Trade and Quality Differentiation among Heterogeneous Firms

- preliminary and incomplete-

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Abstract

In this paper we develop a theoretical model of international trade where firms present productivity differences and choose among various strategies of quality differentiation.

The empirical evidence suggests that productivity heterogeneity and quality differentiation among firms may be important determinants of international trade. Some theoretical contributions have recently developed models of international trade that consider both these components. It turned out that these models perform very well in explaining some relevant features of international trade flows.

Our aim is to analyze how heterogeneity in productivity influences quality strategies and how these two components affect firm export capabilities. This theoretical model differs from the previous literature in the fact that the quality of production is endogenously determined by each firm. We assume that higher quality goods are produced employing a more expensive technology, characterized by increasing return to scale. As the cost structure varies according to the production quality, firms that differ in productivity may adopt different strategies of vertical differentiation. Moreover, in order to analyze the differences in pricing behaviors of vertically differentiated producers, we choose a theoretical framework that allows firms to charge variable markups (Ottaviano and Melitz 2005). Then it is possible to obtain predictions for performances of firms that differ in productivity and in production quality

First, we propose an analysis of the closed economy equilibrium, then we consider the effects of opening up to international trade. The study of the open economy equilibrium focuses on the effects of trade costs on the quality composition of export and production. The theoretical predictions of the model seem to be in line with the results of the main empirical studies on vertical product differentiation and firm heterogeneity in international trade.

JEL Classifications: F12, F14

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1 Introduction

Firm heterogeneity in productivity was first introduced in international trade theory with imperfect competition[1] after some empirical evidence had showed that exporting firms present performance advantages with respect to non-exporters.[2] In fact models of firm heterogeneity predict that only a fraction of domestic firms (the most competitive ones) are able to serve foreign markets.

An other strand of empirical trade literature[3] points out the relevance of vertical product differentiation in international trade. Moreover, these works find support to the so called Alchian-Allen conjecture, according to which exported goods present a higher average quality with respect to products sold in the domestic market.

As the empirical evidence stresses that productivity heterogeneity and quality differentiation are important determinants of international trade, it suggests that both these components should be considered in theoretical models. Actually, Baldwin and Harrigan (2007) have recently showed that a model with firm heterogeneity and vertical differentiation performs very well in explaining some relevant features of international trade flows. In particular, the introduction of quality differentiation justifies why export unit values are positively related to distance, while export volumes are inversely related to that variable.

Our aim is to analyze how heterogeneity in productivity influences quality strategies and how these two components affect firm export capabilities. This theoretical model differs from the previous literature in the fact that the quality of production is endogenously determined by each firm. We assume that higher quality goods are produced employing a more expensive technology, characterized by increasing return to scale. As the cost structure varies according to the production quality, firms that differ in productivity may adopt different strategies of vertical differentiation. Moreover, in order to analyze the differences in pricing behaviors of vertically differentiated producers, we choose a theoretical framework that allows firms to charge variable markups (Ottaviano and Melitz 2005). Then it is possible to obtain predictions about the performances of firms that differ in productivity and in production quality.

First, we propose an analysis of the closed economy equilibrium, then we consider the effects of opening up to international trade. In particular we analyze the impact of trade liberalization on export and quality strategies. Numerical solutions of the model evidence that more pro-

[1] Melitz 2003, Yeaple 2005, Ottaviano and Melitz 2008

[2] Bernard and Jensen 1999, Bernard and at. 2003

[3] Schott (2004), Hummels and Skiba (2004), Hummels and Klenow (2005), Hallak (2006), Fontagné, Gaulier and Zignago (2008)

ductive firms will choose higher production quality. Since exporters are also more productive than non-exporters, the average quality of exported goods exceeds that of domestic sales. This result is supported by the empirical evidence on the Alchian-Allen conjecture. Furthermore, we show that the presence of quality differentiation affects the pro-competitive effect due to an increase of market size and international competition. Finally, we study the effects of a change in trade costs on the quality composition of export and on export unit values. The theoretical predictions seem to be in line with the results of the main empirical studies on vertical product differentiation in international trade.

2 The model

In the economy there are two sectors: in the first sector (say agriculture) firms produce an homogenous good and the market is perfectly competitive; in the second sector (say manufacturing) goods are horizontally and vertically differentiated and there is imperfect competition (monopolistic competition). In the manufacturing sector there are two sources of heterogeneity among firms: they differ in productivity (different marginal costs) and in production quality.

Productivity differentiation will be modeled in the tradition way introduced by Melitz (2003): each firm will face a fixed cost to be allowed to draw a productivity parameter from a certain distribution. After drawing their productivity, each firm decides whether to produce or not and the quality of its production. To simplify the model we assume that there exists only two quality levels: high and low. A firm can produce high quality goods facing a certain fixed cost in R&D or low quality goods without any further investment.

Moreover, higher quality means higher marginal costs as well. However, the relationship between quality and marginal costs do not determine *per se* firm quality strategies and therefore the quality composition of firms in the market.[4] A key role in model is indeed assumed by R&D costs. In fact, most of the results in the model hold even when the differences in the supply side between high and low quality productions are limited to R&D costs.[5] We adopt this setting believing that in reality product innovation and, in general, R&D activity are more and more relevant to upgrade the quality in industrial productions. Nevertheless,

[4] This is a main differece with respect to the model presented by Baldwin and Harrigan (2007), where the relationship between productivity and quality is described by a deterministic function. In paricular, in that model the value of the elasticity of marginal costs to a change in quality determines whether the "best" firms in the market are high or low quality producers.

[5] see Borin (2008)

we keep some differences also in marginal costs both to improve the likeliness of the model and to simplify the algebra.

Our aim is to analyze the relations between firm productivity and their choices about the production quality. Furthermore we want to evaluate how firms' strategies may change when they compete in international markets. As it seems reasonable that producers of vertically differentiated goods may adopt different pricing strategies, we decide to choose a model that allows firm to charge variable markups. In particular we adopted a quasi-linear utility function, employing the framework used by Ottaviano and Melitz (2005).

2.1 Consumption

In the economy there are L consumers, each supplying one unit of labor. The utility function of the representative consumer c is given by:

$$U = q_0^c + \int_0^N \lambda_i q_i^c di - \frac{1}{2}\gamma \int_0^N \lambda_i \left(q_i^c\right)^2 di - \frac{1}{2}\eta \left(\int_0^N \lambda_i q_i^c di\right)^2 \tag{1}$$

here q_0^c is the quantity of consumption in the homogeneous good, q_i^c is he quantity of consumption in the good i of the differentiated sector and λ_i is a quality measure of the i-th good, as it is perceived by customers. In the manufacturing sector we have a continuous of goods that are indexed from 0 to N. The parameter η measures the degree substitutability between the differentiated goods and the numeraire, while γ indexes the degree of product differentiation among differentiated goods. The presence of the quality parameter λ_i in the quadratic part of the utility function $(-1/2\gamma \int_0^N \lambda_i \left(q_i^c\right)^2 di)$ implies that the degree of "love of variety" is higher among high quality goods. Actually, we usually observe a higher level of substitutability among low quality goods, in comparison with high-value products.

Taking the homogeneous good as the numéraire, we can derive the demand for the good i solving the utility maximization problem of the representative consumer.

From FOCs

$$\frac{p_i}{p_0} = \frac{\partial U / \partial q_i^c}{\partial U / \partial q_0^c}$$

where p_i is the price of the i-th good and p_0 is the price of the homogeneous good (as it is the numeraire $p_0 \equiv 1$)

$$\frac{\partial U}{\partial q_0^c} = 1$$

$$\frac{\partial U}{\partial q_i^c} = \lambda_i - \frac{1}{2}\gamma\lambda_i q_i^c - \eta\lambda_i Q^c$$

where $Q^c \equiv \int_0^N \lambda_i q_i^c di$

$$p_i = \lambda_i - \frac{1}{2}\gamma\lambda_i q_i^c - \eta\lambda_i Q^c$$

$$q_i^c = \frac{1}{\gamma} - \frac{1}{\gamma\lambda_i}p_i - \frac{\eta}{\gamma}Q^c$$

$$\lambda_i q_i^c = \frac{\lambda_i}{\gamma} - \frac{1}{\gamma}p_i - \frac{\eta}{\gamma}\lambda_i Q^c \qquad (*)$$

$$Q^c = \int_0^N \frac{\lambda_i}{\gamma} - \frac{1}{\gamma}p_i - \frac{\eta}{\gamma}\lambda_i Q^c di$$

$$Q^c = \frac{N\Lambda}{\gamma} - \frac{N}{\gamma}P - \frac{\eta N\Lambda}{\gamma}Q^c$$

where $\Lambda \equiv \left(\int_0^N \lambda_i di\right)/N$ and $P = \left(\int_0^N p_i di\right)/N$

$$Q^c = \frac{N\Lambda}{\gamma + \eta N\Lambda} - \frac{N}{\gamma + \eta N\Lambda}P \qquad (**)$$

plugging $(**)$ in $(*)$ we obtain the demand for the good i of representative consumer c

$$q_i^c = \frac{1}{\gamma + \eta N\Lambda} - \frac{1}{\gamma}\frac{p_i}{\lambda_i} + \frac{\eta N\Lambda}{\gamma(\gamma + \eta N\Lambda)}\frac{P}{\Lambda}$$

