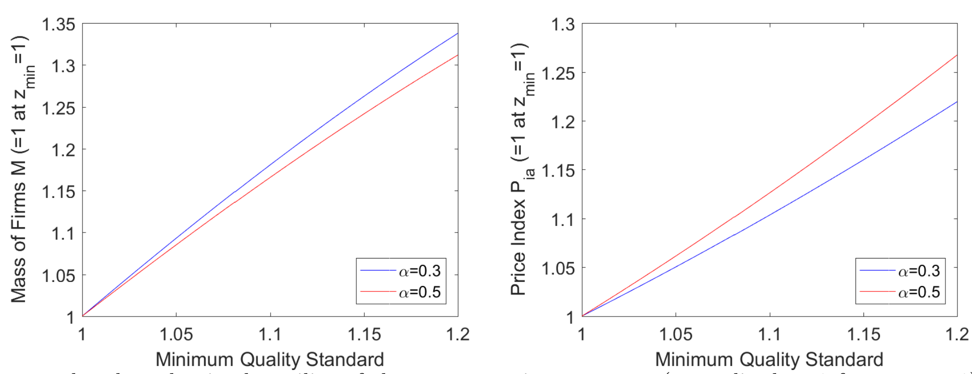
Figure 4: Minimum Quality Standard and Welfare



The figure plots the value in the utility of the representative consumer (normalized to 1 for $z_{min} = 1$) for alternative parameter values described in the figure. The main parameters used are: $\kappa = 4$, $b = f = f_E = 1$.

Figure 5: Effects of Minimum Quality Standard

(a) Mass of Entrants (b) Price Index



The two figures plot the value in the utility of the representative consumer (normalized to 1 for $z_{min} = 1$) for alternative parameter values described in the figures. The main parameters used are: $\kappa = 4$, $b = f = f_E = 1$, and $\sigma = 4$

5.3 Quality Certification

In this section, I show the derivations for the analysis of the effects of quality certifications in a closed economy. Firms with quality $z \in [b, z^*_{ia}]$ without certification earn profits:

$$\pi_{ia}(z) = f\left(\left(\frac{z^*_{ia}}{z}\right)^{(\sigma-1)\alpha} - 1\right) \tag{38}$$

Firms with quality $z \in [z_g, z^*_{ct}]$ pay the fixed cost K and earn profits:

$$\pi_{ct}(z) = (f + K)\left(\left(\frac{z^*_{ct}}{z}\right)^{(\sigma-1)\alpha} - 1\right) \tag{39}$$

For the clarity of this section, I focus here on the case in which $z_g > z^*_{ia}$ and leave the other to the following Appendix 5.3.1.

Having defined the cutoffs, I can characterize the equilibrium equations of the model. First, the zero expected profit condition, which defines the equilibrium values of the cutoffs along with the ratio between (20) and (21), is:

$$fJ(b, z^*_{ia}) + (f + K)J(z_g, z^*_{ct}) = f_E \tag{40}$$

This condition shows the effects of the certification on the cutoff z^*_{ia}. Consider the zero expected profit conditions (40) and (12): since the function $J(b, z^*_{ia})$ is increasing in z^*_{ia} and J declines with the addition of the quality certification, z^*_{ia} decreases. Hence, the quality certification causes the exit of some medium-quality firms, as stated in section 2.4.

The average quality can be represented by the function $\bar{z}(\underline{z}, z^*)$:

$$\bar{z}(\underline{z}, z^*) = [\int_{\underline{z}}^{z^*} z^{\frac{\sigma-1}{\sigma}} \mu(z, \underline{z}, z^*) dz]^{\frac{\sigma}{\sigma-1}} \tag{41}$$

where the conditional pdf $\mu(z, \underline{z}, z^*)$ also depends on the bounds of integration, as it equals:

$$\mu(z, \underline{z}, z^*) = \begin{cases} \frac{g(z)}{G(z^*) - G(\underline{z})} & \text{if } z \in [\underline{z}, z^*] \\ 0 & \text{otherwise} \end{cases} \tag{42}$$

Under Pareto, the average quality equals:

$$\bar{z}(\underline{z}, z^*) = \left[\frac{\kappa}{\kappa - \left(\frac{\sigma-1}{\sigma}\right)}\left(\frac{\underline{z}^{-\kappa+\left(\frac{\sigma-1}{\sigma}\right)} - (z^*)^{-\kappa+\left(\frac{\sigma-1}{\sigma}\right)}}{\underline{z}^{-\kappa} - (z^*)^{-\kappa}}\right)\right]^{\frac{\sigma}{\sigma-1}} \tag{43}$$

Thus, we can change the notation and let $\bar{z}_{ia} = \bar{z}(b, z^*_{ia})$ and $\bar{z}_{ct} = \bar{z}(z_g, z^*_{ct})$. Taking the ratio of the two cutoffs (21) and (20) yields:

$$\left(\frac{z^*_{ct}}{z^*_{ia}}\right)^{(\sigma-1)\alpha} = \left(\frac{\bar{z}(z_g, z^*_{ct})}{\bar{z}(b, z^*_{ia})}\right)^{\sigma-1} \frac{f}{f+K} \tag{44}$$

The mass of entrants equals:

$$M = \frac{L}{\sigma(fR(b, z^*_{ia}) + (f+K)R(z_g, z^*_{ct})} \tag{45}$$

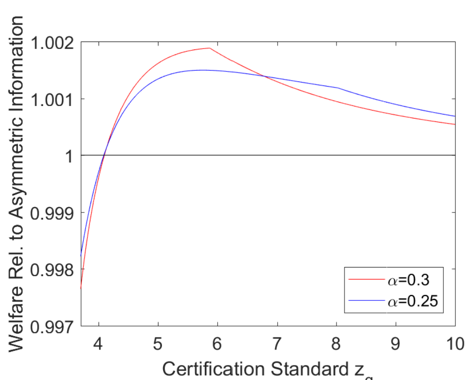
From the cutoff definitions, the price index equals:

$$P_{ct}^{\sigma-1} = (z^*_{ct})^{(\sigma-1)\alpha} \frac{\sigma^\sigma(f+K)}{L(\sigma-1)^{\sigma-1}\bar{z}_{ct}^{\sigma-1}} \tag{46}$$

