HETEROGENEOUS FIRMS, QUALITY, AND TRADE*

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Abstract

We present a simple and tractable trade model of heterogeneous firms, endogenous quality choice, and endogenous markups. A key feature of the model is that competition not only lowers the cost threshold between the firms that produce and those that exit, but it also raises the scope for quality differentiation. With both these channels present, the most productive firms respond to competition by raising quality, prices, and markups, while the least productive either exit or respond in the exact opposite manner.

The model generates a unified theory and a supply-side explanation for an extremely rich set of stylized facts relating to (i) productivity heterogeneity, (ii) product quality heterogeneity, (iii) markups heterogeneity, (iv) heterogeneity in the response of firms to competition, and (v) heterogeneity in the sign and magnitude of the correlations between output prices, firm productivity, size, and product quality. In addition, the model predicts that average price and markups exhibit a U-shape response to competition, that imports from developed countries are of higher quality and cost more than imports from developing countries, and that welfare gains are significantly understated when trade-induced competition is accounted for, but trade-induced innovation is not.

Keywords: Intra-industry trade, firm heterogeneity, qualilty choice, non-constant markups, quality ladders

JEL classification: F12, O14, O47

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1 Introduction

We present a simple and tractable trade model of heterogeneous firms with endogenous quality choice and non-constant markups. Our objective is two-fold. First, to provide a unified, supply-side explanation to a very broad set of stylized facts relating to: (i) productivity heterogeneity, (ii) product quality heterogeneity, (iii) markups heterogeneity, (iv) heterogeneity in the response of firms to competition, and (iv) heterogeneity in the direction and size of the relation between output prices, firms size, and product quality.

Second, to exploit the richness of the theory and provide new insights on economic behavior. In particular, we show that average price and markups can exhibit a U-shape response to competition, that the quality and price of a country's exports bundle depends more on the country's ability to innovate than it depends on its size, and that welfare gains from an increase in market size (such as in the case of trade) for developed countries are significantly understated when trade-induced competition is accounted for, but not trade-induced innovation.

The model is based on the seminal work of Melitz and Ottaviano (2008) on linear demand systems and endogenous markups, but extended to include endogenous quality choice. On the demand side, we augment preferences so that consumers care for quality and are willing to pay more for it. On the supply side, we follow Shaked and Sutton (1983, 1987, 1990) and model quality choice as an endogenous sunk cost that firms have to pay. Adding quality raises the demand for a product, lowers its elasticity of substitution, and allows the firm to charge a higher markup and price.

As in most heterogeneous firms trade models with quality choice, our model predicts that more productive firms have higher market shares, are more likely to export, and account for most of a nation's exports.[1,2]

[1] For evidence of firm heterogeneity see Eaton et. al. (2004, 2008,) and Bernard et. al. (2009). Bernard et. al. (2003) and Melitz (2003) provided new intuition as to why more productive firms have higher market shares, are more likely to export, serve more export destinations, and account for most of a nation's exports.

[2] The literature on the importance of product quality in explaining firm behavior goes as far back as Linder (1961) who observed that rich countries produce and consume a higher share of quality goods. Schott (2004), Hummels and Klenow (2005) and Fontagne, Gaulier and Zignano (2008) documented that in developed countries, large portions of exports increases occur through quality upgrades. Bernard et al (2006) and Hallak (2006) showed that capital- and skill-abundant countries use their endowment advantages to produce vertically superior varieties that have higher prices and higher quality. In addition, Verhoogen (2008) attributed the rising wage inequality gap in Mexican manufacturing firms in the 90s to the demand for high quality

They also produce goods of higher quality. [3]

By relaxing the constant markups assumption, we can also account for additional characteristics of firm behavior relating to markups, such as the observations that markups are heterogeneous across firms, they increase in firm productivity and size, and are higher for exporters and for producers of high-quality products.[4] The theory also accounts for the observation that markups are adjusted in response to changes in economic conditions and that the size of these adjustments varies by firm.[5]

A distinct element of the present theory, which constitutes an important contribution, is how we relate market toughness to the behavior of firms, and consequently, to the behavior of economic aggregates such as prices, markups, and welfare. [6]In our setting, market toughness operates through two channels: an increase in competition and an increase in the scope for quality differentiation.

The competition effect is identical to past work. An increase in market toughness, due to an increase in market size for example, raises competition as it encourages more firms to enter the market. There is a drop in the cost threshold between firms that operate in the market and those that exit. Average productivity

products by rich countries, which raised the relative demand for skilled labor. Most importantly, a set of studies argued that observed positive correlations between export prices and productivity (Verhoogen 2008, Baldwin and Harrigan 2011), between output prices and market shares (Verhoogen 2008, Kugler and Verhoogen 2011, Manova and Zhang 2012), and observed patterns between export prices and destination market characteristics (Bastos and Silva 2011, Manova and Zhang 2012, Kneller and Yu 2008) could not be accounted for without considering firms' quality choices.

[3]Some stydies that extend the Melitz (2003) model of heterogeneous firms and constant markups by considering how firms optimally choose quality are Johnson (2012), Verhoogen (2008), Baldwin and Harrigan (2011), and Kugler and Verhoogen (2011). Additional examples of studies that use a CES specification and rely on demand-side effects to identify quality are Schott (2004), Hallak (2006), Hallak and Schott (2011), Baldwin and Ito (2008), Fajgelaum, Grossman, and Helpman (2011), Feenstra and Romalis (2012), Eslava, Fieler, and Xu (2012) and Crozet, Head and Mayer (2009).

[4]See Roberts and Supina (2000), and De Loecker and Warzynski (2012).

[5]See Rotemberg and Woodford (1991, 1992, 1995, 1996), Gali (1994), Hornstein (1993), Edmunds and Veldkamp (2006), Bilbiie et al. (2006) and references therein for evidence on changes in markups over business cycles. See Antoniades and Zaniboni (2013), Auer and Chaney (2008), Gopinath, Itskhoki, and Rigobon (2010), Burstein and Jaimovich (2009), Fitzgerald and Haller (2010) and Berman et al. (2012) for evidence on heterogeneous changes in markups across firms in response to exchange rate movements.

[6]Market toughness refers to the situation where new firms enter the economy. Past work relates market toughness to an increase in the size of the economy caused either by an increase in population or by trade liberalization. We show in the model that market toughness may also arise from changes in innovation capacity that induces more firm entry.

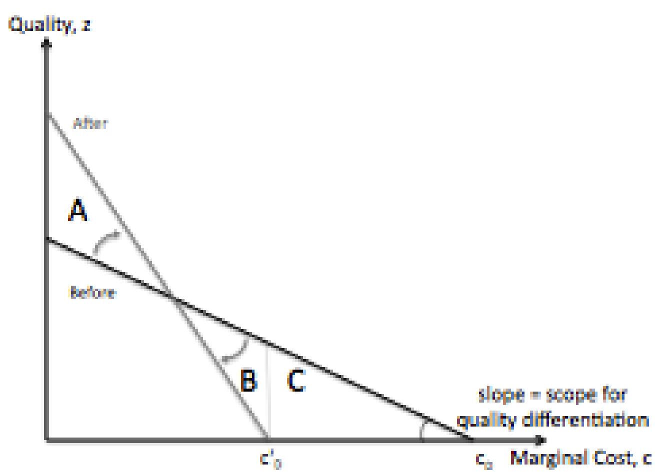
increases, and the remaining firms respond by lowering prices, markups, and quality. Market shares shrink as firms compete with new entrants; the market becomes more fragmented; and average markups and prices fall.

But there is now a second channel through which market toughness affects the economy. An increase in market toughness (e.g. an increase in size) raises the scope for quality differentiation because it makes it easier for firms to recover the fixed cost of innovation. Each firm responds by raising quality, markups, and prices. The (endogenous) relation between the scope for quality differentiation and market toughness is a key element of the model and constitutes an important deviation from past work.

Because the competition and the innovation effects move in opposite directions, their overall impact on firm behavior is ambiguous and depends on firm productivity. For the most productive firms, quality, prices and markups rise as the innovation effect dominates the competition, while for the rest these variables fall as competition dominates. It is the interaction of these two forces that separates the theory from past work and allows it to account for the additional and important characteristics on firm behavior that we discuss next.

We draw a simple diagram to capture the main features of the theory, build some intuition, and discuss additional predictions. Figure 1 plots the optimal quality choice for each firm, with marginal cost (inverse of productivity) measured on the horizontal axis and optimal quality on the vertical axis.