Defining $\tilde{p}_i \equiv p_i/\lambda_i$ and $\tilde{P} \equiv P/\Lambda$, the total demand for the good i is:

$$q_i \equiv Lq_i^c = \frac{L}{\gamma + \eta N\Lambda} - \frac{L}{\gamma}\tilde{p}_i + \frac{L}{\gamma}\frac{\eta N\Lambda}{(\gamma + \eta N\Lambda)}\tilde{P} \qquad (2)$$

the demand for the product i is negatively related to its price $\tilde{p}_i$ (the quality-adjusted price) and positively related to the price of the other goods $\tilde{P}$ (the average quality-adjusted price). Moreover an increase in the quality supplied by the firm i boosts its demand, while an increase in the average quality in the market reduces the demand for good i.[6]

[6] This is one of the differences in the basic setting with respect to the model presented in Borin (2008), where it is employed a different specification for the quality parameter λ_i in the utility function: $U = q_0^c + \int_0^N \lambda_i q_i^c di - \frac{1}{2}\gamma\int_0^N (\lambda_i q_i^c)^2 di - \frac{1}{2}\eta\left(\int_0^N \lambda_i q_i^c di\right)^2$. This utility function implies that the demand for firm i is not always increasing in λ_i. In particular, when the price p_i is very low an in increase in λ_i may reduce the demand for that good. In that model this result is used to explain a

2.2 Production

In both sectors goods are produced using labor as unique production factor, there is perfect labor mobility among firms and between sectors. The homogeneous sector is characterized by constant returns to scale and its market is perfectly competitive. We assume that the production of each unit of homogeneous good requires one unit of labor. This allows us to normalize the wage to one.

The market in the manufacturing sector is imperfectly competitive (monopolistic competition). A firm should bear an initial fixed cost f_e (expressed in unit of labor) to develop its production technology. Facing this fixed cost, each firm becomes aware of its specific productivity level expressed by c. On the basis of its productivity level, the firm takes its decision about production among three different choices. The firm will exit the market if can not run positive profits. Otherwise it can start the production of a low quality version of its good or face a further investment in R&D ($f_H > 0$) to develop a high quality variety of its product.[7] In both cases the following production process will take place under constant returns to scale. The firm-specific marginal cost ($\lambda_i c_i$) will depend on the quality chosen as well. Clearly the entering decision and the choice about the quality of production are interrelate, as expected operating profits and possible further investments depend on the quality strategy adopted. We will first consider the profit maximization problem of the firm taking the quality choice as given and after we will analyze the decision of the firm between high (λ_H) or low (λ_L) quality productions.

Total profits of the firm i are:

$$\pi_i^T = p_i q_i - \lambda_i c_i q_i - f_e - f_i \tag{3}$$

where $\lambda_i = \{\lambda_H, \lambda_L\}$, $f_i = \{f_H, f_L\}$ and $f_L = 0$, as no further investments are required to produce a low quality variety.

F.O.C. of the firm i profit maximization problem implies:

$$\frac{\partial \pi_i^T}{\partial q_i} = 0 \qquad \Rightarrow$$

sort of "exclusivity" of higher quality goods. However this could be considered rather a moot point in presence of perfect information on quality. Furthermore, a simpler positive relation between quality and demand makes the model more tractable, that is particularly important feature to analyze the open economy equilibrium.

[7] I will refer to profits that take in account all the fixed costs as "total profits" ($\pi_i^T = p_i q_i - \lambda_i c_i q_i - f_e - f_j$), we call "profits" the measure that consider only the eventual costs in R&D ($\pi_i = p_i q_i - \lambda_i c_i q_i - f_j$) and we call "operating profits" the difference between revenues and production costs ($\pi_i^o = p_i q_i - \lambda_i c_i q_i$).

$$\frac{\partial p_i}{\partial q_i} q_i + p_i - \lambda_i c_i = 0 \qquad (*)$$

the inverse demand for good i is:

$$p_i = \frac{\gamma\lambda_i}{\gamma + \eta N\Lambda} - \frac{\gamma\lambda_i}{L} q_i + \frac{\eta N \Lambda \lambda_i}{(\gamma + \eta N\Lambda)} \tilde{P} \tag{4}$$

$$\frac{\partial p_i}{\partial q_i} = -\frac{\gamma\lambda_i}{L} \qquad (**)$$

plugging $(**)$ in $(*)$ we obtain the quantity produced for the good i:

$$q_i = \frac{L}{\gamma}\left(\frac{p_i}{\lambda_i} - c_i\right) \tag{5a}$$

that can be rearranged as:

$$q_i = \frac{L}{\gamma\lambda_i}\left(p_i - \lambda_i c_i\right) \tag{5b}$$

Equation (5b) points out that, as usual, the quantity supplied is positively related to the markup $(p_i - \lambda_i c_i)$. As the model does not present any strategic interaction among firms, the result in (5b) still holds when firms set prices (instead of quantities). It means that a firm set the price equal to its marginal cost only when its demand is equal to zero. Without any quality differentiation ($\lambda_i = \lambda \ \forall i$) this would simply happens when c_i is high enough. In fact, for a given quality level quantities sold, markups and thus operating profits are clearly decreasing in the productivity parameter c_i.

In this model a firm decides also the quality of its production, and this could affect its performances. Increasing quality will lead to a potential higher demand,[8] but implies further investments in R&D and higher marginal costs. We can first consider the effect of a change in the quality parameter in the pricing decision. It can be easily figured out combining results on demand (2) and supply side (5b):

$$p_i = \frac{\lambda_i}{2}\left(\frac{\gamma}{\gamma + \eta N\Lambda} + \frac{\eta N\Lambda}{(\gamma + \eta N\Lambda)}\tilde{P} + c_i\right) \tag{6}$$

The price charged is clearly proportional to the quality level chosen. It means that the price quality ratio p_i/λ_i is constant and totally independent from the quality strategy. Plugging this result to equation (5a), it turns out that the quantity sold is also independent from quality

[8] It can be easly demostrate taking the derivatives of the quantity demanded with respect to λ_i: $\partial q_i^{demand}/\partial\lambda_i = Lp_i/\gamma\lambda_i^2 > 0$

and decreasing in c_i.[9] It means that there exists a unique value c_D such that a firm characterized by this productivity level sets a price equal to marginal costs and faces a demand equal to zero. As this firm runs zero operating profits, all the firms with a lower productivity ($1/c < 1/c_D$) will leave the market. Moreover, as long as the production of high quality goods requires a further investment in R&D (f_H), the threshold firm will surely produce a low quality variety. As a matter of fact, its profits will be equal to zero producing low quality and equal to $-f_H$ producing high quality (in both cases operating profits are equal to zero).

Summarizing, the least productive firm in the market is identified by a productivity parameter equal to c_D, it is a low quality producer and it runs zero operating profits. That firm will be indifferent between producing or exiting the market and its price will be equal to the marginal cost ($p_D = \lambda_L c_D$). Furthermore its demand should be equal to zero;[10] considering its inverse demand function it implies:

$$p_D = \frac{\gamma\lambda_L}{\gamma + \eta N\Lambda} + \frac{\eta N\Lambda\lambda_L}{(\gamma + \eta N\Lambda)}\tilde{P} = \lambda_L c_D \tag{7}$$

$$c_D = \frac{\gamma}{\gamma + \eta N\Lambda} + \frac{\eta N\Lambda}{(\gamma + \eta N\Lambda)}\tilde{P} \tag{8}$$

Equation (8) identifies the productivity threshold level. Substituting this result in the general expression of prices (6), we can express prices, quantities, revenues and markups of the generic firm i as a function of c_D.

The price charged by the firm i is:

$$p_i = \frac{\lambda_i}{2}(c_D + c_i) \tag{9}$$

the markup ($\mu_i = p_i - \lambda_i c_i$) charged by the firm i is:

$$\mu_i = \frac{\lambda_i}{2}(c_D - c_i) \tag{10}$$

following equation (5b), quantities sold by the firm i are:

$$q_i = \frac{L}{2\gamma}(c_D - c_i) \tag{11}$$

[9] It can be easly demostrate taking the derivatives of the quantity sold with respect to c_i: $\partial q_i/\partial c_i = -1/2 < 0$

[10] Notice that prices are set endogenously and in this monopolistic-competitive framework a firm will set its price equal to the marginal cost only if the demand is equal to zero.

total revenues ($r_i = p_i q_i$) for the firm i are:

$$r_i = \frac{\lambda_i L}{4\gamma}\left(c_D^2 - c_i^2\right) \tag{12}$$

operating profits ($\pi_i^O = p_i q_i - c_i q_i$) for the firm i are:

$$\pi_i^O = \frac{\lambda_i L}{4\gamma}\left(c_D - c_i\right)^2 \tag{13}$$

Results in (9)-(13) may provide some insights about the role of productivity and quality differentiation in firm performances. This could be a relevant issue for empirical applications, where it is usually difficult to disentangle the effects of these two components employing available firm data.

