VERTI-ZONTAL DIFFERENTIATION IN EXPORT MARKETS

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Many trade models of monopolistic competition identify cost efficiency as the main determinant of firm performance in export markets. To date, the analysis of demand factors has received much less attention. We propose a new model where consumer preferences are asymmetric across varieties and heterogeneous across countries. The model generates new predictions and allows for an identification of horizontal differentiation (taste) clearly distinguished from vertical differentiation (quality). Data patterns observed in Belgian firm-product level exports by destination are congruent with the predictions and seem to warrant a richer modelling of consumer demand.

Non-technical summary

Most models of monopolistic competition treat productive efficiency as the only determinant of firm performance and dedicate much less attention to the analysis of demand factors.

In this paper we propose a new model to put consumer preferences more central in trade theory and to relax the typical symmetric demand assumption. We enrich a "love-for-variety" model such that the demand for each firm-product in every export market is unique and characterized by a unique level of horizontal and vertical product differentiation.

The recent availability of trade data at firm-product-country level calls for a new generation of models that are able to rationalize the large variability observed in micro-level data. The verti-zontal model generates a new set of predictions closer to existing trade patterns. The model accounts for firm-product-country export variation that cannot be explained by income differences or market size differences. The "missing" trade in the data is rationalized through consumer taste differences which interact differently with product quality in every destination market. Cross-sectional Belgian firm-product level exports by destination are congruent with these predictions and are supportive of a richer modelling of consumer demand.

Our results show that within firm-product export prices vary by destination, which our model rationalizes through varying competition effects in the destination. Data also shows that within firm-product export prices across destinations are strongly correlated. This implies that high versus low priced varieties in one country continue to be high and low priced varieties in another country, with few reversals in price rankings across varieties. This suggests that quality and production costs, two important determinants of prices, are intrinsic to a firm-product variety independent of where a variety is shipped to.

The variation in export prices is much better explained by firm-product dummies than by firm-dummies. This suggests that quality and costs must differ widely across products within firms. As such, it confirms our assumption in the model of product heterogeneity within firms in terms of quality and cost whose importance is also argued by the recent multi-product models.

Results also show that export quantities of within firm-products are much more volatile and correlate only weakly across destinations. While measurement error may play a role, we show that it is unlikely to be the main explanation. The evidence we present suggests that here is an idiosyncratic source of variation present in the data, not captured by earlier models. The verti-zontal model rationalizes this by the presence of taste heterogeneity across countries. Taste heterogeneity according to the model can be idiosyncratic and affect quantities (sales), while taste differences need not have an effect on the export price. The definition of horizontal differentiation in this paper therefore corresponds closely to the IO literature. Interestingly, we find taste congruence to be stronger in countries closeby. Put differently, export quantity variation within firm-products is lower in nearby countries. This suggests that taste and distance to destination may be highly correlated, which raises some doubts on the correct specification of many gravity models where distance typically features as the prominent explanation for bilateral trade flows, but which may in fact capture taste effects that run along similar dimensions.

The model also leads to identifiable parameters that allow for an identification of horizontal differentiation (taste) clearly distinguished from vertical differentiation (quality) and that offer possibilities for future policy evaluation in terms of competitiveness of exported products. Since

these parameters stem directly from consumer utility, they can be identified without assuming any distributional functional form for the demand shifters, but require access to firm-product data on cost or markups, which lies beyond the current paper.

Instead, in this paper we take a first step by showing that demand heterogeneity in trade models appears warranted and brings theory closer to empirical observations. This paves the way to further research aimed at disentangling taste heterogeneity from other potential explanations put forward in the recent literature to better explain micro-level trade patterns.