Figure 1 – Quality Ladders and Market Toughness



More productive firms (lower marginal cost) choose higher quality for their products. This can be seen from the black solid line that represents the quality ladder in this economy. The scope for quality differentiation, which we later show to depend on a country- or industry-specific ability to innovate, on market size, and on the degree of product differentiation, defines the slope of the quality ladder. Changes in competition shift the ladder while changes in the scope for quality differentiation change the slope of the ladder.

An increase in market toughness induces competition (shift to the left) and lowers the cost threshold. But it also induces innovation, which raises the scope for quality differentiation (steeper slope). Combined, the competition and innovation effects cause the quality ladder to pivot, as illustrated by the grey line in Figure 1 above. Firms to the left of the pivot point, the more productive ones (Area A), escape competition by raising quality, markups and prices, while firms placed below either exit (Area C), or lower quality, markups, and prices (Area B).

Such a response of firms to market toughness is consistent with a growing body of evidence that highlights the heterogeneous response of firms to competition[7]. In a series of influential papers, Aghion et. al. (1997, 2001, 2005) argue that the relation between the competition and innovation is not linear. Firms at the technological frontier respond to competition by raising quality-improving innovation, whereas firms further below the technological frontier lower innovation. Recent empirical studies provide ample support for their view. These studies show that more productive firms respond to competition by raising innovation, by investing in better technologies, and by upgrading product quality, while the least productive firms respond in opposite ways.[8] Notice that for the firms that escape competition through innovation (Area A) market

[7] A study that draws attention to the fact that firms respond in heterogeneous ways to trade liberalization is Bustos (2011). The author provides a model where more productive firms respond to trade liberalization by upgrading to better technology, while all other firms continue to use the old, and more costly, technology. Her work is a good example of a non-linear, but binary, response of firms to competition.

[8] Amiti and Khandelwal (2009) document that in the US, trade liberalization resulted in quality upgrading for products close to the word quality frontier, and discouraged quality upgrading for products far from the frontier. Bloom et al. (2011) found that high total-factor-productivity (TFP) firms in the EU were more likely to respond to the increased import competition brought by China's entry to the WTO by innovating, than low TFP firms were. Similarly, using Mexican data before and after NAFTA, Iacovone (2012) found that liberalization boosted innovation efforts by more productive firms while it weakened the incentive to innovate for less productive firms (Iacovone 2009). Similarly, Lileeva and Trefler (2010) and Shor (2004) showed that the impact of trade liberalization is heterogeneous across firms. Using a panel of British manufacturing firms, Blundell

shares rise, which is consistent with Sutton's (1989, 1991) observation that competition does not always result in market fragmentation.

The theory also provides clarity on the relation between prices, productivity, market shares, and quality. In heterogeneous firms trade models, firm size is positively related to firm productivity. If no quality is present, these models predict a negative correlation between prices and productivity, and therefore between prices and firm size. However, if quality is present, and if its production raises marginal costs substantially, then the correlation between prices and productivity, and between prices and firm size becomes positive.[9] And since these models produce a quality sorting along the productivity axis, then the correlation between prices and quality is also positive. Put differently, prices are a good proxy for quality.

Yet, empirical evidence suggests that the correlations between prices and productivity, and between firm size and productivity are positive in some industries but negative in others, and that prices are not always a good proxy for quality. Roberts and Supina (1996, 2000), Syverson (2007), and Foster, Haltiwanger, and Syverson (2008) report a negative correlation between market size and output price, while Verhoogen (2008), Kugler and Verhoogen (2011), Hallak and Sivadasan (2011), Manova and Zhang (2012), and Iacovone and Javorcik (2012) report positive correlations. Similarly, Khandelwal (2010) finds that in some industries prices are a good proxy for quality but not in others.

Differences in the scope for quality differentiation across industries help explain these inconsistencies. When the scope for quality differentiation is high, the quality ladder is steep (long ladder). High productivity firms choose high quality, which raises markups substantially. Although marginal costs fall in this model as firm productivity increases, the increase in markups offsets the falling costs, and prices increase as firm productivity, size, and quality increase. However, when there is little scope for quality differentiation the ladder is relatively flat (short ladder). High productivity still translates to higher product quality, but the increase in markups is not sufficient to offset the falling costs because quality and markups do not rise fast enough as productivity rises. Therefore, prices decline as firm productivity, size, and product quality

and Griffith (1999) documented that increased competition tends to simulate innovation by the dominant firms. Finally, Bustos (2011) and Teshima (2010) use very detailed plant-level data from Argentina and Mexico to document firms' investments in technology and innovation in response to trade liberalization.

[9] For a step-by-step exposition, see Baldwin and Harrigan (2011).

increase.

Indeed, Khandelwal (2010) confirms that prices are a good proxy for quality for long quality ladders, but not for short. And Kugler and Verhoogen (2011) argue that the positive correlations they observe in their data is because they consider heterogeneous sectors with higher scope for quality differentiation, whereas the studies that find negative correlations consider homogeneous sectors. In further support to the intuition presented in this model, Kugler and Verhoogen (2011) show that the correlation between prices and firm size increases as the scope for quality differentiation, which is proxy by R&D and advertising spending, increases. And using Chinese data, Manova and Zhang (2012) also confirm that the correlation between export prices and firm revenues increases substantially when the scope for quality differentiation in a given industry is high.

Having completed our discussion on how such a theory can be empirically relevant, the second objective of the paper is to ask whether by exploiting the richness of the model we can develop some new insights on economic behavior.

There are three such insights worth emphasizing. First, we show that average prices and markups (and their dispersion measures) can exhibit a U-shape response to competition, especially in industries or economies where the ability to innovate is high. At early stages of competition only the most productive firms raise markups and average markups fall since the rest of the firms lower them. As competition rises however, and the least productive firms keep exiting the market, the share of firms that respond to competition through quality enhancing innovation rises, which eventually drives average markups up. A similar reasoning applies to the behavior of average prices in response to increases in competition. Because in such a framework the relation between competition and prices can be both negative and positive, depending on the strength of competition, our results suggest that prices are not always a good proxy for competition.

Second, we show that welfare gains associated with an increase in market size, such as in the case of trade for example, are understated, especially in developed countries, when trade-induced competition is accounted for, but trade-induced innovation is not. This happens because market toughness benefits consumers through changes in prices, but also through changes in product quality. For developed countries, where the innovation capacity is higher, the latter effect can be significant. Failing to account for the impact of trade-induced innovation on welfare may be one of the reasons why Arkolakis et. al. (2010, 2012a, 2012b) find that in a very broad set of models - all of which account for trade–induced competition but ignore trade-induced innovation - welfare gains from trade are limited.

Finally, our theory predicts that a trading's partner ability to innovate is more important in determining the price and quality of its exports than its size. In other words, imports from China can still be cheap, while imports from Switzerland can be very expensive.

The remainder of the paper is structured as follows. In Section 2 we introduce the closed economy version of the model. We describe the construction of the quality ladders and we analyze the impact of market toughness on competition and innovation. We account for the various heterogeneities and we then consider the aggregate implications of the model . In section 3 we present the open economy version and highlight some of the key implications that differ from past work. Section 4 concludes.

2 Closed Economy Model

We formalize our theory by introducing endogenous quality choice in the Melitz-Ottaviano (MO, 2008) model of linear demand preferences and endogenous markups. On the demand side, we augment the demand function to include quality.[10] On the supply-side, we follow Shaked and Sutton (1983, 1987, 1990) and model quality choice as an endogenous sunk cost that firms have to pay.[11]

2.1 Consumers

The preferences of a typical consumer are given by

$$U = q_o^c + \alpha \int_{i\in\Omega} q_i^c di + \alpha \int_{i\in\Omega} z_i di - \frac{1}{2}\gamma \int_{i\in\Omega} (q_i^c)^2 di - \frac{1}{2}\gamma \int_{i\in\Omega} (z_i)^2 di + \gamma \int_{i\in\Omega} (q_i^c z_i) di - \frac{1}{2}\eta \left\{ \int_{i\in\Omega} \left(q_i^c - \frac{1}{2} z_i \right) di \right\}^2 \quad (1)$$

[10] Foster, Haltiwanger, and Syverson (2008) consider an almost identical demand system. The emphasis of their work is to document differences between physical and revenue productivity, and they treat quality (which they call taste shifter) as exogenous.