First, as it was expected, a firm with higher productivity (lower c_i) or quality (higher λ_i) obtains higher total revenues and operating profits. The two sources of heterogeneity (production costs and quality) affect in different ways the volumes sold and the pricing strategies. Keeping constant the quality level, a more productive firm (lower c_i) will charge a lower price and will sell more quantities, but, at the same time, it will exploit its competitive advantage increasing the charged markups. On the other hand, given a certain productivity, a higher quality producer will certainly increase its prices and markups, while quality has no effect on the volumes sold. Thus firms that produce higher quality varieties will exploit its advantage only through its pricing strategy.

Finally, comparing two firms with the same performance in terms of operating profits, the more productive one will sell higher volumes, while the higher quality producer will set higher prices and markups. Thus, we can somehow distinguish between these two effects using available firm data. For instance, a good indicator to measure pure firm productivity within a certain market could be the Return on Sales Index (ROS): $\pi_i^O / r_i = (c_D - c_i) / (c_D + c_i)$. In fact, assuming that this theoretical framework holds, this measure of firm performance turns out to be independent from the specific quality of its production.

3 The quality strategy

While the heterogeneity in productivity is assumed to be the result of a stochastic event (each firm draws its parameter c from a certain probability distribution), the quality differentiation arises from an endogenous decision made by the producer. Each firm, knowing its productivity, decides whether to invest other resources (f_H) to develop a high quality variety or to start the production of a low quality good. Clearly, a firm will decide to produce the high quality variety if the operating profits from selling the high quality variety, minus the further fixed costs f_H, exceed the operating profits from selling the low quality variety. Therefore, a firm will produce high quality good if:

$$\pi_i^H - \pi_i^L > f_H$$

We will compute differences in operating profits analyzing the differences in their components (revenues, prices, quantities and costs). From now on we will omit the index i that identify the firm.

Difference in prices from selling a high quality variety (λ_H) with respect to a low quality variety (λ_L):

$$\Delta p = \underbrace{\frac{(\lambda_H - \lambda_L)}{2}(c_D + c_i)}_{>0} \tag{14}$$

There is no difference in quantities sold between producing a high quality variety (λ_H) with respect to a low quality variety (λ_L). The volumes sold depend only on firm productivity (c_i).

Difference in revenues from selling a high quality variety (λ_H) with respect to a low quality variety (λ_L):

$$\Delta r = \underbrace{\frac{(\lambda_H - \lambda_L)L}{4\gamma}\left(c_D^2 - c_i^2\right)}_{>0} \tag{15}$$

Difference in total operating profits from selling a high quality variety (λ_H) with respect to a low quality variety (λ_L):

$$\Delta\pi^O = \underbrace{\frac{(\lambda_H - \lambda_L)L}{4\gamma}(c_D - c_i)^2}_{>0} \tag{16}$$

Showing that the difference between operating profits expressed in (16) is always positive is straightforward as $\lambda_H > \lambda_L$ and $c_D > c_i$ for each firm in the market. Moreover, this difference is increasing with firm productivity ($1/c_i$).[11] Thus a firm will decide to produce a high quality good whenever the difference in operating profits in (16) is higher than f_H:

$$\frac{(\lambda_H - \lambda_L)L}{4\gamma}(c_D - c_i)^2 - f_H > 0 \tag{17}$$

[11] This can be easily shown taking the first derivative of the difference in operating profits with respect to c_i: $\frac{\partial\left(\pi_i^H - \pi_i^L\right)}{\partial c_i} = -2\frac{(\lambda_H - \lambda_L)L}{4\gamma}c_i$

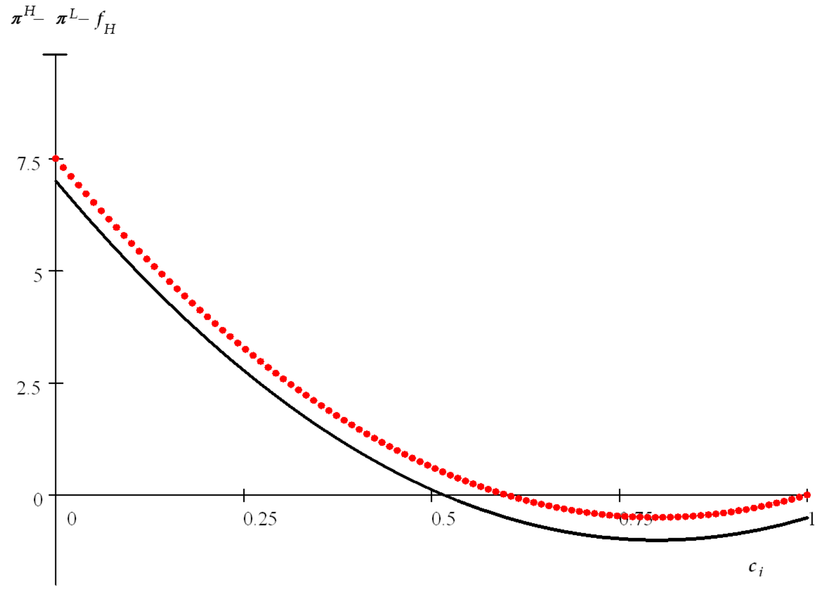

Figure 1: Diffence in operating profits and producivity

Condition (17) establishes the relation between the productivity of a firm and its quality strategy. A firm will be a high quality producer whenever its marginal cost is lower than quality-cut-off c_q, for which the firm is indifferent between choosing λ_H or λ_L. This is shown in figure 1, where we plotted the differences in profits between producing high or low quality goods as a function of the firm specific productivity parameter. From inequality (17) the analytical expression for c_q is given by:[12]

$$c_q = c_D - 2\sqrt{\frac{\gamma f_H}{L(\lambda_H - \lambda_L)}} \tag{18}$$

As it is shown in figure 1, a firm will gain higher profits producing the high quality variety if its productivity parameter is lower than c_q. Therefore, high quality goods are produced by most productive firms in the market. Thus in manufacturing, there will be two categories of producers: high-quality-high-productive firms and low-quality-low-productive firms. Notice that the fraction of producers that belong to each category depends not only on the width of the intervals bounded by the

[12]This is the only feasible solution for the equation $\frac{(\lambda_H - \lambda_L) L}{4\gamma}(c_D - c_i)^2 - f_H = 0$, as the other root will imply $c_q > c_D$ that is meaningless

productivity thresholds (c_q and c_D), but also on the probability distribution of c. In particular, it depends on the probability mass associated to each interval. For instance, assuming that the probability distribution of c is concentrated toward the lower values of productivity (c_D), the model would describe a market in which the high quality goods are supplied by few high productive firms with a large market share while low quality goods are produced by a bulk of small low-productive firms.

The results we have just described hold even assuming that the low and high quality varieties are produced at the same marginal cost c_i. Thus fixed costs in R&D (f_H) have a key in determining the share of high quality producers in the market. This is evident when we consider the analytical expression for the quality cut-off c_q (18). As R&D costs decreases, high quality productions becomes convenient also for less productive firms. At the limit, when R&D costs are equal to zero quality differentiation disappears as all the firms will produce high quality. Of course the benefits from producing a high quality variety depend on the value that consumers assign to quality as well. In the model this is expressed by the difference between λ_H and λ_L, that is clearly positive correlated with c_q.

Expression (18) provides a first insight on the role of market size in quality differentiation. The fact that the high quality technology exhibits increasing returns to scale makes the production of high quality goods more convenient in larger markets. That explains why in expression (18) L seems to be positively related with c_q. In fact, this is what happens when an increase in the market size does not affect market competition (summarized by c_D). We know from the literature on imperfect competition that market size matters for the degree of competition. Moreover, we know that c_D depends also on average quality and price in the market, which in turns depend on the quality cut-off. Then expression (18) can not be considered a reduced form for c_q. Therefore, to study total effects of market size and other variables on quality differentiation we must solve for the equilibrium of the model in order to determine the entry cut off c_D. This is the topic of the next section.