Finally, the ex-post utility becomes:

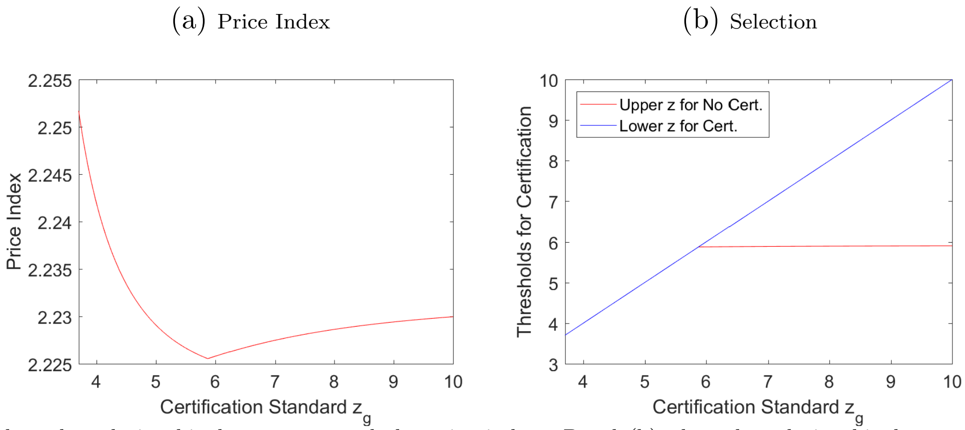
$$U_{ex-post} = P_{ct}^{\sigma-1}\left(\frac{\sigma-1}{\sigma}\right)^{\sigma}\left[M(\bar{z}(b, z^*_{ia})^{\frac{(\sigma-1)^2}{\sigma}}\tilde{U}(b, z^*_{ia}) + \bar{z}(z_g, z^*_{ct})^{\frac{(\sigma-1)^2}{\sigma}}\tilde{U}(z_g, z^*_{ct}))\right]^{\frac{\sigma}{\sigma-1}} \tag{47}$$

Figure 6: Certification Standard and Welfare



The figures plot the value in the utility of the representative consumer (relative to the case of asymmetric information without the option of certification) for alternative parameter values described in the figures. The main parameters used are: $\kappa = 4$, $K = 5$, $b = f = f_E = 1$, and $\sigma = 2.5$.

Figure 7: Certification Standard, Price Index and Selection



Panel (a) plots the relationship between z_g and the price index. Panel (b) plots the relationship between z_g and 1) the threshold $\tilde{z}_{ia}$ such that firms with $z \in [b, \tilde{z}_{ia}]$ do not apply for the certification and 2) the threshold $\tilde{z}_{ct}$ such that firms with $z \in [\tilde{z}_{ct}, z^*_{ct}]$ pay the certification fixed cost. The main parameters used are: $\kappa = 4$, $K = 5$, $b = f = f_E = 1$, and $\sigma = 2.5$.

5.3.1 Additional Sorting Cases

There are four sorting cases shown in figure 8:

1. If $\pi_{ia}(z_g) < \pi_{ct}(z_g)$ and $z_g < z^*_{ia}$, we have the baseline case described above.

2. If $\pi_{ia}(z_g) < \pi_{ct}(z_g)$ and $z_g < z^*_{ia}$, then the set of firms that do not have the certification is $z \in [b, z_g]$ and the set of firms that do have the certification is $z \in [z_g, z^*_{ct}]$. In the numerical exercises considered, this is the relevant outcome.

3. If $\pi_{ia}(z_g) > \pi_{ct}(z_g)$, $z_g < z^*_{ia}$ and $z^*_{ct} > z^*_{ia}$, then the set of firms that do not have the certification is $z \in [b, z^*_m]$ and the set of firms that do have the certification is $z \in [z^*_m, z^*_{ct}]$, where z^*_m is defined as

$$z^*_m = \frac{(f+K)(z^*_{ct})^{(\sigma-1)\alpha} - f(z^*_{ia})^{(\sigma-1)\alpha}}{K} \tag{48}$$

   Both the formulation for the zero-profit condition and for the mass of firms change:

$$f\tilde{J}(b, \tilde{z}_{ia}, z^*_{ia}) + (f+K)\tilde{J}(\tilde{z}_g, \tilde{z}_{ct}, z^*_{ct}) = f_E \tag{49}$$

where $J(\underline{z}, \tilde{z}, z^*)$ is defined as

$$\tilde{J}(\underline{z}, \tilde{z}, z^*) = \int_{\underline{z}}^{\tilde{z}} \left(\left(\frac{z^*}{z} \right)^{(\sigma-1)\alpha} - 1 \right) g(z) dz \tag{50}$$

and $\tilde{z}_{ia}$ is the cutoff quality for firms that do not have the certification, and the set of firms that do have the certification is $z \in [\tilde{z}_g, \tilde{z}_{ct}]$. Similarly, the mass of firms equals:

$$M = \frac{L}{\sigma(f\tilde{R}(b, \tilde{z}_{ia}, z^*_{ia}) + (f+K)\tilde{R}(\tilde{z}_g, \tilde{z}_{ct}, z^*_{ct})} \tag{51}$$