[11] Kugler and Verhoogen (2011) also discuss a production specification where firms have to pay a sunk cost in order to produce quality, but assume markups are constant. Their objective is to investigate how marginal costs change with quality upgrades as the cost of inputs rises.

where q_o^c and q_i^c represent the individual's consumption of the numeraire good and each variety i, respectively. The quality of each variety is given by z_i. If all firms choose no quality ($z_i \equiv 0$), the preference relation is identical to that in MO. The parameters α and η capture the degree of substitution between each variety and the numeraire, and the parameter γ captures the degree of differentiation among the varieties. All parameters are assumed to be positive. The inverse demand for each variety is given by

$$p_i = \alpha - \gamma q_i^c + \gamma z_i - \eta Q^c \tag{2}$$

where $Q^c = \int\limits_{i \in \Omega} \left(q_i^c - \frac{1}{2} z_i\right) di$. By inverting (2) we obtain the demand for each variety consumed

$$q_i = L q_i^c = \frac{\alpha L}{\eta N + \gamma} - \frac{L}{\gamma} p_i + L z_i + \frac{\eta N L}{\gamma(\eta N + \gamma)} \bar{p} - \frac{1}{2} \frac{\eta N L}{\eta N + \gamma} \bar{z} \tag{3}$$

where N is the number of varieties consumed, L is the size of the country, $\bar{p} = (1/N) \int_{i \in \Omega^*} p_i di$, $\bar{z} = (1/N) \int_{i \in \Omega^*} z_i di$, and $\Omega^* \subset \Omega$ is the subset of varieties consumed. This specified preference specification ensures that the demand for good i is linear in price and quality.

2.2 Firms

As in Melitz (2003) and MO (2008), labor is the only factor of production. Firms pay a fixed market entry fee, f_E, and then they draw a productivity parameter that determines their marginal cost, c. The distribution of c is $G(c)$ with support on $[0, c_m]$. Firms with high marginal cost (low productivity) exit the market. The remaining firms maximize profits by taking the number of firms N, the average price $\bar{p}$, and the average level of quality upgrade $\bar{z}$ as given. Firms also choose the optimal level of quality upgrade. The cost function of a surviving firm i is given by

$$TC_i = c_i q_i + \theta \left(z_i\right)^2 \tag{4}$$

The first term comes straight from MO (2008) and captures the variable cost of production. The second term captures the cost of quality upgrading, which is invariant to output. We assume that the cost of quality upgrading is convex. The parameter θ is a key parameter; it captures country- or industry- specific differences in the ability to innovate or in the technology of innovation. In markets where the ability is high, the cost of innovation θ is low. We can use variation in market size L, to classify countries as small and large, and use variation in the cost of innovation θ, to classify countries as developed and developing, by considering how the ability to innovate differs across these types of countries.[12]

The firms first set the output price as a markup over the marginal cost for a given level of quality upgrade.[13] Let c_D be the marginal cost threshold between the firms that produce and the firms that exit. The firm with marginal cost c_D earns zero profits and its demand $q\left(c_D\right)$ is driven to 0. Following MO, we can express all performance measures as functions of c, c_D, and z.

$$p(c,z) = \frac{1}{2}\left[c_D + c\right] + \frac{\gamma}{2}z \tag{5a}$$

$$q(c,z) = \frac{L}{2\gamma}\left[c_D - c\right] + \frac{L}{2}z \tag{5b}$$

$$r(c,z) = \frac{L}{4\gamma}\left[\left(c_D\right)^2 - c^2\right] + \frac{L}{2}zc_D + \frac{L\gamma}{4}z^2 \tag{5c}$$

$$\pi(c,z) = \frac{L}{4\gamma}\left[c_D - c\right]^2 + \frac{L}{2}z\left[c_D - c\right] + \frac{L\gamma}{4}z^2 - \theta z^2 \tag{5d}$$

Next, the firm chooses the optimal quality upgrade by maximizing the profit function (5d) above. The optimal quality z^* is

$$z^* = \lambda(c_D - c)$$

where $\lambda = L/(4\theta - L\gamma)$. To ensure that z is positive, we assume that $\lambda > 0$ or that $4\theta > L\gamma$.

The relation above is extremely important. Firstly, it states that the optimal product quality is a function of two components: the scope for quality differentiation λ, and the productivity of the firm c, relative to the cost threshold c_D. Secondly, it defines the scope for quality differentiation, which is the slope of the quality ladder. The scope depends on the market size L, the cost of innovation θ, and the degree of differentiation among varieties γ. In larger, more differentiated markets, with lower cost of innovation (higher ability to innovate), the scope for quality differentiation is higher because it is easier for firms to recover the fixed cost

[12] For evidence on the technological gap between developed and developing countries, see Trefler (1993), Hall and Jones (1999), Harrigan (1999) and Acemoglu and Zillibotti (2001).

[13] For a given level of output, the firm chooses price and quality simultaneously in order to minimize the cost function. Given the linearity and separability of the model, we can first solve for the optimal price and then for the optimal level of quality.

of innovation.

The versatility of the model comes from the fact that we can express all economic measures as functions of the cost threshold c_D **and** the scope for quality differentiation λ. While past work only considers how changes in the cost threshold affect the economy, we are able to match a richer set of stylized facts by considering how both c_D and λ respond to economic conditions. It is precisely this property of the model that generates the various heterogeneities and leads to novel theoretical predictions on economic aggregates that we discuss next.

Before we illustrate the quality ladders, we can re-write the performance measures as functions of c and c_D.

$$p(c) = \frac{1}{2}(c_D + c) + \frac{\gamma\lambda}{2}(c_D - c) \tag{6a}$$

$$q(c) = \frac{L}{2\gamma}(1 + \gamma\lambda)(c_D - c) \tag{6b}$$

$$r(c) = \frac{L}{4\gamma}\left[(c_D)^2 - c^2\right] + \frac{L\lambda}{2}\left[c_D - c\right]c_D + \frac{L\gamma\lambda^2}{4}\left[c_D - c\right]^2 \tag{6c}$$

$$\pi(c) = \frac{L}{4\gamma}(1 + \gamma\lambda)\left[c_D - c\right]^2 \tag{6d}$$

$$\mu(c) = \frac{1}{2}(1 + \gamma\lambda)(c_D - c) \tag{6e}$$

In a setting with endogenous quality choice the scope for quality differentiation scales up prices, quantities, markups, and profits. Since in such a setting competition affects both c_D and λ, its impact on the variables above will vary across firms.

2.3 Quality Ladders

The essence of the model is in the construction of the quality ladders and in the dynamics that characterize them. To fix ideas consider two sectors with different scopes for quality differentiation λ: sector 1 with low scope and sector 2 with high. Call sector 1 *homogeneous* and sector 2 *heterogeneous*. Furthermore, consider two firms with identical costs $c1$ and $c2$, respectively, operating in each sector.[14]

[14] While we discuss the intuition of the model in the context of sectors, the same intuition applies if you consider differences in the scope for quality differentiation across countries. Such differences can arise for example, if the market size or if the ability to innovate vary across countries. Size L, helps us differentiate between small versus large economies, and the cost of innovation ϑ, between developing and developed.

The solid line in Figure 2 depicts the quality ladder in the homogeneous (left diagram) and the heterogeneous (right diagram) sector. A ladder represents the optimal quality choice by all operating firms. We highlight three important observations. First, the quality ladder in the heterogeneous sector is steeper, since the scope for quality differentiation is higher. Second, the cost threshold in the heterogeneous sector is lower, which indicates that when the scope for quality differentiation is higher, competition is tougher. Third, a firm endowed with cost c operating in the heterogeneous sector does not necessarily choose a higher level of quality when compared to an identical firm operating in the homogeneous sector. This can be seen from the graph by comparing the quality choice of firms endowed with cost $c1$ and $c2$ across the two sectors. We come back and explain this last observation shortly.

In both industries, more productive firms (move from right to left on the cost axis) face lower marginal costs, choose higher product quality, set higher markups, and are larger. But because markups and marginal costs move in opposite directions, higher productivity does not always translate to higher price. When the scope for quality differentiation is high (i.e. $\lambda > c_D/\gamma$), prices increase in productivity because markups are substantially large. However, when the scope is low, prices fall.

The relation between output prices and productivity across the two sectors is illustrated by the gray line in Figure 2. When the scope for quality differentiation is low (left diagram), prices are negatively correlated with firm productivity, negatively correlated with firm size, and negatively correlated with quality.[15] When the scope is high (right diagram), prices are positively correlated with firm productivity, positively correlated with firm size, and positively correlated with quality. Hence, consistently with empirical evidence, the scope for quality differentiation across sectors determines both the sign and the magnitude of these correlations.

That is, in long quality ladders prices are a good proxy for quality but not in short ladders (Khandelwal 2010). Prices are negatively correlated with firm size in homogeneous sectors (Roberts and Supina 1996, 2000; Syverson 2007; and Foster, Haltiwanger, and Syverson 2008) but they are positively correlated in heterogeneous sectors (Verhoogen 2008; Kugler and Verhoogen 2011; Hallak and Sivadasan 2011; Manova and Zhang 2012; and Iacovone and Javorcik 2012). And the correlation between prices and firm size increases as the scope for quality differentiation rises (Kugler and Verhoogen 2011; Manova and Zhang 2012).