1   Introduction

Many existing trade models of monopolistic competition identify cost efficiency as the main determinant of firm performance in export markets. In contrast, the analysis of demand factors has received less attention. Demand is typically assumed to be symmetric across varieties and countries. This symmetry in demand is imposed on very different products sold within the same country as well as for the same goods sold across different countries. These restrictive assumptions have led scholars to introduce random firm and country-specific shocks to match features of the data.[1]

The purpose of this paper is to relax the symmetric demand assumption in a love-for-variety trade model by allowing consumers in export markets to differ in two major respects. First, the demand function is allowed to vary across varieties within a destination country. This amounts to assuming that *preferences are asymmetric*. For example, suppose that the set of differentiated varieties is types of beers. Under asymmetric preferences, we allow the demand faced by Heineken to be different from the demand faced by Budweiser in a particular country. Second, the demand function can vary for the same variety across destination countries, depending on consumer taste and product characteristics. This amounts to assuming that *consumers across countries are heterogeneous in taste*. For example, the demand for Heineken can be stronger than the demand for Budweiser in one country, but it can be the opposite in another country where both beers are also sold.

Although firm heterogeneity in efficiency has empirically been confirmed to be very important in explaining firms' entry into export markets, this seems less the case for firm-level sales variation in different countries conditioning upon entry. Several papers analyzing the variability in firm-level prices and sales across a range of export destinations have reached the conclusion that cost factors alone cannot account for all the variation in the data and conclude that demand factors are important too.[2] In this paper we aim to rationalize the observed firm-destination variation by supplementing firm heterogeneity in costs with consumer heterogeneity. We do so by allowing each destination country to have a different set of asymmetric preferences over the varieties on offer. This is achieved in a simple and intuitive way in the quadratic utility used by Ottaviano, Tabuchi and Thisse (2002), Melitz and Ottaviano (2008), and others. We build the model in two steps. We first introduce asymmetry in preferences across varieties within one country. Next, we allow every country to be characterized by a different set of asymmetric preferences across varieties. Hence, *each variety has a country-specific demand*, which offers an explanation for the strong variation observed in the quantities of identical varieties sold in various countries.

It is important to point out that varying variety-country sales need not result from market size differences nor from income differences, but from asymmetric preferences between varieties and taste heterogeneity across countries. Put differently, whereas in Melitz and Ottaviano (2008) firm-product-quantity variation across destinations may result from varying market size or from a varying number of competing varieties by destination, the new preferences introduced here

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[1]Bernard, Redding and Schott (2011), Hallak and Sidavasan (2013) and Munch and Nguyen (2013).

[2]Based on French data, Eaton, Kortum and Kramarz (2011) find that firm efficiency is not the main determinant of sales variation across markets (see also Brooks, 2006). Similarly, Kee and Krishna (2008) find that the correlation between firm-level sales of Bangladeshi firms in different destination markets is close to zero.

show that even when exporting to a country of similar size, similar income level and the same number of competing varieties, quantities shipped may still vary due to taste differences affecting the market outcome in a way that has not been considered before.

In addition to firm-product heterogeneity in cost and taste, we also allow consumer preferences to be asymmetric in quality differences between varieties.[3] Without quality differentiation, the model would wrongly attribute the high sales of high priced varieties within a country entirely to taste differences, which is unlikely. Since quality also affects demand, it should be incorporated in the model in order to allow for a correct identification of taste effects. The model does not impose any correlation between cost, taste and quality but allows these parameters to move freely and independently of each other. For example, we do not impose any relationship between marginal cost and the quality of a variety, thus allowing higher quality to either stem from fixed costs such as investment in research and development or from the use of higher-quality and more expensive inputs. Nor do we impose a relationship between taste and quality. Thus, while both quality and taste affect the demand for a variety, they may work in opposite directions. The demand for a variety is thus ultimately determined by the interplay of the quality and taste.