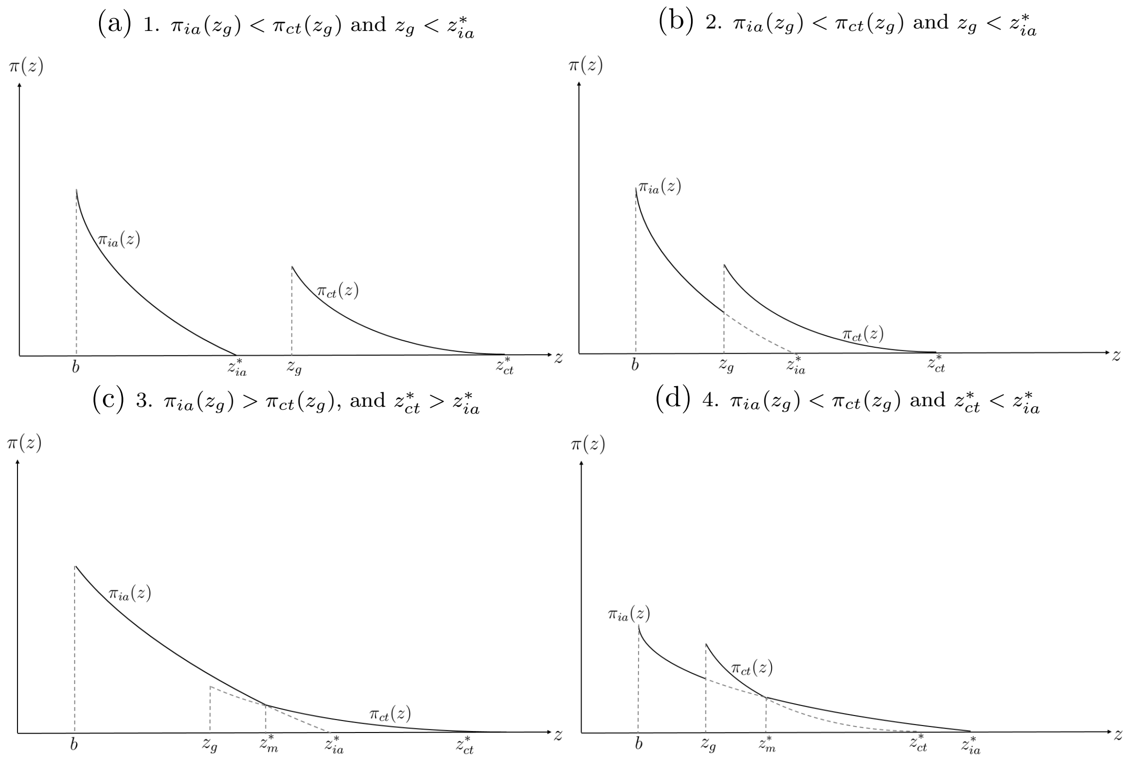
where $\tilde{R}(\underline{z}, \tilde{z}, z^*)$ is defined as:

$$\tilde{R}(\underline{z}, \tilde{z}, z^*) = \int_{\underline{z}}^{\tilde{z}} \left(\frac{z^*}{z} \right)^{(\sigma-1)\alpha} g(z) dz \tag{52}$$

The other general equilibrium variables are computed the same way described above, but using the appropriate limits of integration.

4. If $\pi_{ia}(z_g) < \pi_{ct}(z_g)$ and $z^*_{ct} < z^*_{ia}$, then the set of firms that do not have the certification is $z \in \{[b, z^*_g], [z^*_m, z^*_{ia}]\}$ and the set of firms that do have the certification is $z \in [z^*_g, z^*_m]$. The other general equilibrium variables are computed the same way described above, but using the appropriate limits of integration for the set of firms with no certification.

Figure 8: Quality Certification and Sorting



5.4 Trade

5.4.1 Perfect Information

Following the same structure of the closed economy model, I first briefly outline the outcomes of trade in the presence of perfect information. I denote the destination with subscript $j = D, X$ for domestic and export markets. The price of firm z in destination j is given by:

$$p(z) = \frac{\sigma}{\sigma - 1} z^{\alpha} \tau_j \tag{53}$$

where $\tau_D = 1$ and $\tau_X = \tau$. Firm profits equal:

$$\pi_j(z) = \frac{L(\sigma-1)^{\sigma-1}\tau_j^{1-\sigma}}{\sigma^{\sigma} P_{pi}^{1-\sigma}} z^{(\sigma-1)(1-\alpha)} - f \tag{54}$$

Setting profits to zero yields the market quality cutoff z_j^*:

$$z_j^* = \left(\frac{\sigma^\sigma P_{pi}^{1-\sigma} f}{L(\sigma-1)^{\sigma-1}} \tau_j^{1-\sigma} \right)^{\frac{1}{(\sigma-1)(1-\alpha)}} \tag{55}$$

We can express the export quality cutoff as a function of the domestic quality cutoff:

$$z_X^* = z_D^* \tau^{\frac{1}{1-\alpha}} \tag{56}$$

Since $\tau > 1$, only firms with high enough quality can export. The equilibrium cutoff is pinned down by the zero expected profit condition:

$$f \int_{z_D^*}^{\infty} \left(\left(\frac{z}{z_D^*} \right)^{(\sigma-1)(1-\alpha)} - 1 \right) g(z) dz + f \int_{z_X^*}^{\infty} \left(\left(\frac{z}{z_X^*} \right)^{(\sigma-1)(1-\alpha)} - 1 \right) g(z) dz = f_E \tag{57}$$

combined with the expression (56). Following the proof in Melitz (2003), I compare the zero-profit condition under trade and under autarky. In autarky, the zero-profit condition is:

$$f \int_{z_{pi}^*}^{\infty} \left(\left(\frac{z}{z_{pi}^*} \right)^{(\sigma-1)(1-\alpha)} - 1 \right) g(z) dz = f_E \tag{58}$$

By comparing (58) to (57), we can conclude that $z_D^* > z_{pi}^*$, since the left-hand side of both equations is declining in the cutoffs: trade selects out the lowest quality firms that were able to survive under autarky.