[15]While we do not depict firm size on the same diagram, it is easy to see from equations 7c and 7d that firm size, either measured by revenue or by profit, increases in firm productivity.

Next we show that market toughness affects firms in heterogeneous ways. This is illustrated in Figure 1 discussed in the introduction. Market toughness, which is linked to an increase in market size L and/or an increase in the ability of firms to innovate (decrease in θ) operates through two channels: First, market toughness raises competition and lowers the cost threshold between the firms that operate in the economy and those that exit. Second, market toughness raises the scope for quality differentiation because it makes it easier for firms to recover the fixed cost of innovation associated with quality production. While the former channel is standard in the literature, the latter is a major departure and constitutes an innovation in the model.

In such a setting, as market toughens, the quality ladder pivots clockwise. The cost threshold falls, causing the least productive firms to exit (Area C). From the firms that remain in business, the least productive ones respond to competition by lowering quality, markups, and prices (Area B). In contrast, the more productive ones respond to competition by raising quality, markups, and prices (Area A). Market shares rise for the firms that respond to competition by raising quality-improving innovation , but fall for all others firms.

By endogenizing quality choice, markups, and the scope for quality differentiation, we are therefore able to come up with a unified theory and a supply-side explanation for a rich set of stylized facts related to (i) productivity heterogeneity, (ii) product quality heterogeneity, (iii) markups heterogeneity, (iv) heterogeneity in the response of firms to competition, and (v) heterogeneity in the sign and magnitude of the correlations between prices, productivity, size, and quality.

2.4 Free-Entry Equilibrium

We close the model by considering the free-entry condition. In equilibrium, firms expect zero profits. Therefore

$$f_E = \int_0^{c_d} \pi(c,z)dG(c) = \frac{L}{4\gamma}\int_0^{c_D} \left[c_D - c\right]^2 dG(c) + \frac{L}{4}\lambda\int_0^{c_z} \left[c_D - c\right]^2 dG(c) \tag{7}$$

The condition above determines the cutoff cost c_D. The number of surviving firms can be found from (2). Set $q_i = 0$, then

$$c_D = \frac{1}{\eta N + \gamma}(\alpha\gamma + \eta N \bar{p} - \frac{1}{2}\eta N \gamma \bar{z}) \tag{8}$$

It can be shown that

$$N = \frac{2\gamma}{\eta}\frac{(a - c_D)}{(c_D - \bar{c})} \tag{9}$$

The expression above is identical to the MO model without quality choice. However, in the endogenous quality version of the model the cost threshold is lower because competition is now tougher. And since the cost threshold is lower, the number of firms is higher.

2.5 Aggregate Predictions

Above, we have seen how firms optimize and how they respond to competition. Here we consider how these choices by the firms operating in a setting that is characterized by endogenous markups and endogenous quality affect aggregate variables in the economy. To do so, we parameterize the cost distribution.

Following Melitz (2003) and Melitz and Ottaviano (2008), suppose that the cost draws come from a Pareto distribution given by $G(c) = \left(\frac{c}{c_M}\right)^k$, $c \in [0, c_M]$. The cost threshold in the closed economy is

$$c_D = \left[\frac{\gamma\phi}{(1+\gamma\lambda)L}\right]^{\frac{1}{k+2}} \tag{10}$$

where $\phi = 2c_m^k(k+1))(k+2)f_E$. This cost threshold is a measure of competition within the economy. The lower c_D is, the more competition exists. As the scope for quality differentiation rises, the cost threshold falls.

The average marginal cost in the economy is

$$\bar{c} = \frac{kc_D}{k+1} \tag{11}$$

The higher the average marginal cost is, the lower the average productivity. Since country size and the scope for quality differentiation both affect the cost threshold c_D, the model allows for the possibility that small countries with high innovation capacity will be more productive than large countries with low innovation capacity. The average quality in the economy is

$$\bar{z} = \lambda\left(\frac{c_D}{k+1}\right) \tag{12}$$

Given average productivity $\bar{c}$ and the cost threshold c_D, we can use (9) to solve for the number of firms.

$$N = \frac{2(k+1)\gamma}{n} \frac{(\alpha - c_D)}{c_D} \tag{13}$$

The average (unweighted) price in the economy is given by

$$\bar{p} = \left(\frac{2k + 1 + \gamma\lambda}{2k+2} \right) c_D \tag{14}$$

Average markups are

$$\bar{\mu} = \frac{1}{2}(1 + \gamma\lambda) \frac{1}{k+1} c_D \tag{15}$$

Average profits are given by

$$\bar{\pi} = f_E \left(\frac{c_M}{c_D} \right)^k \tag{16}$$

Finally, welfare is

$$U = 1 + \frac{1}{2\eta}(\alpha - c_D) \left[\alpha - \frac{k+1}{k+2} c_D \right] + \gamma\lambda(\alpha - c_D) \left[\frac{12\alpha - 2(c_D - 3\alpha)k - (2 + 3\gamma\lambda)c_D}{2(k+2)\eta} \right]$$

Aggregate measures of the economy are now functions of the cost threshold **and** the scope for quality differentiation. Competition affects the aggregate measures through two channels: it lowers the cost threshold and it raises the scope for quality differentiation. Because through the first channel competition suppresses quality, markups, and prices, while through the second it raises them, the total effect of competition on these measures will be ambiguous.

We illustrate that there is a U-shape response of prices, and markups to competition by considering how two economies identical in all aspects but in the cost of innovation θ, respond to an increase in market size. We use the increase in market size as proxy for competition. One economy, call it *developing*, has high cost of innovation, and the other, call it *developed*, has low cost. Figure 3 plots the cost threshold, the number of firms, the scope for quality differentiation, the average quality, price, and markups,and consumer welfare in each economy as market size increases. A solid black line represents the develop economy and a dash black line the developing. For comparison purposes, we also consider an economy where there is no scope for quality differentiation, such as the one modeled in MO. That economy is represented by a gray line.

As the market size increases, more firms enter the market and competition becomes tougher. Average productivity rises. In the developed economy, competition is much tougher, which results in a lower cost threshold, higher productivity (lower average cost), and a higher number of firms at each level of the competition.

As the level of competition increases, the scope for quality differentiation rises and so does average quality. In the developed economy the average quality of goods produced (and consumed) is higher than in the developing economy. This observation is known as the Linder hypothesis. While past work offers a demand-side explanation to the hypothesis based on the assumption that consumers in developed countries have higher preferences for quality goods (Verhoogen 2008; Linder 1961; Hallak 2008, Fajberbaum et. al. 2011), we show that supply-side effects based on differences in the scope for quality differentiation across countries offer an alternative explanation.

Next, we consider how average markups and average price respond to competition. Initially, both average markups and price fall. However, as competition increases further and product quality rises, average markups rise. Eventually, the increase in average markups pulls up average price. The U-shape respond of average markups and price to competition is a novel prediction of this model.[16]

We conclude this section with a very important observation. Welfare increases substantially for the developed country as competition rises. This may come as a surprise. Welfare gains are typically associated with lower markups resulting from increased competition or trade. Yet, in the developed country average markups and price eventually rise, so intuitively we should expect welfare to fall. What happens here is that consumers like to pay low prices but they also like quality. And although prices and markups start to rise in the developed country after some level of competition, quality rises much faster, which ends up raising consumer welfare substantially. What the model reveals is that ignoring to account for the fact that consumers like quality understates welfare gains associated with competition and trade, and that this bias is larger for more developed countries.[17] Put differently, developed countries that are characterized by a higher

[16] In the appendix we show that the variance of the firm performance measures is also a function of the cost threshold and the scope for quality differentiation. The response of price and markup dispersions to competition also exhibits a U-shape behavior.

[17] For example, in Arkolakis et. al. (2010, 2012a, 2012b) the authors show that in a very broad class of trade models, welfare gains from trade are limited. However, in all the models considered, competition does not affect the scope for quality

scope for quality differentiation stand to gain more from increases in market and competition- as happens in the case of trade, for example – whereas developing/poor countries gain little.