4 Closed Economy Equilibrium

The market equilibrium is reached when the expected total profits are equal to zero. Prior to entry, the expected firm total profits are given by $\int_0^{c_D} \pi\left(c_i\right) dG(c_i) - f_e$, where $G(c_i)$ is the cumulative distribution function of the productivity parameter. Considering the results for operating profits in equations (13) the free entry condition is:

$$\int_0^{c_q} \frac{\lambda_H L}{4\gamma}(c_D - c_i)^2 - f_H \, dG(c_i) + \int_{c_q}^{c_D} \frac{\lambda_L L}{4\gamma}(c_D - c_i)^2 \, dG(c_i) = f_e \quad (19)$$

In order to obtain a result for the key cut-off values (c_D and c_q), it is necessary to choose a specific parametrization for the distribution of the productivity parameter c. Following the previous literature on heterogeneous firms theory,[13] we assume that each firm draws its productivity $1/c_i$ from a Pareto distribution with lower productivity bound $1/c_M$ and shape parameter $k \geq 1$:

$$G(c_i) = \left(\frac{c_i}{c_M}\right)^k \quad , \quad c_i \in [0, c_M] \quad (20)$$

Firms with a productivity between $1/c_D$ and $1/c_M$ will exit the market. The conditional distribution of surviving firms will be a Pareto, as well, with shape parameter k $\left(G_D(c_i) = (c/c_D)^k\right.$, $\left.c_i \in [0, c_D]\right)$; the higher is k the more the distribution will be concentrated toward low productivity levels. We apply the Pareto distribution to the free entry condition expressed in (19); the algebra of these computation is presented in Appendix A.

As it is clear from the last results in the Appendix A, it is not possible to derive explicit analytical expressions for the cut-off parameters that characterize the market (c_D and c_q). In order to analyze how the equilibrium distribution of firms among high and low quality producers changes as some key parameters vary, we will rely on numerical methods assigning different values to the parameters of the model. The baseline calibration is reported in Table 1. The parameter λ_L has been normalized to 1 so that we can identify c_i as the marginal cost for producing of a low quality variety. Some other scale parameters have been normalized to 1 (c_M, f_e, f_H), while to be consistent with the theory λ_H is greater than λ_L. The value for the shape parameter of the productivity distribution k is set following recent empirical evidence on similar theoretical models.[14]

about here Table 1

4.1 R&D cost effects

First we consider the effect of a change in the fixed costs in R&D (f_H) on the quality composition of firms and sales. In figures 2-5, we have plotted

[13] Meltiz (2003), Helpman , Melitz and Yeaple (2004), Melitz and Ottaviano (2005), Baldwin and Harrigan (2007).

[14] see Ottaviano *et al.* (2007), Corcos *et al.* (2007), Del Gatto *et al.* (2006)

the results of the numeric simulations implemented to address this issue. From these results it turns out that when the costs of developing a high quality variety tends to zero ($f_H \longrightarrow 0$) there will be producers in the market. On the contrary, when these fixed costs becomes too high ($f_H > \overline{f_H}$) the quality upgrading is not a profitable strategy for any firm. Thus quality differentiation occurs only when R&D costs are strictly positive and not too high in comparison with the advantage they generate in the market ($\lambda_H - \lambda_L$). Obviously as f_H increases producing high quality becomes more expensive, thus the quality cut-off c_q shrinks (figure 2).

about here Figure 2

about here Figure 3

More interesting is the analysis on the global cut-off (c_D). In comparison with the effect on the quality cut-off, a change in the R&D costs seems to affect only marginally the overall cut off c_D. A closer look on this relation (figure 3) reveals that, when R&D costs are relatively small, the entry cut-off (c_D) decreases as f_H increases. While for relatively high values of f_H, the overall cut-off tends to rise with R&D costs. When f_H is positive but relatively small, a balk of low productive firms produce high quality; as f_H increases many of these firms will prefer to produce low quality entering in closer competition with the threshold producer. Thus the least productive firms suffer a higher competition and the overall cut-off tends to shrink.

On the other hand, when the R&D costs are considerably high, high quality goods are produced only by the most productive firms. The prevailing effect of an increase in f_H is a decrease in the competitiveness of some of these outstanding competitors. This reduces the overall degree of competition in the market, allowing less productive firms to stay in the market.

about here Figure 4

So far we have analyzed the effects of changes in R&D costs on the different thresholds that characterize the structure of the market. As we have previously pointed out, the fraction of producers that belong to each category depends not only on the width of the different intervals on c, but also on the probability distribution of the productivity parameter. To have a more precise insight about the relevance of each group of producer we have computed the probability mass associated to each productivity interval. The results, shown in figure 4, confirm the patterns followed by the respective thresholds. From this picture it is evident that the fraction of high-quality firms may be quite small for relatively high values of f_H. Nevertheless, these firms are the more productive in the market and they can exploit their competitive advantage due to quality differentiation. It means that their relative importance is much higher when we consider their market share in terms of sales for each level of f_H, as figure 5 shows.

about here Figure 5

4.2 Market size effects

The second issue that we have analyzed is the effect of market size on the different threshold levels. Figure 6 points out that the entry cut-off is a decreasing function of the market dimension (L). This result emphasizes the pro-competitive effect of an increase in the market size and it is consistent with the previous literature on heterogeneous firms (Melitz (2003), Ottaviano and Melitz (2008), Yeaple (2005)). Moreover, we have compared the effect of market size in the case of quality differentiation with the same relation in the original model of Ottaviano and Melitz (2008). The comparison is made setting the quality parameter equal to λ_L for each firm in the model without quality differentiation[15]. Figure 6 reveals that the pro-competitive effect is stronger in presence of quality differentiation. This is due to the fact that a larger market size favors especially producers that are able to invest in R&D improving their quality.

about here Figure 6

about here Figure 7

Considering the effect of market size on the quality threshold c_q (figure 7), we can see that a larger market implies a higher productivity level to make profitable the high quality strategy. This is due to the general pro-competitive effect induced by market size. On the other hand, as the technology of quality upgrading present increasing return to scale, the average costs of producing high quality varieties decreases with market size. As matter of fact the negative effect on c_q is much weaker than the effect on the overall cut-off c_D. Therefore the share of high quality producers rises with the market dimension. It is clearly pointed out by figures 8 and 9, that represent the probability mass associated to each productivity interval in general terms and for firms in the market. As only the high quality producers may exploit the advantage of a higher

[15] In both cases we started the simulation from a common market size that ensures to all the competitors that bear the fixed costs f_e to enter the market.

market size (lower average costs), it makes the competition even tougher for the least productive low quality producers. Thus, if quality upgrading is a strategy mainly adopted by high productive firms, the presence of quality differentiation magnifies the pro-competitive effects of market size[16].

Finally note that the relevance of high quality producers is as usual higher if we consider their market size instead of the fraction of firms in the market (figure 9). Furthermore the effect of market size is even stronger in increasing the total market share of high quality producers in terms of sales.

about here Figure 8

about here Figure 9

5 Open Economy

Considering the variation of market size in the model, we obtain a first insight about the consequences of opening up to international trade. Actually the analysis developed in the previous section can be considered as the effect of international trade integration in absence of trade barriers and transport costs. We have seen that in a more integrated market the competition is tougher, which means that average productivity increases and markups decrease (for a given productivity and quality level). Finally, the average quality of sales is higher in wider markets, as the share of high quality producers grows with market size.

In reality most of the goods are not freely traded. Because of trade costs and imperfect competition, markets are segmented and firms may adopt different pricing strategies for each market. Moreover, in this model firms are heterogeneous in productivity and in production quality. It means that the exporting strategy can be adopted only by a certain group of producers and that international competition may affect differently different categories of producers. To understand these linkages between productivity, export and quality strategies, we now extend the model to a two-country setting.

We assume that there are two countries (A and B) with a number of workers equal to L^A and L^B for each country. Consumers present the same preferences in both countries, then the individual demand schedule

[16] This result is even stronger with equal marginal costs for producing high and low quality (given a certain the productivity parameter c). Moreover, the result holds also with the different specification of quality in the utility function emplyed in Borin (2008)

(2) is identical across countries. Firms can produce in one market and export in the other, incurring a per-unit trade cost. To avoid to consider a transportation sector, we model trade barriers as a sort of iceberg cost. At the same time we assume trade costs to be independent from the quality of delivered goods. Then, the delivered cost of a good produced by the i-th firm is: $c_i(\lambda_i + \tau - 1)$, where $\lambda_i \geq 1$ and $\tau \geq 1$.[17] We think that is useful to disentangle the effect on marginal costs due to quality and to trade costs for two main reasons. First because it is likely that transport costs may be equal for goods of different quality, and second because employing non-tariff barriers is a more and more common trade policy. The effects on export quality of the distance between the exporter and the foreign market, as well as the presence of non-trade barriers have been also analyzed in few empirical works.[18]

As the markets are segmented and firms produce under constant returns to scale, they independently maximize the profits earned from domestic and exports sales. In particular a firm in country s set a domestic price equal p_D^s and a foreign price $\pi_D^s = [p_D^s - \lambda_i c_i]\, q_D^s$ and $\pi_X^s = [p_X^s - c_i(\lambda_i + \tau - 1)]\, q_X^s$. We first look at optimal pricing strategy for a given quality level. Then we assume that firms compare maximized profits producing low and high quality and choose the best strategy.