5.4.2 Information Asymmetries

In this section, I consider the derivations for the model with informational asymmetries and two countries. Market clearing implies that the mass of firms equals:

$$M = \frac{L}{f\sigma(R(b, z_{D,ia}^*) + R(b, z_{X,ia}^*))} \tag{59}$$

From the cutoff condition (23), the price index equals:

$$P_{ia}^{\sigma-1} = \frac{f\sigma^{\sigma}}{L(\sigma-1)^{\sigma-1}} (z_{D,ia}^{*})^{(\sigma-1)\alpha} \tag{60}$$

Finally, the ex-post utility becomes:

$$U_{ex-post} = \left(\frac{\sigma-1}{\sigma}\right)^{\sigma} P_{ia}^{\sigma-1} \left[M\left(\tilde{U}(b, z_{D,ia}^{*}) + \tau^{1-\sigma}\tilde{U}(b, z_{X,ia}^{*})\right)\right]^{\frac{\sigma}{\sigma-1}} \tag{61}$$

5.4.3 Minimum Quality Standard and Trade

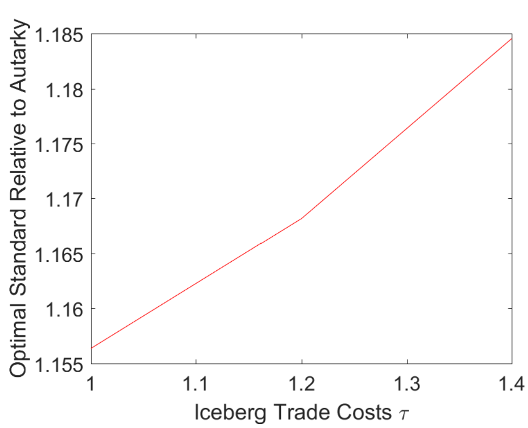
To find the value of utility of the representative consumer under trade and a minimum quality standard, it suffices to substitute z_{min} for b in (59), (60), and (61), to obtain:

$$M = \frac{L}{f\sigma(R(z_{min}, z_{D,ia}^{*}) + R(z_{min}, z_{X,ia}^{*}))} \tag{62}$$

$$P_{ia}^{\sigma-1} = \frac{f\sigma^{\sigma}}{L(\sigma-1)^{\sigma-1}} (z_{D,ia}^{*})^{(\sigma-1)\alpha} \tag{63}$$

$$U_{ex-post} = \left(\frac{\sigma-1}{\sigma}\right)^{\sigma} P^{\sigma-1} \left[M\left(\tilde{U}(z_{min}, z_{D,ia}^{*}) + \tau^{1-\sigma}\tilde{U}(z_{min}, z_{X,ia}^{*})\right)\right]^{\frac{\sigma}{\sigma-1}} \tag{64}$$

Figure 9: Trade and Minimum Quality Standard



The figure plots the value of the optimal quality standard z_{min} normalized by the autarky optimal standard, equal in this parametrization to 1.155. The optimal standard is evaluated at different values of the iceberg trade cost τ. Quality is assumed to be Pareto distributed with shape parameter $\kappa = 4$ and shift parameter $b = 1$. The main parameters used are: $L = f = f_E = 1$, $\sigma = 2.5$, and $\alpha = 0.3$.

5.4.4 Quality Certifications and Trade

In this section, I show the derivations for the effects of quality certifications in the model with two countries. By solving the firm problem, and setting firm profits to zero, the quality cutoffs for domestic sales (z_D^*) and exports (z_X^*) equal:

$$z_D^* = \left(\frac{L(\sigma-1)^{\sigma-1} \bar{z}_{ia}^{\sigma-1}}{\sigma^\sigma P_{ct}^{1-\sigma} f} \right)^{\frac{1}{(\sigma-1)\alpha}} \tag{65}$$

$$z_X^* = z_D^* \tau^{-\frac{1}{\alpha}} \tag{66}$$

where $\bar{z}_{ia}$ is a weighted average of the average quality of domestic sales and exports:

$$\bar{z}_{ia} = \frac{G(z_D^*)}{G(z_D^*) + G(z_X^*)} \bar{z}(b, z_D^*) + \frac{G(z_X^*)}{G(z_D^*) + G(z_X^*)} \bar{z}(b, z_X^*) \tag{67}$$

Firms can also pay an extra fixed cost K, which guarantees that the quality level of the product is above a certain level z_g. Firms with $z \in [z_g, z_{ct}^*]$ possess the certification and z_{ct}^* is implicitly defined as:

$$z_{ct}^* = z_D^* \left(\frac{\bar{z}(z_g, z_{ct}^*)}{\bar{z}_{ia}} \right)^{\frac{1}{\alpha}} \left(\frac{f}{f+K} \right)^{\frac{1}{\alpha(\sigma-1)}} \tag{68}$$

The zero expected profit condition, which defines the equilibrium values of the cutoffs along with (44), is:

$$f(J(b, z_D^*) + J(b, z_X^*)) + (f+K)J(z_g, z_{ct}^*) = f_E \tag{69}$$

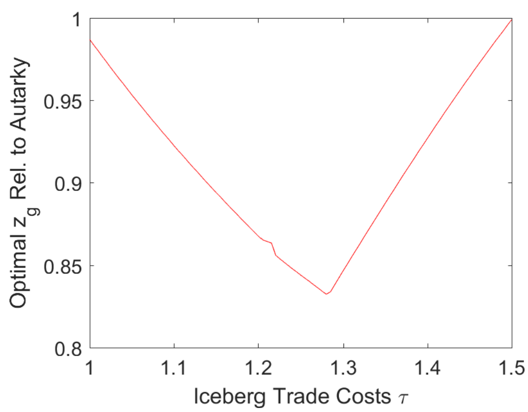
Hence, the introduction of a certification technology causes a reduction in the domestic and export cutoffs: the certification causes a reduction in the quality sold domestically and abroad if it is not under the certification umbrella. Substituting (68) and (66) into (69) and solving the zero expected profit condition pins down the domestic cutoff and, in turn, the other two cutoffs as well. Given the cutoffs, I can solve for the mass of entrants, price index, and utility of consumers, which equal:

$$M = \frac{L}{\sigma(f(R(b, z_D^*) + R(b, z_X^*)) + (f+K)R(z_g, z_{ct}^*)} \tag{70}$$

$$P_{ct}^{\sigma-1} = (z_D^*)^{(\sigma-1)\alpha} \frac{\sigma^\sigma f}{L(\sigma-1)^{\sigma-1}\bar{z}_{ia}^{\sigma-1}} \tag{71}$$

$$U_{ex-post} = P_{ct}^{\sigma-1}\left(\frac{\sigma-1}{\sigma}\right)^\sigma \left[M[\bar{z}_{ia}^{\frac{(\sigma-1)^2}{\sigma}}(\tilde{U}(b, z_D^*) + \tau^{1-\sigma}\tilde{U}(b, z_X^*)) + \bar{z}(z_g, z_{ct}^*)^{\frac{(\sigma-1)^2}{\sigma}}\tilde{U}(z_g, z_{ct}^*))]\right]^{\frac{\sigma}{\sigma-1}} \tag{72}$$

Figure 10: Trade and Certification



Optimal z_g for different values of τ. Quality is assumed to be Pareto distributed with shape parameter $\kappa = 4$ and shift parameter $b = 1$. The main parameters used are: $L = f = f_E = 1$, $\sigma = 2.5$, $\alpha = 0.3$, and $K = 5$.

5.4.5 Price Signaling

In this section, I present an extension to the baseline model in which firms are able to imperfectly signal their quality to consumers with their prices. In particular, let $z_s(\omega)$ denote the signaled level of quality for firm ω. The ex-ante utility for consumers equal:

$$U_{ex-ante} = \left[\int_\Omega (\bar{z}_{ia}^\beta z_s(\omega)^{1-\beta} q(\omega))^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}} \tag{73}$$

where $\beta \in [0,1]$. The shifter applied to quantity $q(\omega)$ is a Cobb-Douglas aggregation of the average quality in the market $\bar{z}_{ia}$ and the quality signaled by a firm $z_s(\omega)$. If $\beta = 1$, price signaling is absent, and the model reverts to the baseline one.

Solving the consumer problem yields the following demand function:

$$q(\omega) = P_{ia}^{\sigma-1} z_s(\omega)^{(1-\beta)(\sigma-1)} p(\omega)^{-\sigma} \tag{74}$$

where $P_{ia} = \left[\int_{\omega \in \Omega} \left(\frac{p(\omega)}{z_s(\omega)^{1-\beta}} \right)^{1-\sigma} d\omega \right]^{\frac{1}{1-\sigma}}$ is the price index.

Firms have access to the following signaling technology:

$$z_s(\omega) = vp(\omega)^{\theta} \tag{75}$$

where v and θ are positive constants. This functional form is a short-hand for the separating equilibrium discussed in the framework of Wolinsky (1983), in which each price signals a unique quality level, and higher-quality firms charge higher prices. To ease the notation, I set $v = 1$. Notice that this simplification does not affect the results, since v is a constant. Substituting (75) in (74) yields:

$$q(\omega) = P_{ia}^{\sigma-1} p(\omega)^{-\sigma+\theta(1-\beta)(\sigma-1)} = P_{ia}^{\sigma-1} p(\omega)^{-\epsilon} \tag{76}$$

where $\epsilon = \sigma - \theta(1-\beta)(\sigma-1)$, and I restrict the parameter space so that $\epsilon > 1$. The presence of a signaling technology allows high-quality firms to obtain a larger demand shifter. Since the price affects both the demand shifter and the quantity demanded conditional on the demand shifter, the result is that in the presence of signaling technology, the demand becomes less elastic ($\epsilon < \sigma$). Hence, in the presence of asymmetric information and a signaling technology, high-quality firms still sell lower quantities relative to low-quality firms, but the signaling technology reduces such a difference. That the presence of price signaling makes demand less elastic is a common feature of price signaling: see Jones and Hudson (1996) for a discussion.

Since the demand (76) is isomorphic to the demand in the baseline framework, it is straightforward to derive the solution to the firm's problem and the equilibrium equations of the model. First, the optimal price charged by a firm with quality z equals:

$$p(z) = \frac{\epsilon}{\epsilon - 1} z^{\alpha} \tag{77}$$

Substituting (77) into (75) yields:

$$z_s(z) = \left[\frac{\epsilon}{\epsilon - 1}\right]^{\theta} z^{\alpha\theta} \tag{78}$$

Hence, the ratio of any two signaled qualities equals:

$$\frac{z_s(z)}{z_s(z')} = \left(\frac{z}{z'}\right)^{\alpha\theta} \tag{79}$$

The parameter θ controls the efficacy of the signaling technology. For $\theta = 1/\alpha$, the relative quality signaled through prices is exactly equal to the actual quality of the firms. The profits of a firm with quality z are given by:

$$\pi(z) = \frac{L(\epsilon - 1)^{\epsilon - 1}}{\epsilon^{\epsilon} P_{ia}^{1-\sigma}} z^{-(\epsilon - 1)\alpha} - f \tag{80}$$

Setting the profits equal to zero determines an upper cutoff for quality z^*_{ia}:

$$z^*_{ia} = \left(\frac{L(\epsilon - 1)^{\epsilon - 1}}{\epsilon^{\epsilon} P_{ia}^{1-\sigma} f}\right)^{\frac{1}{(\epsilon - 1)\alpha}} \tag{81}$$

The equilibrium cutoff is pinned down by the zero expected profit condition:

$$f \int_b^{z^*_{ia}} \left(\left(\frac{z^*_{ia}}{z}\right)^{(\epsilon - 1)\alpha} - 1\right) g(z) dz = f_E \tag{82}$$

$$f J(b, z^*_{ia}) = f_E \tag{83}$$

Notice that, in terms of equilibrium, this extension is isomorphic to the baseline model with a lower elasticity of substitution σ.