3 Open Economy Model

3.1 Consumers

We extend the closed economy model to a two-country setting. There is a home (H) and a foreign (F) country. Each country is endowed with L^H and L^F workers (consumers). For simplicity, assume that consumers have identical preferences across the two countries and that there is no labor mobility. As in the closed-economy setting, the demand for good i in country l ($l = \{H, F\}$) is given by

$$q_i^l = L^l q_i^c = \frac{\alpha L^l}{\eta N^l + \gamma} - \frac{L^l}{\gamma} p_i^l + L^l z_i + \frac{\eta N^l L^l}{\gamma(\eta N^l + \gamma)} \bar{p}^l - \frac{1}{2} \frac{\eta N^l L^l}{\eta N^l + \gamma} \bar{z}^l \tag{17}$$

where p_i^l and q_i^l is the price of good i and quantity demanded in country l, respectively. Average price and quality in country l are given by $\bar{p}^l$ and $\bar{z}^l$. There are N^l firms selling in country l. These are both domestic firms and foreign exporters.

3.2 Firms:

As in the closed economy setting, a firm chooses whether or not to produce, and the level of quality for each market. The firm now has the option to export. There is a positive cost to exporting, so not all firms choose to export. A firm that exports sets different levels of quality and different prices for the domestic and the foreign markets.[18]. The delivery cost of a unit with cost c to country l is $\tau^l c$.[19] Let $p^l(c)$ and $q^l(c)$ be the domestic level of the profit maximizing price and quantity, respectively. The operating profits from domestic and foreign sales are given by

differentiation. Failing to account for this channel and for the fact that competition can raise average quality, may offer an explanation to the suprising results in their work.

[18] For empirical evidence on firms setting different levels of quality across export destinations, see Manova and Zhang (2012).

[19] An alternative specification is to consider a per-unit export cost, where the cost of delivering a unit with cost c to country l is $\tau^l + c$. While we do not report this specification here, the solution is available by the author upon request.

$$\pi^l_D(c,z) = \left[p^l_D(c,z) - c\right] q^l_D(c,z) \tag{18a}$$

$$\pi^l_X(c,z) = \left[p^l_X(c,z) - \tau^h c\right] q^l_X(c,z) \tag{18b}$$

The profit maximizing prices and quantities must satisfy

$$q^l_D(c,z) = \frac{L^l}{\gamma}\left[p^l_D(c,z) - c\right] \tag{19a}$$

$$q^l_X(c,z) = \frac{L^h}{\gamma}\left[p^l_x(c,z) - \tau^h c\right] \tag{19b}$$

The production cutoffs are defined as

$$c^l_D = \sup\left\{\pi^l_D(c) > 0\right\} = p^l \tag{20a}$$

$$c^l_X = \sup\left\{\pi^l_X(c) > 0\right\} = \frac{p^h}{\tau^h} \tag{20b}$$

Combining the cutoffs conditions for the two countries, it is easy to show that $c^h_X = c^l_D/\tau^l$. The optimal price and quantity for the domestic and the foreign market can now be expressed as functions of the cutoff cost thresholds.

$$p^l_D(c,z) = \frac{1}{2}(c^l_D + c) + \frac{\gamma}{2}z^l_D \tag{21a}$$

$$p^l_X(c,z) = \frac{\tau^h}{2}(c^l_X + c) + \frac{\gamma}{2}z^l_X \tag{21b}$$

$$q^l_D(c,z) = \frac{L^l}{2\gamma}(c^l_D - c) + \frac{L^l}{2}z^l_D \tag{21c}$$

$$q^l_X(c,z) = \frac{L^h}{2\gamma}\tau^h(c^l_X - c) + \frac{L^h}{2}z^l_X \tag{21d}$$

Given prices and quantities, operating profits for the firm in each market are given by

$$\pi_D^l(c,z) = \frac{L^l}{4\gamma}(c_D^l - c)^2 + \frac{L^l}{2}(z_D^l)(c_D^l - c) + \frac{\gamma L^l}{4}(z_D^l)^2 - \theta(z_D^l)^2 \tag{22a}$$

$$\pi_x^l(c,z) = \frac{L^h}{4\gamma}(\tau^h)^2(c_X^l - c)^2 + \frac{L^h}{2}\tau^h(z_X^l)(c_X^l - c) + \frac{\gamma L^h}{4}(z_X^l)^2 - \theta(z_X^l)^2 \tag{22b}$$

The optimal levels of product quality z^* for the domestic and the foreign market are given by

$$z_D^*(c) = \lambda_D^l(c_D^l - c) \tag{23}$$

$$z_X^*(c) = \lambda_X^l(\tau^h)(c_X^l - c) \tag{24}$$

where $\lambda_D^l = L^l/(4\theta^l - L^l\gamma)$, and $\lambda_X^l = L^h/(4\theta^l - L^h\gamma)$ are the scopes for quality differentiation in the domestic and in the foreign markets, from the point of view of a firm operating in country l, which faces a cost of innovation θ^l. To ensure that all qualities are positive, we assume that all λ's are positive.

We complete the model by substituting the optimal value of z^* into (21a) and (22a).

$$p_D^l(c) = \frac{1}{2}(c_D^l + c) + \frac{1}{2}\gamma\lambda_D^l(c_D^l - c) \tag{25}$$

$$p_X^l(c) = \frac{1}{2}(\tau^h)(c_X^l + c) + \frac{1}{2}(\tau^h)\gamma\lambda_X^l(c_X^l - c) \tag{26}$$

$$q_D^l(c) = \frac{L^l}{2\gamma}(1 + \gamma\lambda_D^l)(c_D^l - c) \tag{27}$$

$$q_X^l(c) = \frac{L^h}{2\gamma}(\tau^h)(1 + \gamma\lambda_X^l)(c_X^l - c) \tag{28}$$

$$\pi_D^l(c) = \frac{L^l}{4\gamma}(1 + \gamma\lambda_D^l)(c_D^l - c)^2 \tag{29}$$

$$\pi_X^l(c) = \frac{L^h}{4\gamma}(\tau^h)^2(1 + \gamma\lambda_X^l)(c_X^l - c)^2 \tag{30}$$

3.3 Free-Entry Condition

At equilibrium, the expected profit of a firm is 0. Therefore

$$f_E = \int_0^{c_d^l} \pi_D^l(c)dG(c) + \int_0^{c_x^l} \pi_X^l(c)dG(c) \tag{31}$$

We assume that cost draws come from the same Pareto parameterization as in the closed economy model. Given the parameterization, the expressions for the profits in the domestic and foreign markets, and the fact that $c_X^h = c_D^l/\tau^l$, we can now re-write the free-entry condition as

$$L^l(1+\gamma\lambda_D^l)(c_D^l)^{k+2} + L^h(1+\gamma\lambda_X^l)(c_D^h)^{k+2}\rho^h = \gamma\varphi \tag{32}$$

where $\phi = 2c_m^k(k+1))(k+2)f_E$, $\rho^h = (\tau^h)^{-k}$. We can write a similar condition for the foreign country. This yields a system of two equations and two unknowns which we solve for c_D^l and c_D^h.

$$c_D^l = \left\{ \frac{\gamma\varphi}{L^l} \left[\frac{(1+\gamma\lambda_D^h) - \rho^h(1+\gamma\lambda_X^l)}{(1+\gamma\lambda_D^l)(1+\gamma\lambda_D^h) + \rho^l\rho^h(1+\gamma\lambda_X^l)(1+\gamma\lambda_X^h)} \right] \right\}^{1/(k+2)} \tag{33}$$

Country characteristics of both trading partners, along with the trade barriers, determine the cost threshold.

We can now express the aggregate measures in the economy as functions of the cost threshold c_D^l. As in the case of the closed economy, these measures will also be functions of the scope for quality differentiation in each market, from the perspective of the domestic and the foreign firms facing θ^l and θ^h costs of innovation, respectively.

We proceed in two steps. First, we compute the average price, quality, and markups for the domestically produced and for the foreign produced bundles of goods consumed at home. Then, we aggregate across the two bundles to obtain the average price, quality, and markups for all goods, domestic and foreign, consumed at home.