As for the closed economy equilibrium , the profit maximizing prices and output levels must satisfy: $q_D^s = (L^s/\lambda_i\gamma)\,(p_D^s - \lambda_i c_i)$ and $q_D^s = (L^z/\lambda_i\gamma)\,(p_X^s - c_i(\lambda_i + \tau - 1))$. Notice that only firms earning non-negative profits in a market (domestic or export) will choose to sell in that market. This leads to similar cost cut-off rules for firms selling in either market. Thus $1/c_D^s$ and $1/c_X^s$ will be the minimum productivity levels for firm of country s to sell in the domestic and foreign market.

Solving the profit maximization problem of the $i-$th firm, we get the following results for prices, quantities and operating profits in the domestic (s) and in the foreign market (z).

$$p_D^s = \frac{\lambda_i}{2}\,(c_D^s + c_i) \qquad\qquad p_X^s = \frac{\lambda_i}{2}\left(c_D^z + c_i \frac{(\lambda_i + \tau - 1)}{\lambda_i}\right) \tag{21}$$

quantities sold by the firm i are:

[17] We can think to normalize λ_L to 1, so that c_i represent the marginal cost for producing a low quality variety of good i. Thus, trade costs would be exactly as iceberg costs only for low quality products.

As usual $\tau = 1$ correspond to free trade.

[18] Aw and Roberts (1985), Hummels and Skiba (2004), Baldwin and Harrigan (2007), Fontagnè and al. (2008)

$$q_D^s = \frac{L^s}{2\gamma}\left(c_D^s - c_i\right) \qquad q_X^s = \frac{L^z}{2\gamma}\left(c_D^z - c_i\frac{(\lambda_i+\tau-1)}{\lambda_i}\right) \tag{22}$$

operating profits in the two markets are:

$$\pi_D^s = \frac{\lambda_i L^s}{4\gamma}\left(c_D^s - c_i\right)^2 \qquad \pi_X^s = \frac{\lambda_i L^z}{4\gamma}\left(c_D^z - c_i\frac{(\lambda_i+\tau-1)}{\lambda_i}\right)^2 \tag{23}$$

From results in (22-23) we can see that there is a direct relation with the export cut-off (c_X^s) for producers of country s and the overall entry cut off of market z (c_D^z). In particular a country s producer will run zero profits exporting abroad when its productivity parameter is equal to c_X^s :

$$c_X^s = c_D^z\frac{\lambda_i}{\lambda_i+\tau-1} \tag{24}$$

Clearly the level of c_X^s depends on trade costs and on the quality of the least productive exporter. In the next section, considering the quality strategy in open economy, we will impose a restriction in the model to uniquely identify the export cut off c_X^s.

5.1 Quality strategy and open economy equilibrium

As we have seen in the closed economy analysis, a firm will be a high quality producer if its profits are higher producing the high quality variety. The differences in operating profits in the domestic and in the foreign market are given by:

$$\Delta\pi_D^s = \frac{(\lambda_H-\lambda_L)\,L^s}{4\gamma}\left(c_D^s - c_i\right)^2 \tag{25}$$
$$\Delta\pi_X^s = \frac{\lambda_H L^z}{4\gamma}\left(c_D^z - c_i\frac{(\lambda_H+\tau-1)}{\lambda_H}\right)^2 - \frac{\lambda_L L^z}{4\gamma}\left(c_D^z - c_i\frac{(\lambda_L+\tau-1)}{\lambda_L}\right)^2$$

It can be easily proved that both this differences are decreasing in c_i, thus the high quality producers will be more productive than low quality competitors. Determining the quality cut off c_q^s requires a further assumption about the relative position of the export cut off c_X^s with respect to c_q^s. For simplicity we will assume that $c_X^s \geq c_q^s$, so that there is quality differentiation also among exporters. In the other case ($c_X^s < c_q^s$), only high quality firms will be able to export and c_q^s would be determined exactly as in closed economy solving the equation $\Delta\pi_D^s - f_h = 0$ for c_i. For a more complete analysis it is possible to consider both the case: $c_X^s \geq c_q^s$ and $c_X^s < c_q^s$. Nevertheless, at this stage we are particularly interested in the case in which there is quality differentiation among exporters ($c_X^s \geq c_q^s$). Actually one of the aims of the study is to look at the possible effect of trade costs on the quality composition of exported goods. Obviously there can not be such a change in composition as long as only high quality producers will export.

When $c_X^s \geq c_q^s$, a firm will be indifferent between producing high or low quality if the following equality holds:

$$\Delta\pi_D^s + \Delta\pi_X^s = f_h \tag{26}$$

Solving (26) for c_i it is possible to determine the unique c_q^s that satisfies $c_X^s \geq c_q^s$.

Summarizing, for each market there will be three different cut-off: an entry cut off (c_D^s), an export cut-off that determines which firm will sell abroad or serve only the domestic market, and a quality cut-off (c_X^s) that identifies which firms will produce high and low quality. Given that the least productive exporter is a low quality producer, we can determine the relation that ties up the entry cut-off in county z and the export cut off in country s: $c_X^s = c_D^z \lambda_L/(\lambda_L + \tau - 1)$.

To identify the overall productivity thresholds in the two markets (c_D^A and c_D^B) it is necessary to set the open economy equilibrium of the model. The two markets are in equilibrium when the expected total profits are equal to zero. Prior to entry, the expected firm total profits in a certain market s are given by $\displaystyle\int_0^{c_D^z} \pi_D^s(c_i)\, dG(c_i) + \int_0^{c_X^s} \pi_X^s(c_i)\, dG(c_i) - f_e$. The expected total profits are composed by the expected profits from selling in the domestic market and the profits from exporting, where the probability of being an exporter is lower than the probability of producing at least for the domestic market: $G(c_D^s) > G(c_X^s)$. Given the results for operating profits from domestic and foreign sales, the free entry equilibrium condition is given by:

$$\begin{aligned}
&\int_0^{c_q^s} \frac{\lambda_H L^s}{4\gamma}\left(c_D^s - c_i\right)^2 - f_H \; dG(c_i) + \int_{c_q^s}^{c_D^s} \frac{\lambda_L L^s}{4\gamma}\left(c_D^s - c_i\right)^2 dG(c_i) + \\
&\quad + \int_0^{c_q^s} \frac{\lambda_H L^z}{4\gamma}\left(c_D^z - c_i\frac{(\lambda_H + \tau - 1)}{\lambda_H}\right)^2 dG(c_i) + \\
&\quad + \int_{c_q^s}^{c_X^s} \frac{\lambda_L L^z}{4\gamma}\left(c_D^z - c_i\frac{(\lambda_L + \tau - 1)}{\lambda_L}\right)^2 dG(c_i) = f_e
\end{aligned} \tag{27}$$

The system composed by the two entry conditions for domestic and foreign market in (27), along with the conditions on c_q^s and c_X^s for each market described by equation (24) and (26) establishes the long run open economy equilibrium of the model.

5.2 Trade costs, quality composition and export unit values

To analyze the open economy equilibrium we will rely on numerical solutions choosing a specific form for the productivity distribution ($G(c_i)$) and assigning numeric values to the parameters of the model. As before, we assume a Pareto distribution for $1/c$ described in the previous sections. Moreover, we start considering complete symmetry between the two markets. The baseline calibration for the parameters is the same used to study the closed economy equilibrium, described in table 1.[19]

Assuming perfect symmetry also in trade costs between market A and B, we study the effect of a variation in trade costs in the quality composition. In figures 10-12, we have plotted the results of numeric simulations we have made to address this issue.[20] To measure the degree of trade "freeness" we follow Ottaviano and Melitz (2008) choosing the variable $\phi = 1/\tau^k$. This variable is bounded between zero and 1, where $\phi = 1$ corresponds to free trade and $\phi = 0$ to autarky.

From figure 10 it is evident the pro-competitive effect of trade liberalization. The share of firms that are able to enter the domestic market shrinks as ϕ increases. In fact, the tougher competition due to international trade causes a reduction in the entry threshold (c_D^s). On the other hand, as trade costs decrease the share of firms that are able to serve also the foreign market increases.

Looking at the group of firms that are in the market (figure 11), it is evident that trade liberalization allows a wider number of low quality producers to enter in the foreign market. Moreover, in absolute terms trade liberalization does not have a strong impact on the share of high quality producers in the market. Nevertheless the relative weight of high quality producers seems to be slightly increasing with trade liberalization.

[19]The only difference is in the market size, as here we have two countries. To keep perfect symmetry between the markets and to show that the open economy version of the model is in line with the previous analysis, we set the dimension of each market equal to 1/2 that used in the baseline calibration of the closed economy equilibrium ($L^s = L^z = L/2$). Thus, the free trade open economy equilibrium sould be exactly equal to the closed economy equilibrium previously studied.