Market clearing implies that the mass of firms equals:

$$M = \frac{L}{f \epsilon R(b, z^*_{ia})} \tag{84}$$

where $R(b, z^*_{ia})$, as in the baseline model, equals:

$$R(\underline{z}, z^*) = \int_{\underline{z}}^{z^*} \left(\frac{z^*}{z}\right)^{(\epsilon-1)\alpha} g(z) dz \tag{85}$$

From the cutoff condition (81), the price index equals:

$$P_{ia}^{\sigma-1} = \frac{f \epsilon^{\epsilon}}{L(\epsilon-1)^{\epsilon-1}} (z^*_{ia})^{(\epsilon-1)\alpha} \tag{86}$$

Hence, the ex-post utility becomes:

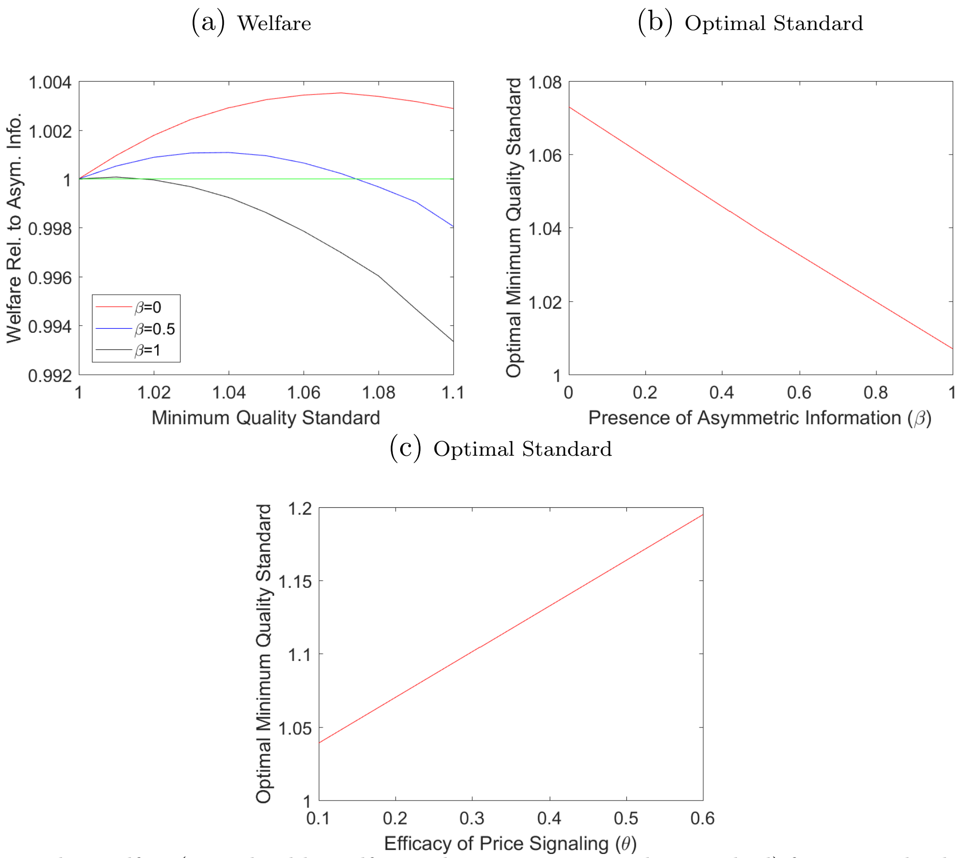
$$U_{ex-post} = \frac{L^{\frac{1}{\sigma-1}}(\epsilon-1)}{\epsilon^{\frac{\sigma}{\sigma-1}} f^{\frac{1}{\sigma-1}}} (z^*_{ia})^{(\epsilon-1)\alpha} \left[\frac{\tilde{U}(b, z^*_{ia})}{R(b, z^*_{ia})}\right]^{\frac{\sigma}{\sigma-1}} \tag{87}$$

where

$$\tilde{U}(\underline{z}, z^*) = \int_{\underline{z}}^{z^*} z^{(\sigma-1)(1-\epsilon\alpha)/\sigma} g(z) dz \tag{88}$$

Minimum Quality Standard. Let us first consider how price signaling influences the effects of minimum quality standards. As in the baseline mode, I consider a Pareto distribution for quality, with shape parameter κ and shift parameter b. Even in the presence of imperfect signaling, the minimum quality standard improves welfare. As shown in Panel (a) of Figure 11, the hump-shaped relationship between welfare and standard persists at different values of β. A surprising result is that a stronger role for the price signaling technology (lower β) or a more effective price signaling technology (higher θ) is associated with a larger positive effect of the minimum quality standard. This is due to the fact that in the presence of price signaling, the increase in prices due to the standard has a less pronounced effect on welfare, since demand is less elastic. A more restrictive standard has the negative welfare effect of increasing the average price because only higher-quality, higher-cost firms remain in the market. With price signaling, the presence of higher prices signals higher quality and, thus, the negative welfare effect of the standard is minimized.

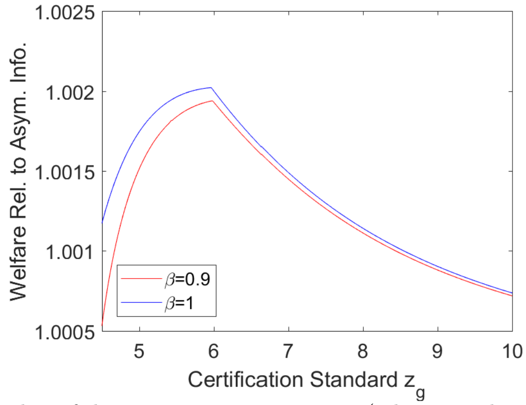
Figure 11: Minimum Quality Standard and Price Signaling



The first figure plots welfare (normalized by welfare under no minimum quality standard) for varying levels of the minimum quality standard and different values of β. The second figure plots the optimal minimum quality standard for different values of β and the third figure for different values of θ. The main parameters used are: $\kappa = 4$, $b = f = f_E = 1$, $\alpha = 0.075$, $\sigma = 3.2$, $\theta = 0.1$. In Panel (b), $\theta = 0.1$. In Panel (c), $\beta = 0.5$.