Let N_D^l and N_X^h represent the domestic and foreign firms selling in the domestic country, respectively, and $N^l = N_D^l + N_X^h$ the total number of firms servicing the domestic market. The average prices of domestic, of foreign, and of all goods consumed in the domestic market are given by:

$$\bar{p}_D^l = \left[\frac{2k+1+\gamma\lambda_D^l}{2k+2}\right] c_D^l \tag{34}$$

$$\bar{p}_X^h = \left[\frac{k+1+\gamma\lambda_X^h}{2k+2}\right] c_D^l \tag{35}$$

$$\bar{p}_D = \left[\frac{2k+1+\gamma\overline{\lambda}_D}{2k+2}\right] c_D^l \tag{36}$$

where $\overline{\lambda}_D = (N_D^l \lambda_D^l + N_X^h \lambda_X^h)/N^l$ is the (weighted) average scope for quality differentiation of all N^l firms servicing the domestic market. Equations (35) and (36) show that that the price distribution in country l of domestic firms and exporters producing in h and servicing the domestic market will be the same if and only if $\theta^l = \theta^h$.[20] But in general, the two price distributions will differ. More specifically, the basket of imported goods from h will cost more if the ability to innovate in h is higher than in l, i.e. if $\theta^l > \theta^h$. It will also be of higher quality as we show next. The average price $\bar{p}_D$ of the consumption basket in the domestic market will now be a function of the (weighted) average scope for quality differentiation between the N_D^l domestic and N_X^h foreign firms servicing the domestic market. In a sense, $\overline{\lambda}_D$ represents the *effective* scope for quality differentiation in the domestic market. What is nice here, is that we can now express all aggregate measures as functions of the effective scope, and then consider how trade openness affects the economy through its impact on $\overline{\lambda}_D$. We elaborate more on this next, but first we complete the presentation of all aggregate measures.

Average quality and markups are given by:

$$\overline{z}_D^l = \lambda_D^l \left[\frac{1}{k+1} \right] c_D^l \tag{37}$$

$$\overline{z}_X^h = \lambda_X^h \left[\frac{1}{k+1} \right] c_D^l \tag{38}$$

$$\overline{z}_D = \overline{\lambda}_D \left[\frac{1}{k+1} \right] c_D^l \tag{39}$$

and

$$\overline{\mu}_D^l = \frac{1}{2}(1 + \gamma \lambda_D^l) \left[\frac{1}{k+1} \right] c_D^l \tag{40}$$

$$\overline{\mu}_X^h = \frac{1}{2}(1 + \gamma \lambda_X^h) \left[\frac{1}{k+1} \right] c_D^l \tag{41}$$

$$\overline{\mu}_D = \frac{1}{2}(1 + \gamma \overline{\lambda}_D) \left[\frac{1}{k+1} \right] c_D^l \tag{42}$$

The total number of firms, both domestic and foreign, servicing the domestic market is

[20] Since $\lambda_D^l = L^l/(4\theta^l - L^l)$ and $\lambda_X^h = L^l/(4\theta^h - L^l)$, the two measures will be the same if and only if $\theta^l = \theta^h$.

$$N^l = \frac{2(k+1)\gamma}{n} \frac{(\alpha - c_D^l)}{c_D^l} \tag{43}$$

and total welfare is given by

$$U^l = 1 + \frac{1}{2\eta}(\alpha - c_D^l)\left[\alpha - \frac{k+1}{k+2}c_D^l\right] + \gamma\overline{\lambda}_D(\alpha - c_D^l)\left[\frac{12\alpha - 2(c_D^l - 3\alpha)k - (2 + 3\gamma\overline{\lambda}_D)c_D^l}{2(k+2)\eta}\right] \tag{44}$$

With the open economy model fully specified, we proceed to discuss some of the key implications of the theory. Since the impact of trade in a setting with heterogeneous firms and endogenous quality choice has been thoroughly analyzed in the past (see Melitz and Ottaviano 2008), we highlight the implications that are unique in the context of this theory.

The transition from autarky to trade is equivalent to an increase in market size and operates through two channels: it induces more competition and it affects the scope for quality differentiation.[21] Hence, the intuition from our earlier discussion on the impact of market toughness on aggregate measures in a closed economy setting also applies in the discussion of trade openness.

Trade-induced competition suppresses quality, price, and markups, while trade-induced innovation raises quality, price, and markups. How these aggregate measures respond to trade openness now depends on how similar or dissimilar the trading partners are with respect to their innovation capacities. As seen from equations (37), (40), and (43), trading with a developed country raises average quality, price, and markups because it raises the effective scope for quality differentiation of all firms servicing the domestic market. Trading with a developing country lowers the effective scope and lowers these measures. For trading partners that are similar in their innovation capacity, which is proxy by the inverse of θ^l and θ^h, the changes in these measures will not be substantial since $\overline{\lambda}_D$ will not differ much from λ_D^l. However, for countries that are farther apart in their innovation capacities, the change in the effective scope will be substantial, and so will the change in the aggregate measures.

Another related, yet important implication of the model is that imported goods from developed countries will be of higher quality and will cost more than imported goods from developing countries. To see this, consider what equation (36) implies for the average price of a bundle of imported goods originating from

[21] It becomes identical to an increase in market size if no trade barriers are present.

country h relative to the price of a bundle of imported goods from country i. Foreign firms in both countries will be subject to the same domestic cost threshold c_D^l and the same market size L^l.[22] Therefore, what will drive differences in the price of the two bundles of imported goods is only differences in the innovation capacities across the two exporters, namely θ^h and θ^i. The country with the highest innovation capacity will export a more expensive bundle of goods. A similar argument based on equation (39) shows that the export bundle of the country with higher innovation capacity will also be of higher quality. And if we were to generalize this to N countries exporting to l, then we would see that differences in the innovation capacity across countries are sufficient to explain differences in the average quality and price of each bundle of exported goods. The fact that innovation capacity of the exporter is more important than its size when explaining patterns of trade is emphasized by Schott (2004) who documented that China's exports to the US are cheap and of low quality.

4 Conclusion

We presented a simple and tractable trade model of heterogeneous firms, endogenous quality choice, and endogenous markups. A key feature of the model is that all firm performance measures and all economic aggregates can be written as functions of the cost threshold and the scope for quality differentiation. By considering how changes in economic conditions affect both the threshold and the scope we come up with a very rich and empirically relevant theory.

Indeed, we provide a supply-side explanation for a very rich set of facts related to (i) productivity heterogeneity, (ii) product quality heterogeneity, (iii) markups heterogeneity, (iv) heterogeneity in the response of firms to competition, and (v) heterogeneity in the sign and magnitude of the correlations between various firm performance measures. We also make some novel theoretical predictions about aggregate economic measures.

Besides matching firm behavior and patterns of trade, there are several other areas where we think such a theory is relevant. First, the theory can provide guidance to studies on international price differences,(e.g.

[22] Although in this case c_D^l will be different from the solution in (34) since there are more than one countries exporting to l, all exporters will still face the same domestic cost threshold.

Feenstra and Romalis [2012]; Feenstra and Weinstein [2012]) by providing a framework that allows both markups and quality to adjust in response to changes in economic conditions. Second, the theory can be relevant for studies that consider how trade liberalization affects the wage gap between high-skilled and low-skilled workers. An extension of the paper where quantity (the first term of the cost function) is produced from low-skilled workers, while quality (the second term) is produced from high-skilled would provide a good framework for such studies since it accounts for trade-induced competitionbut also for trade-induced innovation.

References

[1] Acemoglu, Daron, and Fabrizio Zilibotti, "Productivity Differences," Quarterly Journal of Economics, 116 (2001), 563– 606.

[2] Aghion, Philippe and Peter Howitt, Christopher Harris, and John Vickers, "Competition and Growth with Step-by-Step innovation: An example," European Economic Review, 41 (1997), 771–782.

[3] Aghion, Philippe, Peter Howitt, and John Vickers, "Competition, Imitation and Growth with Step-by-Step Innovation," Review of Economic Studies, 68 (2001), 467–492.

[4] Aghion, Philippe, Nick Bloom, Richard Blundell, Rachel Griffith, and Peter Howitt, "Competition and Innovation: An Inverted-U Relationship," The Quarterly Journal of Economics,120 (2005), 701–728.

[5] Amiti, Mary, and Amit Khandelwal, "Import Competition and Quality Upgrading," The Review of Economics and Statistics, forthcoming

[6] Antoniades, Alexis, and Nicola Zaniboni, "Retailer Pass-Through and Its Determinants Using Scanner Data," Working Paper 2012

[7] Arkolakis, Costas, Arnaud Costinot, and Andres Rodriguez-Clare, "Gains From Trade under Monopolistic Competition: A Simple Example with Translog Expenditure Functions and Pareto Distributions of Firm-Level Productivity," 2010. Yale Unviersity working paper.

[8] ———, "New Trade Models, Same Old Gains?," American Economic Review, 102 (2012a), 94-130.

[9] Arkolakis, Costas, Arnaud Costinot, Dave Donaldson, and Andres Rodriguez-Clare, "The Elusive Pro-Competitive Effects of Trade," March (2012b). MIT working paper.

[10] Auer, Raphael, and Philip Saure, "Spatial Competition in Quality," Mimeo, Swiss National Bank, 2009.

[11] Atkeson, Andrew, and Ariel Burnstein, "Pricing-to-Market, Trade Costs, and International Relative Prices," American Economic Review, 98 (2008), 1998-2031

[12] Baldwin, Robert. and Harrigan, James, "Zeros, Quality and Space: Trade Theory and Trade Evidence", American Economic Journal: Microeconomics, 3 (2011), 60–88.