Clear definitions of horizontal and vertical differentiation until now only exist in discrete choice models with indivisible varieties and with consumers making mutually exclusive choices, used in Industrial organization (Tirole, 1988) and, more recently, in trade (Khandelwal 2010; Fajgelbaum, Grossman and Helpman, 2011). Discrete choice models incorporate both types of differentiation (Anderson, de Palma and Thisse, 1992). In contrast, a clear distinction between horizontal (taste) and vertical (quality) differentiation is largely absent in models where consumers have a love-for-variety and purchase many products in varying quantities. This is what we aim to accomplish in this paper where we propose love-for-variety preferences that include horizontal and vertical differentiation, which we refer to as *verti-zontal* preferences. Typically, varieties of the same good are horizontally differentiated when there is no common ranking across consumers when varieties are equally priced. In other words, horizontal differentiation reflects consumers' tastes that affect how much firms can sell of each variety. In contrast, varieties are vertically differentiated when all consumers agree on their ranking, and thus quality affects prices in all destination countries.

Unlike discrete choice models, we do not aggregate utility over individual consumers within a country but instead work with a representative consumer per country. This approach is predominantly data driven since shipments in trade by firm-product are typically only available at destination country-level. Our model is not unique in explaining the quantity variation observed in the data, but we will discuss why it is the single one to explain the joint variation in price and quantity of exported firm-products in the data (section 4.3).

The introduction of asymmetries in quadratic utility and of heterogeneity across representative consumers results in a number of appealing features.

First, horizontal differentiation in our model is captured by one single parameter that varies

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[3]There are two strands of literature on that. The first one is about quality in the CES, such as Baldwin and Harrigan (2011), Johnson (2012), Kugler and Verhoogen (2012), and Verhoogen (2008). The second one is about quality in quadratic preferences, such as Foster, Haltiwanger and Syverson (2008), Kneller and Yu (2008) and Eckel, Iacovone, Javorcik and Neary (2011).

across varieties and consumers for which we provide a micro-foundation that goes back to spatial models of product differentiation à la Hotelling (1929). This approach allows us to determine precisely how this parameter affects demand and sales *asymmetrically*.

Second, our analysis generalizes quasi-linear preferences to introduce demand heterogeneity in a way that permits a separate identification of horizontal and vertical differentiation in a particular sense: the consumer-specific parameter of horizontal differentiation only affects equilibrium quantities but not prices. Thus, horizontal differentiation can be separated from vertical differentiation at the firm-product-country level and can empirically be distinguished by any researcher with access to data on firm characteristics. Horizontal differentiation in CES models cannot explain variation in sales for the same firm-product across countries because the elasticity of substitution is constant across varieties. To remedy for this, one can introduce a firm-product specific demand shock per country that accounts for sales variation of the same firm-product across countries without affecting prices. Horizontal differentiation between products is then the combination of a constant parameter of substitution and a variable shock at the firm-product level. Because the parameter of substitution also enters the price equation, a clear separation of horizontal and vertical differentiation is difficult to attain with the CES. Therefore we need a set of preferences which allows for a clear separation of quality and taste since both shift demand in different ways. Otherwise quality differences between varieties could be confounded with taste differences, and vice versa. In this paper we show that taste differences can shift demand without affecting price, while quality differences always imply a price change.

Third, asymmetric preferences in quadratic utility also result in a richer set of country-specific competition effects. With symmetric preferences, competition effects are a sole function of the number of firms in the destination country, which depends on market size. Allowing for asymmetric preferences generates competition effects that now also depend on the quality of the varieties on offer in the destination country and their interaction with local tastes. In addition, allowing for consumer heterogeneity across countries implies that two countries of similar size and GDP can still be subject to varying levels of competition. Even when the quality on offer in these two countries is the same, competition effects can differ because in one country high quality varieties meet better local tastes. Allowing for asymmetric preferences in quality and taste across varieties and taste heterogeneity across countries also generates market structures ranging from monopoly to perfect competition. This is shown by defining several market aggregates, which together capture the extent of country-specific competition effects. All in all, the new preferences presented here provide a link to the industrial organization literature where market structure is more central than in standard trade models.