[20]We have plotted the results relative to country A, but they are identical to those of country B, given the perfect simmetry between the two countries

The absence of a clear and sharp increasing relation between the freeness of trade and the share of high quality producers may seem puzzling. In fact in previous sections we show the existence of a positive relation between market size and the fraction of high quality producers in the market (figure 9). We know that it corresponds to trade integration when goods are freely traded. Introducing trade costs, trade liberalization affects the relative importance of high quality producers in the market through two effects with opposite sign. On one side international integration makes the competition tougher, providing incentives for quality differentiation. On the other side, with lower trade costs the advantage of high quality producers in foreign markets shrinks and this makes the upgrading quality strategy less profitable.

The second effect is clearly visible when we look at the quality composition of export (figure 12). As trade costs rise ($\phi \to 0$) the share of high quality goods exported increases. When trade costs are too high only high quality producers are able to serve foreign markets. This result confirms the so called Alchian-Allen conjecture, that predicts a positive correlation between trade costs and the quality of exported goods. A different fomulation of the Alchian-Allen conjecture claims that the quality of exported goods is higher with respect to domestic sales. Actually, this is always verified by the results of the model.

about here Figure 10

about here Figure 11

about here Figure 12

The Alchian-Allen conjecture have been tested in empirical works looking at the relation between trade costs (or distance) and export unit values.[21] The empirical evidence finds a positive relation between distance from the exporter to the importer country and the free on board (FOB) export unit values. An other strand of empirical trade literature[22] finds that the presence of non tariff barriers increases export unit values. We have verified these empirical findings in the model computing export unit values as the ratio between total revenues of exporters in the foreign market and volumes sold abroad. The total value of export has been computed employing FOB prices defined as: $p_X^s - c_i(\tau - 1)$.

[21] Baldwin and Harrigan (2007) , Hummels and Skiba (2004) , Fontagné, Gaulier and Zignago (2008)

[22] Aw and Roberts 1985, Khandelwal 2007

Figure 13 confirms that, on average, it exists a positive correlation between trade costs and FOB export unit values. This is due to the effect of trade costs (distance or trade barriers) on the quality composition of export. As trade costs rise the share of high quality exporters, the average price of goods sold abroad increases. Figure 13 shows also that the relation is not monotonic. In fact when trade costs are relatively high and there are few low quality exporters, an increase in trade costs boosts also the share of the most productive firms among the high quality producers. These firms present lower marginal costs with respect to other high quality producers and charge lower prices.[23] An other explanation of this non-monotonic relation is the presence of dumping strategy implemented by exporters when trade costs grow.[24] Nevertheless, we can see from the linear regression line drew in figure 13 that the model may reproduce the average positive relation between trade costs and export unit values found in the empirical literature.[25]

about here Figure 13

6 Conclusions

In this paper we analyzed the relations between differences in productivity among firms and the quality of their productions. We presented a model of international trade with monopolistic competition that combines horizontal and vertical differentiation with firm heterogeneity in productivity. Peculiarities of the model are also that the quality of production is endogenously determined by each firm and the technology adopted by high quality producers presents increasing return to scale.

Employing a theoretical framework that allows firms to charge variable markups, we have analyzed how market performances and pricing strategies vary among firms that differ in productivity and in production quality. As it was expected, we have found that a firm obtains higher total revenues and operating profits the higher is its productivity and the quality of goods sold. Considering separately the two sources of

[23] This composition effect is due to the fact that in the model there are only two possible quality levels.

[24] This dumping behavior is shown in the original model of monopolistic competition with quasi-linear utility function of Ottaviano *et al.* (2002)

[25] The sensitivity tests implemented show that this relation is not always robust to changes in the parameters of the model (i.e. R&D costs, productivity distribution *etc.*). Actually the empirical evidence points out the existence of the positive relation between export unit values and distances considering trade flows in all the products or in manufacturing (Baldwin and Harrigan 2007 , Hummels and Skiba 2004 , Fontagné, Gaulier and Zignago 2008). Further empirical investigations should be conducted to check if the relation may vary according to sector and market characteristics, as the theoretical results suggest.

differentiation (productivity and quality), we have shown that a more productive firm will charge lower prices and will sell more quantities, even if its markups are higher. On the other side, a firm that produces higher quality varieties will certainly increase prices and markups, while quality has no effects on the volumes sold.

Then we have analyzed how differences in productivity affect quality strategies. It turned out that high quality goods are produced by firms with high productivity levels, while low quality products are supplied by a bulk of small low-productive firms. Solving the market equilibrium condition through numerical computations, we found that a decrease in R&D costs obviously increases the portion of firms that produce high quality goods. It has also an impact on the overall threshold that defines the fraction of firms that are able to enter the market. For high levels of R&D costs, a decrease in this parameter lower the entry cut-off level of marginal costs. On the contrary, if R&D costs are relatively low a reduction in this component allows other less competitive firms to enter the market.

Moreover, we found that the fraction of high quality producers rises as market size increases. A wider market induces also a tougher competition, so that less productive firms are pushed out from the market. This pro-competitive effect is magnified by the increase in average quality of sales.

The analysis on market size effects provides a first insight about the consequences of opening up to international trade in the model. To understand the linkages between productivity, export and quality strategies, we have extend the model to a two-country setting. As in the other theoretical contributions on firm heterogeneity we find that exporters are more productive than non exporters. As the most productive firms tend to produce high quality, the average quality of goods sold abroad is higher with respect to domestic sales. Moreover, the fraction of high quality producers among exporters grows with trade costs. When trade costs are independent from the quality of delivered goods (distance, non tariff-barriers), unit values of export tend on average to increase with trade costs. All these results are in-line with most empirical evidence in international trade.

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Appendix A

Parametrization of technology

Pareto cumulative distribution function of $1/c$:

$$G(c_i) = \left(\frac{c}{c_M}\right)^k \quad , \quad c_i \in [0, c_M]$$

Pareto density function of $1/c$:

$$g(c_i) = \frac{k}{c_M}\left(\frac{c}{c_M}\right)^{k-1}, \quad c_i \in [0, c_M]$$

where $k > 1$.

The expected value for the operating profits is given by:

$$\int_0^{c_q} \frac{\lambda_H L}{4\gamma}(c_D - c_i)^2 - f_H dG(c_i) + \int_{c_q}^{c_D} \frac{\lambda_L L}{4\gamma}(c_D - c_i)^2 dG(c_i) = f_e$$

Expected value for c: $\int_0^{c_M} k\left(\frac{c}{c_M}\right)^k dc = \frac{k}{k+1}c_M$

Second moment for c: $\int_0^{c_M} k\left(\frac{1}{c_M}\right)^k c^{k+1}dc = \frac{k}{k+2}(c_M)^2$

We solve the expected value for profits comuputing separately its two

components:

$$\int_0^{c_q} \frac{\lambda_H L}{4\gamma}(c_D - c_i)^2 - f_H dG(c_i) =$$

$$= \frac{\lambda_H L}{4\gamma}\int_0^{c_q} c_D^2 + (c_i)^2 - 2c_D c - f_H dG(c_i) =$$

$$= \frac{\lambda_H L}{4\gamma}\left[c_D^2 G(c_q) + \int_0^{c_q}(c_i)^2 dG(c_i) - 2c_D\int_0^{c_q} c_i dG(c_i)\right] - f_H G(c_q) =$$

$$= \frac{\lambda_H L}{4\gamma c_M^k}\left[c_D^2 (c_q)^k + \frac{k}{k+2}(c_q)^{k+2} - 2c_D\frac{k}{k+1}(c_q)^{k+1}\right] - f_H\left(\frac{c_q}{c_M}\right)^k$$

$$\int_{c_q}^{c_D} \frac{\lambda_L L}{4\gamma}(c_D - c_i)^2 dG(c_i)$$

$$= \frac{\lambda_L L}{4\gamma}\int_{c_q}^{c_D} c_D^2 + (c_i)^2 - 2c_D c dG(c_i) =$$

$$= \frac{\lambda_L L}{4\gamma}\left[c_D^2 (G(c_D) - G(c_q)) + \int_{c_q}^{c_D}(c_i)^2 dG(c_i) - 2c_D\int_{c_q}^{c_D} c_i dG(c_i)\right] =$$

$$= \frac{\lambda_L L}{4\gamma c_M^k}\left[c_D^{k+2}\left(\frac{2}{(k+2)(k+1)}\right) - c_D^2 (c_q)^k - \frac{k}{k+2}(c_q)^{k+2} + 2c_D\frac{k}{k+1}(c_{q2})^{k+1}\right]$$

$$\int_0^{c_q} \frac{\lambda_H L}{4\gamma}(c_D - c_i)^2 - f_H dG(c_i) + \int_{c_q}^{c_D} \frac{\lambda_L L}{4\gamma}(c_D - c_i)^2 dG(c_i) =$$

$$= \frac{L}{4\gamma c_M^k}\left[\begin{array}{c}(\lambda_H-\lambda_L)\left[c_D^2\left(c_q\right)^k+\frac{k}{k+2}\left(c_q\right)^{k+2}-2c_D\frac{k}{k+1}\left(c_q\right)^{k+1}\right]+\\ +\lambda_L c_D^{k+2}\left(\frac{2}{(k+2)(k+1)}\right)\end{array}\right]+$$
$$-f_H\left(\frac{c_q}{c_M}\right)^k$$