[13] Baldwin, Richard and Tadashi Ito, "Quality Competition Versus Price Competition Goods: An Empirical Classification," Journal of Economic Integration , 26 (2011), 110-135

[14] Bastos, Paulo, and Joana Silva, "The Quality of a Firm's Exports: Where You Export to Matters," Journal of International Economics, 82 (2010), 99–111.

[15] Berman, Nicolas, Philippe Martin, and Thierry Mayer, "How do Different Exporters React to Exchange Rate Changes?" The Quarterly Journal of Economics, 127 (2012), 437-492.

[16] Bernard, Andrew, Jonathan Eaton, Bradford Jensen, and Samuel Kortum, "Plants and Productivity in International Trade," American Economic Review, 93 (2003), 1268–1290.

[17] Bernard, Andrew, Bradford Jensen, and Peter Schott, "Trade Costs, Firms and Productivity," Journal of Monetary Economics, 53 (2006), 917–937.

[18] ———, "Importers, Exporters, and Multinationals: A Portrait of Firms in the U.S. that Trade Goods," in Producer Dynamics: New Evidence from Micro Data, Timothy Dunne, Bradford Jensen, and Mark Roberts, eds. (Chicago: University of ChicagoPress, 2009).

[19] Florin O. Bilbiie, Fabio Ghironi, and Marc Melitz, "Endogenous Entry, Product Variety, and Business Cycles," Journal of Political Economy, 120 (2012), 304-345.

[20] Bloom, Nicholas, Mirko Draca, and John Van Reenen, "Trade Induced Technical Change? The Impact of Chinese Imports on IT and Innovation," NBER Working Paper # 16717 (2011)

[21] Blundell, Richard, Rachel Griffith, and John van Reenen, "Market Share, Market Value and Innovation in a Panel of British Manufacturing Firms," Review of Economic Studies, 66 (1999), 529–54.

[22] Burnstein, Ariel and Nir Jaimovich, "Understanding Movements in Aggregate and Product-level Real Exchange Rates," Working Paper (2012)

[23] Bustos, Paula, "Trade Liberalization, Exports and Technology Upgrading: Evidence on the Impact of MERCOSUR on Argentinean Firms", American Economic Review, 101 (2011), 304–340.

[24] Crozet, Matthieu, Keith Head, and Thierry Mayer, "Quality Sorting and Trade: Firm-level Evidence for French Wine," CEPR discussion paper no. 7295, (2009).

[25] De Loecker, Jan, and Frederic Warzynski, "Markups and Firm-Level Export Status," American Economic Review,102 (2012), 2437–2471

[26] Eaton, Jonathan, Samuel Kortum, and Francis Kramarz, "Dissecting Trade: Firms, Industries, and Export Destinations," American Economic Review Papers and Proceedings, 94 (2004), 150–154.

[27] ———, "An Anatomy of International Trade: Evidence from French Firms," Econometrica, 79 (2008), 1453–1498.

[28] Edmunds, Chris, Veldkamp, Laura, "Income dispersion, asymmetric information and fluctuations in market efficiency," NYU Working Paper (2006).

[29] Fajgelaum, Pablo, Gene Grossman, and Elhanan Helpman, "Income Distribution, Product Quality, and International Trade" Journal of Political Economy, 119 (2011), 721-765

[30] Fitzgerald, Doireann and Stephanie Haller, "Pricing-to-Market: Evidence From Plant-Level Prices," Working Paper (2012)

[31] Foster, Lucia, Haltiwanger John, and Chad Syverson,. (2008), "Reallocation, Firm Turnover and Efficiency: Selection on Productivity or Profitability?", American Economic Review, 98, 394–425.

[32] Gali, Jordi, "Monopolistic Competition, Business Cycles, and the Composition of Aggregate Demand," Journal of Economic Theory, 63 (1994), 73–96

[33] Gopinath, Gita, Oleg Itskhoki, and Roberto Rigobon, "Currency Choice and Exchange Rate Pass-through," American Economic Review, 100 (2010), 304–336.

[34] Hall, Robert E., and Charles I. Jones, "Why Do Some Countries Produce So Much More Output per Worker than Others?" Quarterly Journal of Economics, 114 (1999), 83–116.

[35] Hallak, Juan-Carlos, "Product Quality and the Direction of Trade," Journal of International Economics, 68 (2006), 238–265.

[36] ———, "A Product-Quality View of the Linder Hypothesis", The Review of Economics and Statistics, 92 (2010), 453-466

[37] Hallak, Juan-Carlos, and Peter Schott, "Estimating Cross-Country Differences in Product Quality," Quarterly Journal of Economics, 126 (2011), 417–474.

[38] Hallak, Juan-Carlos, and Jagadeesh Sivadasan, "Firms' Exporting Behavior under Quality Constraints," Research Seminar in International Economics No. 628 (2011)

[39] Harrigan, James, "Estimation of Cross-Country Differences in Industry Production Functions," Journal of International Economics, 47 (1999), 267–294.

[40] Hornstein Andreas, "Monopolistic Competition, Increasing Returns to Scale, and the Importance of Productivity Shocks," Journal of Monetary Economics, 31 (1993), 299–316

[41] Hummels, David, and Peter Klenow, "The Variety and Quality of a Nation's Exports," American Economic Review, 95 (2005), 704–723.

[42] Iacovone, Leonardo, "The Better You Are The Stronger It Makes You: Evidence on the Asymmetric Impact of Liberalization," Journal of Development Economics, 99 (2012), 474–485

[43] Iacovone, Leonardo, and Beata Javorcik, "Getting Ready: Preparing for Exporting," Mimeo, University of Oxford, 2012.

[44] Johnson, Robert, "Trade and Prices with Heterogeneous Firms", Journal of International Economics, 86 (2012), Pages 43–56

[45] Khandelwal, Amit, "The Long and Short (of) Quality Ladders," Review of Economic Studies, 77 (2010), 1450–1476.

[46] Kneller, Richard, and Zhihong Yu, "Quality Selection, Chinese Exports and Theories of Heterogeneous Firm Trade,"Mimeo, University of Nottingham, 2008.

[47] Kugler, Maurice, and Eric Verhoogen, "Prices, Plant Size, and Product Quality," Review of Economic Studies,forthcoming, 20 (2011), 1-33.

[48] Lilieva, Alla, and Daniel Trefler, “Improved Access to Foreign Markets Raises Plant-Level Productivity ... for Some Plants," Quarterly Journal of Economics, 125 (2010), 1051–1099.

[49] Linder, Staffan Burenstam, "An Essay on Trade and Transformation," Stockholm: Almqvist and Wiksell, (1961)

[50] Manova, Kalina, and Zhiwei Zhang, “Export Prices Across Firms and Destinations, Quarterly Journal of Economics, 127 (2012), 379-436

[51] Melitz, Marc, “The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity," Econometrica, 71 (2003), 1695–1725.

[52] Melitz, Marc, and Gianmarco Ottaviano, “Market Size, Trade, and Productivity," Review of Economic Studies, 75 (2008), 295–316.

[53] Roberts, Mark, and Supina, Dylan, “Output Price, Markups, and Producer Size’, European Economic Review, 40, 909–921.

[54] ———, “Output Price and Markup Dispersion in Micro Data: The Roles of Producer Heterogeneity and Noise", in Baye, M. R. (ed.) Advances in Applied Microeconomics, Vol. 9 (Amsterdam: JAI) (2000), 1–36.

[55] Rotemberg, Julio, and Woodford, Michael, "Markups and the businesscycle," NBER Macroeconomics Annual, (1991), 63–129.

[56] ———, "Oligopolistic Pricing and the Effects of Aggregate Demand on Economic Activity," Journal of Political Economy, 100 (1992), 1153–1207

[57] ———, "Dynamic General Equilibrium Models with Imperfectly Competitive Product Markets," T.F. Cooley (Ed.), Frontiers of BusinessCycle Research, Princeton University Press, Princeton (1995), 243–293

[58] ———, "Imperfect Competition and the Effects of Energy Price Increases on Economic Activity," Journal of Money Credit and Banking, 28 (1996), 549–577

[59] and M. Woodford (eds.) The Handbook of Macroeconomics. Amsterdam: North-Holland.

[60] Schott, Peter, "Across-Product versus Within-Product Specialization in International Trade," Quarterly Journal of Economics, 119 (2004), 647–678.

[61] Schor, Adriana, "Heterogeneous Productivity Response to Tariff Reduction. Evidence from Brazilian Manufacturing Firms," Journal of Development Economics, 75 (2004), 373-396.