Fourth, our main objective is to better describe consumers' choices. Selection issues and zero trade flows in exports, whose importance have recently been discussed in the trade literature (e.g. Helpman, Melitz and Rubinstein, 2008), do not alter the main message of this paper. In other words, a richer supply side and various entry settings can be added to our model without changing our main results. Heterogeneous consumers across countries with asymmetric preferences across varieties suffice to rationalize the observed export prices and quantities of individual varieties shipped across countries. We disregard market participation issues because *our results hold for any number of varieties present in destination countries and any distribution*

of the quality and taste parameters.

Last, since the parameters stem directly from the utility function, we can provide a clear micro-foundation for them, which improves upon the firm and country-specific shock approach that has been used in empirical work to fit the data but that has little theoretical underpinnings. The parameters of the new model that we propose can be written as a function of observables and no distributional functional forms for demand shocks need to be made. This also leads to identifiable structural parameters on quality and taste that account for parallel and slope shifters in demand. This offers possibilities for quantifying the primitives of the model and for comparing them with alternative explanations put forward in the literature in order to assess their relative importance in explaining the strong quantity variation of identical varieties across countries.

Our empirical analysis aims to verify whether the data are consistent with the verti-zontal model. For this purpose we use a cross-sectional analysis of firm-product exports by destination shipped from Belgium, where products are available at the 8-digit level. Our findings are congruent with the verti-zontal model. However, we acknowledge that alternative explanations may also be at work. While taste differences offer a plausible explanation for an empirical regularity hitherto not well understood, future work should be aimed at disentangling taste effects from other potential explanations. A full identification of the model's parameters would require a much richer dataset and is left for future research.

The next section first discusses the standard quadratic utility before introducing the new consumer preferences. Section 3 discusses market equilibria and parameter identification. Section 4 uses firm-product level cross-sectional exports data for Belgium to explore data patterns. Section 5 concludes.

2 The consumer program

2.1 The standard quadratic utility

Consider an economy endowed with a set I of consumers and two goods - a differentiated good supplied as a continuum S of varieties and the numéraire. In the existing literature using the quadratic utility, consumers share the same preferences given by

$$U = \alpha \int_S q(s) \mathrm{d}s - \frac{\beta}{2} \int_S [q(s)]^2 \, \mathrm{d}s - \frac{\gamma}{2} \left[\int_S q(s) \mathrm{d}s \right]^2 + q_0. \tag{1}$$

In this expression, the utility depends on the consumption $q(s)$ of variety s belonging to a set S of differentiated varieties and on the consumption q_0 of the numéraire. The parameter $\alpha > 0$ captures the preference for the differentiated good with respect to the numéraire, while $\gamma > 0$ is the degree of substitutability between any pair of varieties in S: a higher γ means that varieties are closer substitutes. The quadratic utility function exhibits a *love for variety* whose intensity is measured by the value of the parameter $\beta > 0$.[4] An important property of (1) is that the three parameters are identical for all varieties. Thus, two implicit assumptions are

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[4]Different from Ottaviano, Tabuchi and Thisse (2002), the parameter β used here captures the degree of horizontal differentiation net of the substitutability among varieties.

made. First, all varieties face the same demand in each country. Second, any particular variety faces the same demand no matter which country it is sold in. In other words, *all varieties enter consumer preferences symmetrically around the world*, which is clearly restrictive. In terms of our beer example, symmetric preferences amounts to assuming that Heineken and Budweiser face exactly the same demand within a country and this in every country they are sold in.

2.2   The quadratic utility with verti-zontal preferences

We now relax the symmetry assumption within a country, but continue to assume homogeneous consumers across countries. In terms of our beer example, this means that we allow varieties Heineken and Budweiser to face a different demand within a country, depending on their quality and the taste for them, but the demand for each individual beer variety is the same across countries. As such the extent to which each beer is liked (or disliked) is the same for all consumers. In subsection 2.4. where we introduce heterogenous consumers, the preference of one beer over another is also allowed to vary by country.