Quality Certification. The derivations for the case of quality certification are analogous to the baseline model and are available upon request. As in the baseline model, a quality certification can improve welfare in the presence of price signaling. Furthermore, the welfare effects of the certification are larger in the absence of price signaling. In fact, price signaling and quality certifications are substitutes: they allow a high-quality firm to sell larger quantities relative to the case of asymmetric information. Hence, when price signaling is allowed, the welfare effects of quality certifications are diminished (see Figure 12).

Figure 12: Certification and Price Signaling



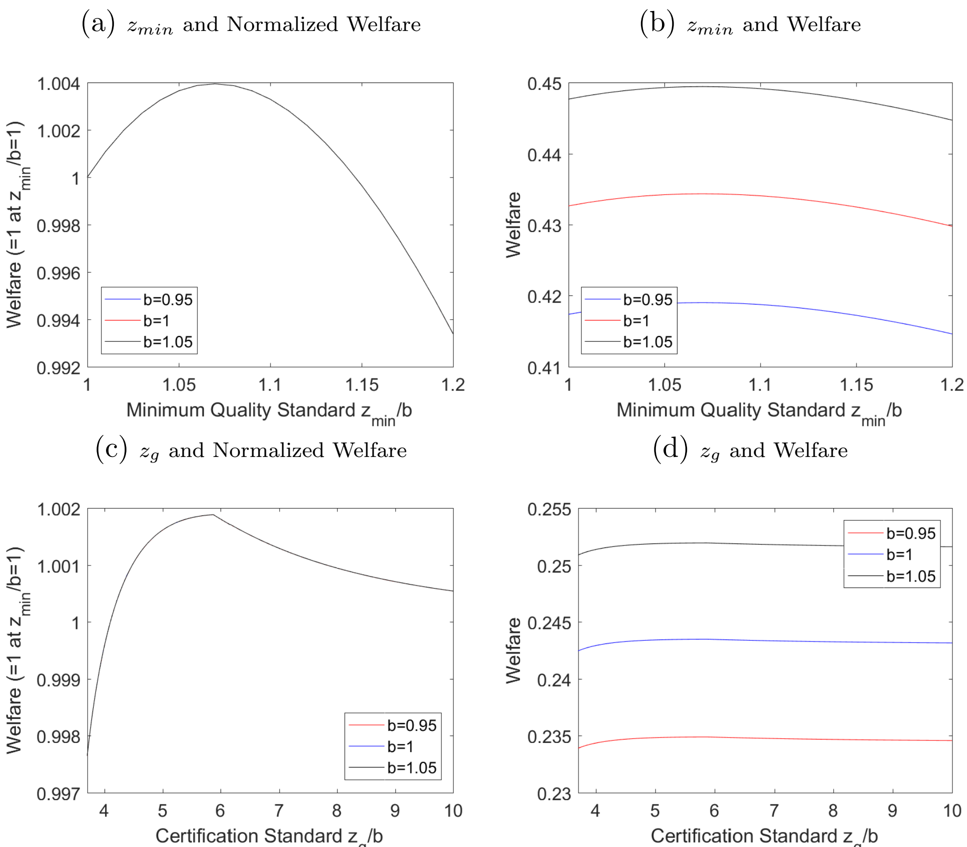
The figure plots the value in the utility of the representative consumer (relative to the case of asymmetric information without the option of certification) for alternative parameter values described in the figure. The main parameters used are: $\kappa = 4$, $b = f = f_E = 1$, $\alpha = 0.3$, $\sigma = 2.5$, $\theta = 0.1$, and $K = 5$.

5.4.6 Changes in the Lower Bound of the Quality Distribution

In this section, I briefly show how changing the level of the lower bound of the quality distribution b leaves the welfare effects of quality standard and certification standard unchanged. The reason for that is that changes in b only affect the level of the quality distribution and not the effects of changes in standards. To see this, consider welfare under a minimum quality standard. First, notice that the ex-post utility (34) does not directly depend on b, since such term cancels out in the ratio between (37) and (36). However, b affects the level of the quality cutoff, since it is a shifter on (35). In the zero-profit condition (12), this means that changes in b affect the level of the quality cutoff for a given z_{min} but not the effects of changes in z_{min} on z^*. Hence, a higher level of b increases the utility but not how a minimum quality standard or a certification can improve welfare.

In Panels (a) and (b) of Figure 13, I show the welfare effects of minimum quality standards for different values of b. Panel (b) shows that higher levels of b are associated with higher welfare, since the quality level is shifted upward. However, when I normalize welfare by its value in the market allocation (with no minimum quality standard) in Panel (a), there are no differences in welfare effects for different values of b. In Panel (c) and (d) I show the same pattern for the case of quality certifications.

Figure 13: Welfare for Different Values of b



Panel (a) and (c) plot welfare (normalized by welfare under no minimum quality standard or certification standard) for varying levels of z_{min} (a) and z_g (c), and different values of b. Panel (b) and (d) plot welfare with no normalization. The main parameters used are: $\kappa = 4$, $f = f_E = 1$, $\alpha = 0.3$, $\sigma = 4$ for Panels (a) and (b) and $\kappa = 4$, $f = f_E = 1$, $\alpha = 0.3$, $\sigma = 2.5$, $K = 5$ for Panels (c) and (d).