[62] Shaked, Avner, and John Sutton "Natural Monopolies," Econometrica, 51 (1983), 1469-1483.

[63] ————, "Product Differentiation and Industrial Structure," Journal of Industrial Economics, 36 (1987), 131-146

[64] ————, "Multiproduct Firms and Market Structure," Rand Journal of Economics, 21, (1990), 45-62

[65] Sutton, John, "Endogenous Sunk Costs and the Structure of Advertising Intensive Industries", European Economic Review, 33 (1989), 335-344

[66] ————, "Sunk Costs and Market Structure," Cambridge, MA, MIT Press (1991)

[67] Syverson, Chad, "Prices, Spatial Competition, and Heterogeneous Producers: An Empirical Test", Journal of Industrial Economics, 55 (2007), 197–222.

[68] Teshima, Ken, "Import Competition and Innovation at the Plant Level: Evidence from Mexico", Working Paper (2010)

[69] Trefler, Daniel, "International Factor Price Differences: Leontief Was Right!" Journal of Political Economy, 101 (1993), 961–987.

[70] Verhoogen, Eric, "Trade, Quality Upgrading andWage Inequality in theMexican ManufacturingSector," Quarterly Journal of Economics, 123 (2008), 489–530.

A Variance of firm performance measures

Let $\sigma_y^2 = \frac{1}{G(c_D)} \int\limits_0^{c_D} [y(c) - \overline{y}]^2 \, dG(c)$ denote the variance of a firm performance measure y(c). Then,

$$\sigma_y^2 = \frac{1}{4}(-1 + \gamma\lambda)\sigma_c^2 \tag{A.1}$$

$$\sigma_\mu^2 = \frac{1}{4}(1 + \gamma\lambda)\sigma_c^2 \tag{A.2}$$

$$\sigma_q^2 = \frac{L^2}{4\gamma^2}(1 + \gamma\lambda)^2\sigma_c^2 \tag{A.3}$$

$$\sigma_r^2 = \frac{L^2}{16}(1 + \gamma\lambda)\sigma_c^2\psi \tag{A.4}$$

where $\sigma_c^2 = \left[k/((k+1)^2(k+2))\right] c_D$ and $\psi = (3 + 5k^2 + 3 + 5k^2 + 7k + 4k^2\gamma\lambda + 5k\gamma^2\lambda^2 + k^3 + 14k\gamma\lambda + 11\gamma^2\lambda^2 + 10\gamma^2\lambda^2)/(\gamma^2(1+k)^2(k+3)) > 0$.

Figure 2 – Quality Ladders

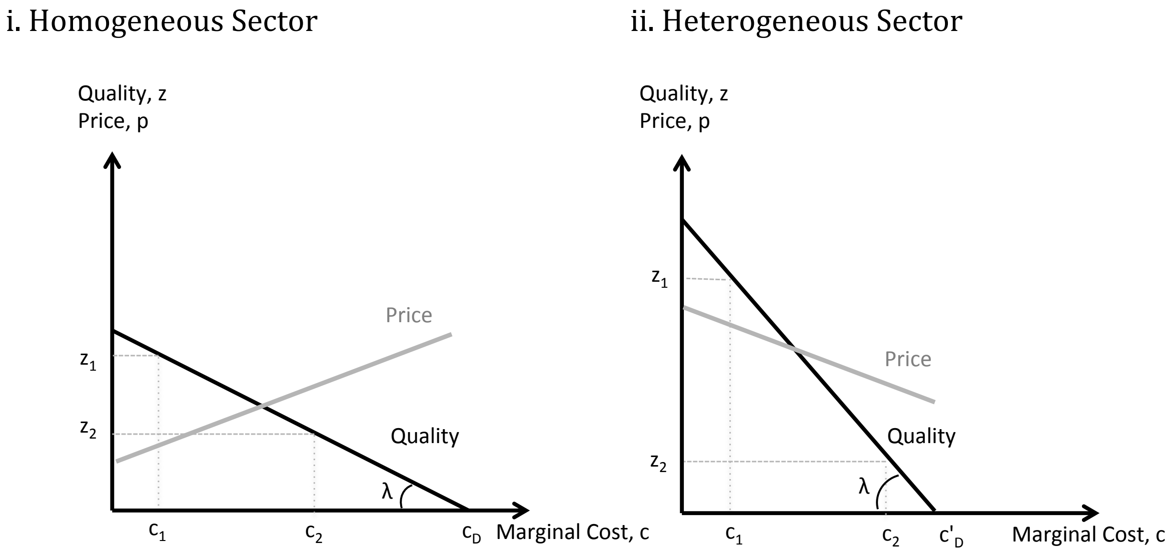
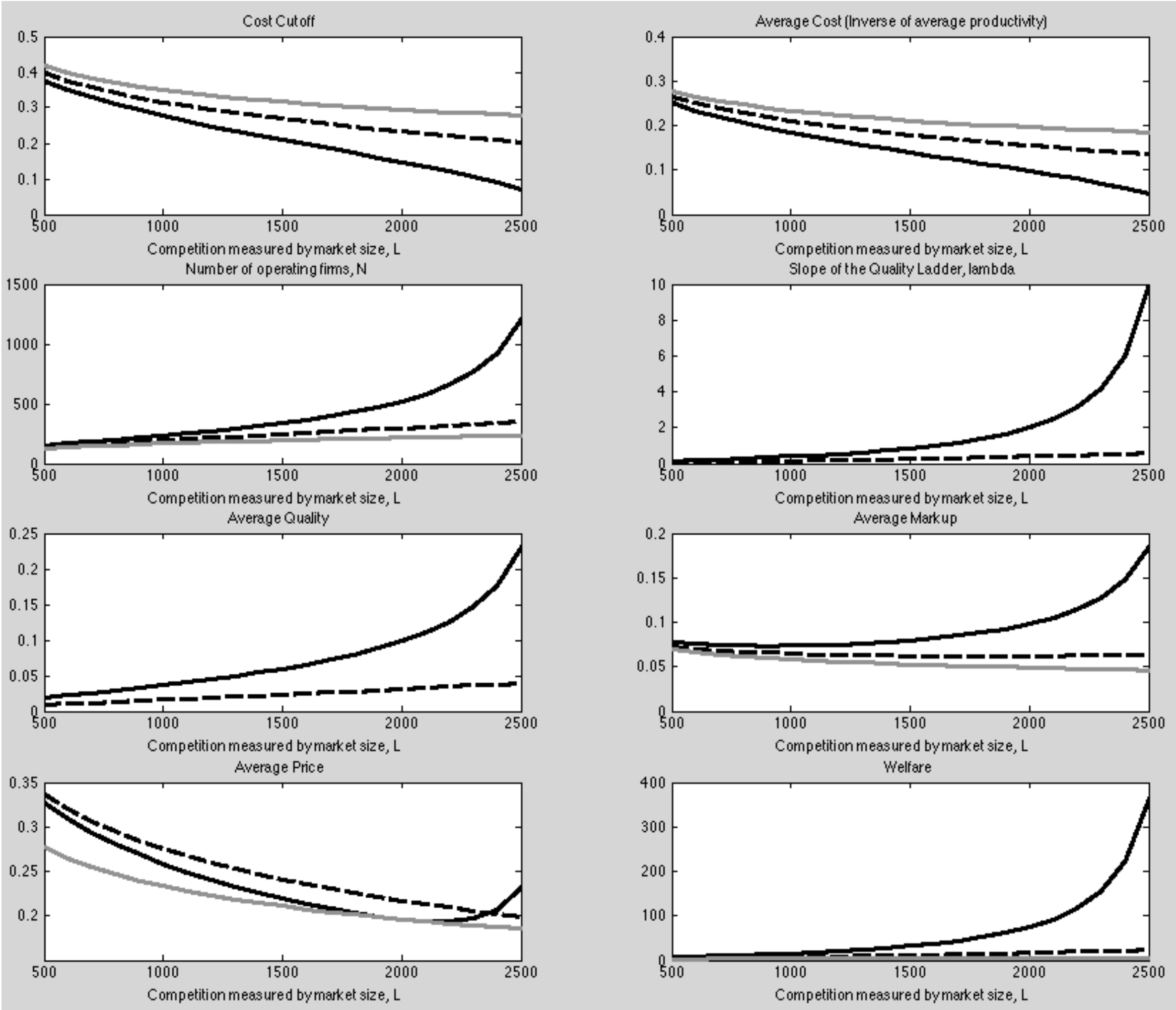


Figure 3 – Aggregate Variables and Market Competition



— Melitz-Ottaviano
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