Under asymmetric preferences, but with homogeneous consumers everywhere, the quadratic utility (1) is extended as follows:

$$U = \int_S \alpha(s)q(s)\mathrm{d}s - \frac{1}{2}\int_S \beta(s)\left[q(s)\right]^2 \mathrm{d}s - \frac{\gamma}{2}\left[\int_S q(s)\mathrm{d}s\right]^2 + q_0. \tag{2}$$

The quadratic utility (2) differs from (1) by the fact that parameters α and β now depend on s, which indicates that they are variety-specific. Units in which varieties are measured are the same, kilograms of chocolate, bottles of beer and the like. So, we compare one unit of each variety with one unit of another.[5] While notationally (2) and (1) may not appear all that different, (2) represents a very different set of preferences. To justify (2), we find it is important to offer a clear interpretation for the parameters and do so by discussing their micro-foundations in detail. We first show that $\beta(s)$ captures the idea of "taste mismatch" between the consumer and variety s, thus characterizing the extent of idiosyncratic horizontal differentiation across varieties.

Taste mismatch $(\beta(s))$.   In the product characteristics space, the distance to the shop reflects *taste mismatch* between a consumer's ideal variety and the one on offer in the shop's location. Introducing love-for-variety into Hotelling's (1929) model by giving the consumer a utility function as in (2), as the consumers are allowed to visit more than one shop, we can also show that the parameter $\beta(s)$ corresponds to the distance that a consumer has to travel to reach the shop. As a result, we can interpret $\beta(s)$ in (2) as a parameter expressing the mismatch between the horizontal characteristics of variety s and this consumer's ideal. Thus, we show that the definition of horizontal differentiation in the context of indivisible varieties, with consumers making mutually exclusive choices, concurs with the definition of horizontal differentiation in preferences where consumers buy more than one variety and the differentiated goods are divisible. By drawing a parallel between the taste parameter $\beta(s)$ and the distance a consumer has to travel

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[5]Normalizing α to 1 in (1) is not a problem. By contrast, when α is variety-specific as in (2), normalizing $\alpha(s)$ to 1 is problematic because we may end up with variety-specific units, e.g. kilograms for some varieties and tons for the others, which is not meaningful. In the empirical section, we always measure quantities in the same unit.

to a shop, like in the Hotelling setting, we get a clear interpretation for this parameter.[6] This spatial metaphor, which is important for the micro-foundation of the parameter $\beta_i(s)$ in (2), is developed in detail in Appendix A.[7]

Quality ($\alpha(s)$). The parameter α in both (1) and (2) corresponds to consumers' willingness-to-pay (WTP) for the first unit of variety s in the absence of substitutable varieties. While in the standard quadratic utility, as for example in (1), the quality of all varieties is assumed to be the same, in (2) we now allow the quality of each variety to be unique. To better explain the interpretation of $\alpha(s)$, consider the case of two varieties, s and r, whose degree of substitutability is captured by the parameter $\gamma > 0$. In this case, a consumer's utility is equal to

$$U = \alpha(s)q(s) - \frac{\beta(s)}{2}\left[q(s)\right]^2 + \alpha(r)q(r) - \frac{\beta(r)}{2}\left[q(r)\right]^2 - \frac{\gamma}{2}q(r)q(s) + q_0. \tag{3}$$

In (3), $\alpha(s) - \gamma q(r)/2$ is the marginal utility derived from consuming an arbitrarily small amount of variety s when $q(r)$ units of variety r are consumed. This marginal utility varies inversely with the consumption of the other variety because the consumer has a lower valuation for variety s when her consumption of its substitute r is larger. Note that the intercept $\alpha(s) - \gamma q(r)/2$ of the demand function for variety s is positive provided that its desirability ($\alpha(s)$) dominates the negative impact of the consumption of the other variety, $q(r)$, weighted by the degree of substitutability between the two varieties (γ).