The zero profit condition for entering the market is:

$$\frac{L}{4\gamma c_M^k}\left[\begin{array}{c}(\lambda_H-\lambda_L)\left[c_D^2\left(c_q\right)^k+\frac{k}{k+2}\left(c_q\right)^{k+2}-2c_D\frac{k}{k+1}\left(c_q\right)^{k+1}\right]+\\ +\lambda_L c_D^{k+2}\left(\frac{2}{(k+2)(k+1)}\right)\end{array}\right]+$$
$$-f_H\left(\frac{c_q}{c_M}\right)^k=f_e$$

Table 1
Baseline calibration
$L = 25$
$\gamma = 0.5$
$\lambda_L = 1$
$\lambda_H = 2$
$f_H = 1$
$f_e = 1$
$k = 2$
$c_M = 1$

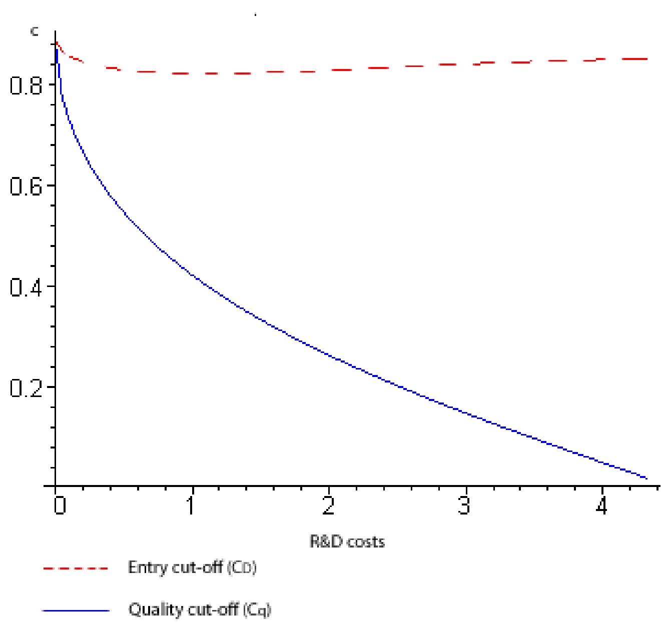

Figure 2: R&D costs, entry and high quality cut-off

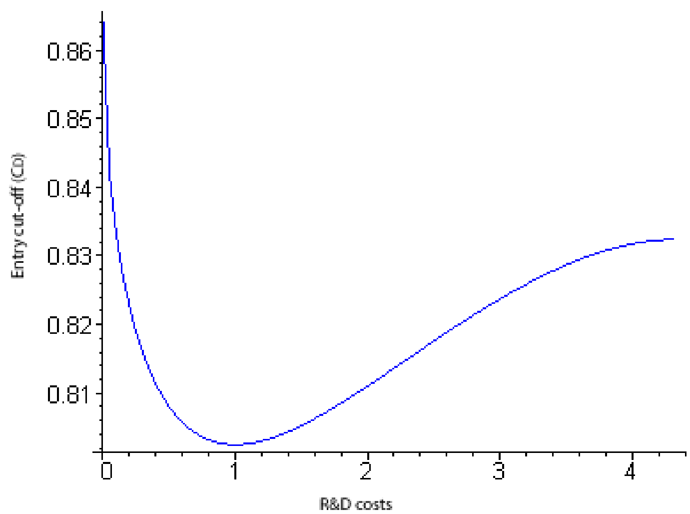

Figure 3: R&D costs and entry cut-off

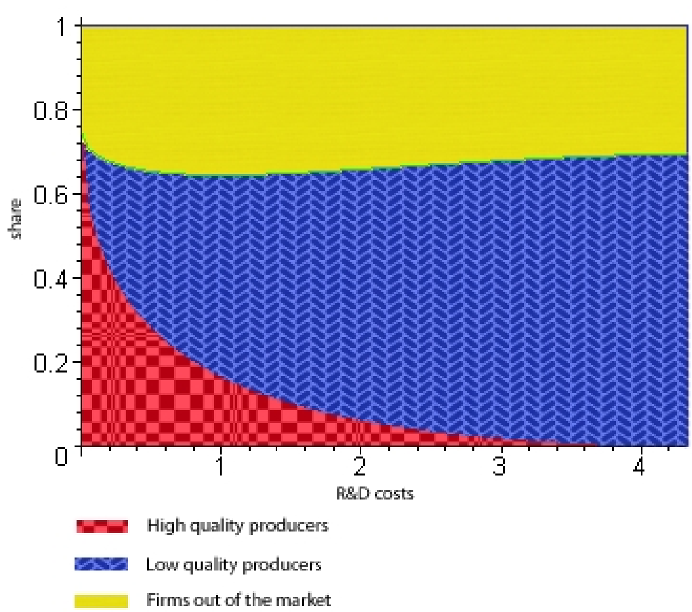

Figure 4: R&D costs and shares of firm groups

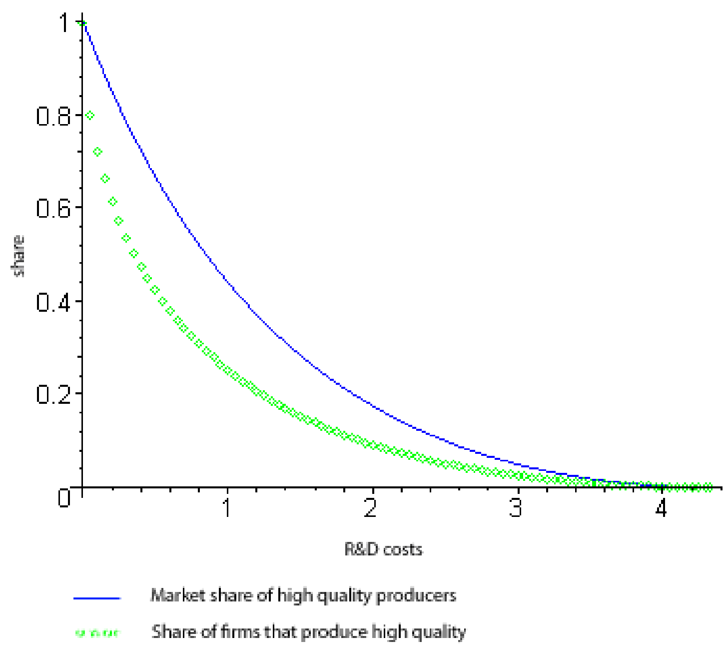