5.4.7 Fixed Cost of Quality

In this section, I discuss how the main results of the closed economy model with asymmetric information vary by introducing the assumption that firms pay a fixed cost which is a function of quality. In particular, while in the baseline model the fixed cost f is independent of the quality level, in this extension the fixed cost is fz^{δ}, with $\delta \geq 0$. The parameter δ captures the fixed cost elasticity with respect to quality. The firms with higher quality pay a higher fixed cost is a feature of the model of Gaigné and Larue (2016a).

The solution to the consumer and firm problem is identical to the baseline model, since fixed costs do not affect the equality between marginal revenues and marginal costs that determines the pricing equation. The profits of a firm with quality z equal:

$$\pi_{ia}(z) = \frac{L(\sigma-1)^{\sigma}}{\sigma P_{ia}^{1-\sigma}} z^{-(\sigma-1)\alpha} - f z^{\delta} \tag{89}$$

Setting profits to zero yields the quality cutoff z_{ia}^*:

$$z_{ia}^* = \left(\frac{L(\sigma-1)^{\sigma-1}}{\sigma^{\sigma} P_{ia}^{1-\sigma} f} \right)^{\frac{1}{\delta+(\sigma-1)\alpha}} \tag{90}$$

Hence, we can rewrite profits as:

$$\pi_{ia}(z) = f(z_{ia}^*)^{\delta} \left(\left(\frac{z_{ia}^*}{z} \right)^{(\sigma-1)\alpha} - \left(\frac{z_{ia}^*}{z} \right)^{-\delta} \right) \tag{91}$$

The equilibrium value for z_{ia}^* is pinned down by the zero expected profit condition:

$$f(z_{ia}^*)^{\delta} \int_{z_{min}}^{z_{ia}^*} \left(\left(\frac{z_{ia}^*}{z} \right)^{(\sigma-1)\alpha} - \left(\frac{z_{ia}^*}{z} \right)^{-\delta} \right) g(z)dz = f_E \tag{92}$$

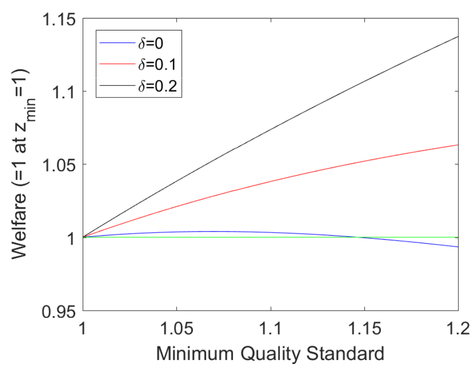
where $z_{min} = b$ in the market allocation and the minimum quality standard in the presence of government intervention. Under the Pareto assumption for the distribution of firm's quality, the zero expected profit condition becomes:

$$\kappa b^{\kappa} z_{min}^{-\kappa} f(z_{ia}^*)^{\delta} \left[\frac{\left(\frac{z_{ia}^*}{z_{min}} \right)^{(\sigma-1)\alpha} - \left(\frac{z_{ia}^*}{z_{min}} \right)^{-\kappa}}{\kappa + (\sigma-1)\alpha} - \frac{\left(\frac{z_{ia}^*}{z_{min}} \right)^{-\delta} - \left(\frac{z_{ia}^*}{z_{min}} \right)^{-\kappa}}{\kappa - \delta} \right] = f_E \tag{93}$$

Given the equilibrium value for z_{ia}^*, I can compute the equilibrium value of the price index using (90). Then, both the price index and the equilibrium cutoff can be used to compute the utility of the representative consumer.

I examine the effects of a minimum quality standard using numerical methods as in the baseline model. Figure 14 shows that higher values of the elasticity of fixed costs with respect to quality are associated with larger benefits of the minimum quality standard. If fixed costs depend on quality, in the presence of asymmetric information, there is a tougher selection on high-quality firms which not only have the highest prices but also the highest fixed costs. Hence, the fixed costs exacerbate the adverse selection and, thus, magnify the welfare effects of minimum quality standards.

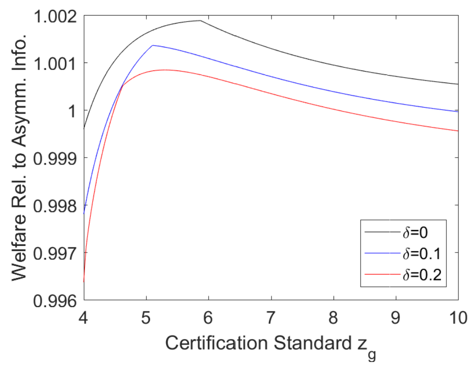
Figure 14: Minimum Quality Standard and Welfare with Fixed Costs of Quality



The figure plot the value of the utility of the representative consumer for different values of the minimum quality standard, relative to the market allocation (when the standard equals $b = 1$.). The main parameters used are: $\sigma = 4$, $\alpha = 0.3$, $\kappa = 4$, and $L = b = f = f_E = 1$.

Examining the effects of quality certification sits uneasy with this extension because introducing a fixed cost for certification K complicates the expression for the quality cutoff. In order to have a tractable expression for the quality cutoff, one needs to assume that the fixed cost for certification also depends on quality with the same elasticity of the fixed cost, namely, the fixed cost paid by a firm with certification is $(f + K)z^{\delta}$. Although this scenario is implausible, it provides a conservative case for quality certification: even if certifications are more expensive for higher quality firms, they can still improve welfare. Unsuprisingly, in this case higher levels of the fixed cost elasticity δ, which increase the fixed cost for the highest quality firms, are associated with lower welfare gains (see Figure 15).

Figure 15: Quality Certification and Welfare with Fixed Costs of Quality



The figure plot the value of the utility of the representative consumer for different values of the minimum quality standard, relative to the market allocation (when the standard equals $b = 1$.). The main parameters used are: $\sigma = 2.5$, $\alpha = 0.3$, $\kappa = 4$, and $L = b = f = f_E = 1$.