Figure 5: R&D costs and market share of high quality producers

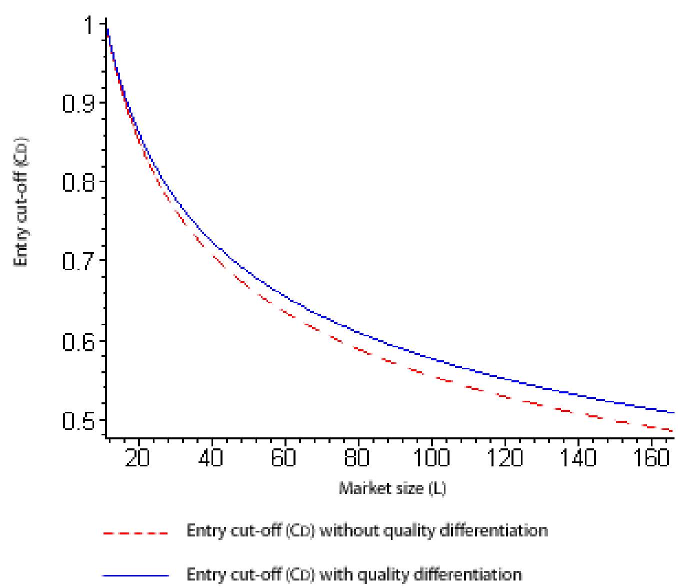

Figure 6: Market size and entry cut-off

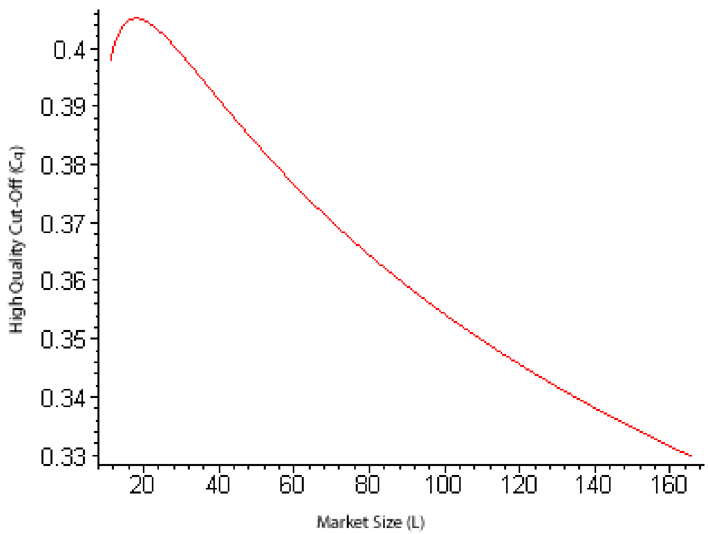

Figure 7: Market size and high quality cut-off

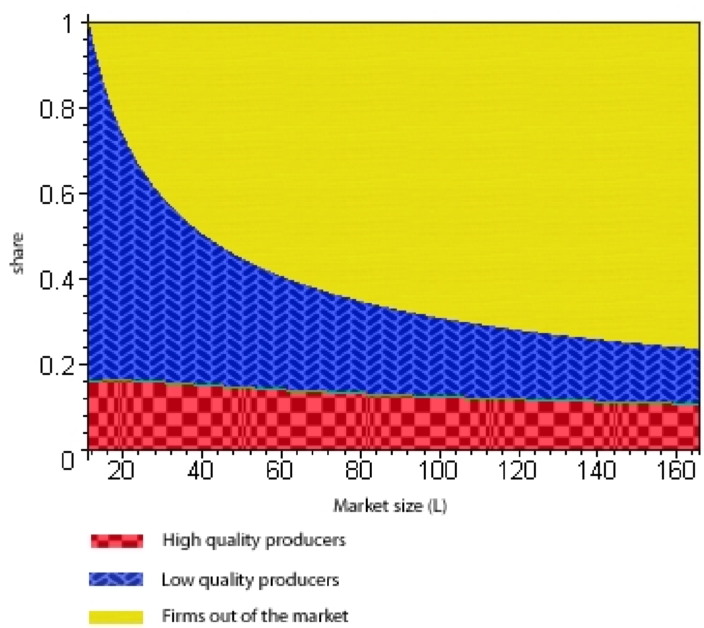

Figure 8: Market size and shares of firm groups

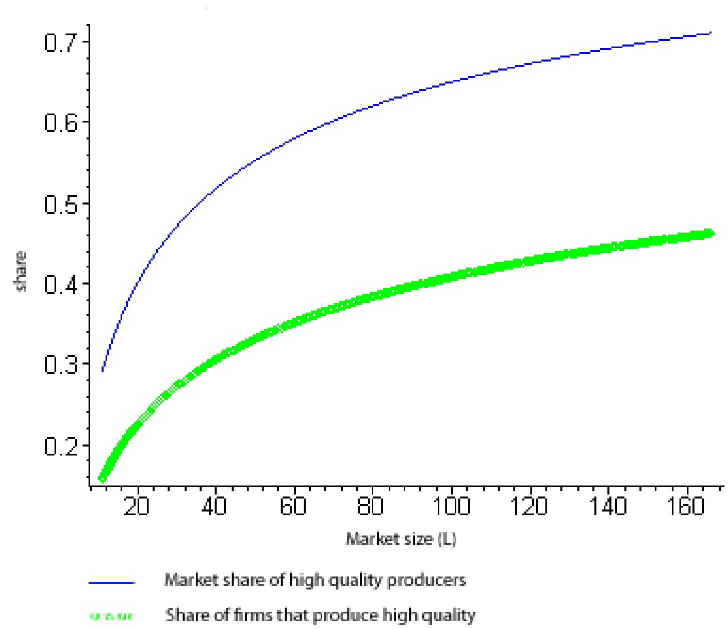

Figure 9: Market size and market share of high quality producers

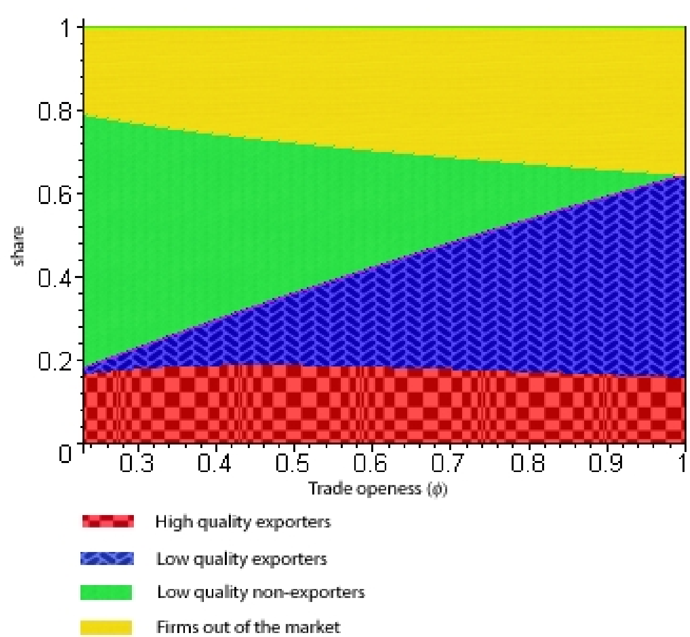

Figure 10: Trade costs and shares of firm groups

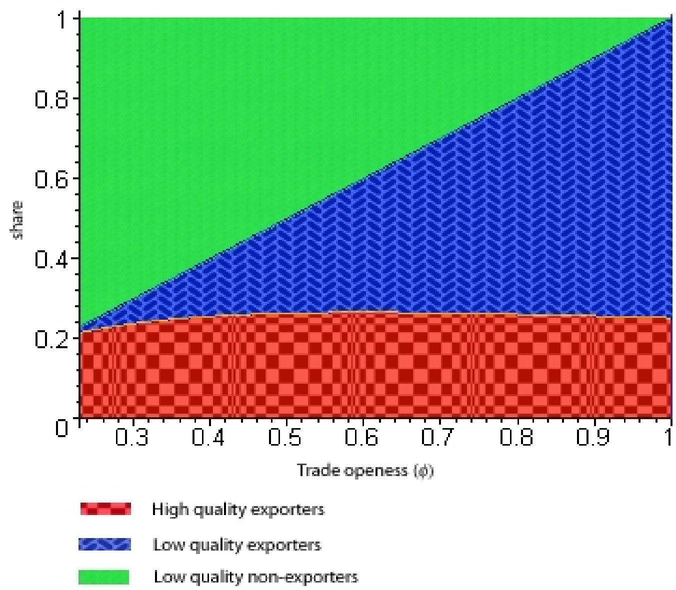

Figure 11: Trade costs and shares of firm groups in the market

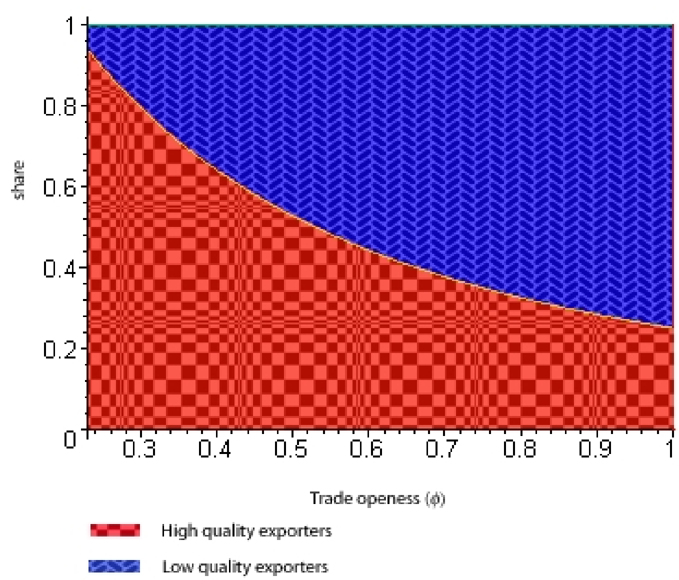

Figure 12: Trade costs and quality export composition

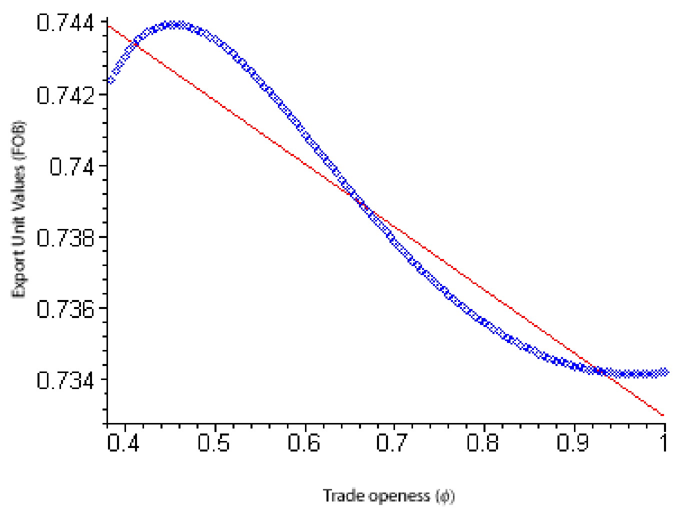

Figure 13: Trade costs and export unit values (FOB)