The budget constraint is

$$p(r)q(r) + p(s)q(s) + q_0 = y$$

where $p(r)$ and $p(s)$ are the prices of varieties r and s respectively, and y is income. Plugging the budget constraint in (3) and differentiating with respect to $q(s)$ yields the inverse demand for variety s:

$$p(s) = \alpha(s) - \frac{\gamma}{2}q(r) - \beta(s)q(s). \tag{4}$$

The WTP for variety s shifts downward to account for the fact that variety r is consumed together with variety s, while the two varieties are substitutes. The value of the shifter increases with the total consumption of the other variety ($q(r)$) and the degree of substitutability (γ).

Following the literature, we now define two varieties as vertically differentiated when all consumers view the vertical characteristics of variety s as dominating those of variety r. Therefore, in line with the definition of vertical differentiation, we say that varieties s and r are vertically differentiated when the WTP for the first marginal unit of variety s exceeds that of variety r, i.e. $\alpha(s) > \alpha(r)$. Because a higher $\alpha(s)$ implies that the WTP for variety s increases regardless of the quantity consumed, $\alpha(s)$ can be interpreted as an index of the quality of this variety. Since the WTP for a variety decreases with its level of consumption, an alternative definition would be to say that varieties s and r are vertically differentiated when $\alpha(s) - \beta(s)q > \alpha(r) - \beta(r)q$ for

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[6]Because a Hotelling-like spatial model is formally equivalent to a discrete choice model and vice versa, $\beta(s)$ may also interpreted as the realization of a random variable.

[7]Another interpretation of $\beta(s)$ is related to the concavity of the variety-specific utility function. As the mismatch between variety s and the consumer's ideal increases, it is natural to expect the consumer's marginal utility to decrease faster. This can be seen by differentiating (2) with respect to $q(s)$.

all $q > 0$. However, this definition overlaps with the very definition of the WTP that captures more features than vertical attributes, such as the quantity consumed. Furthermore, we will see that the equilibrium price of variety s always increases with $\alpha(s)$, which we find sufficient to express the idea that a higher quality variety is expected to be priced at a higher level.[8]

Substitutability (γ).   This brings us to the parameter γ. Allowing it to vary across varieties, while analytically feasible, would be cumbersome and difficult to measure empirically as it would amount to identifying a level of substitutability for each and every pair of varieties in the market. We thus follow a pragmatic approach and assume the degree of substitutability between varieties to be defined at the product level and not to vary across varieties of this product. In terms of our beer example, parameter γ captures the fact that Heineken and Budweiser are similarly imperfect substitutes in every country where they are sold, but the parameters $\alpha(s)$ and $\beta(s)$ allow Heineken and Budweiser to enter consumer preferences differently in every country they are sold in. While this is a simplification that should be pointed out, it seems a plausible one. The analytical benefit of keeping γ constant will become clear when we discuss competition effects.

2.3   Consumer optimization

Let us now proceed with the maximization of the utility in (2) when a consumer faces the set S of varieties. Plugging the budget constraint

$$\int_S p(s)q(s)\mathrm{d}s + q_0 = y$$

in (2) and differentiating with respect to $q(s)$ yields the inverse demand for variety s:

$$p(s) = \alpha(s) - \gamma Q - \beta(s)q(s) \tag{5}$$

where

$$Q = \int_S q(s)\mathrm{d}s$$

is the per-capita total consumption of the differentiated good, which acts as a demand shifter for variety s. Note that $\alpha(s)$ also shifts the intercept of the inverse demand, while $\beta(s)$ affects its slope.

Using (5), we readily see that the demand for variety s may be written as follows:

$$q(s) = \frac{\alpha(s) - p(s)}{\beta(s)} - \frac{\gamma(\mathbb{A} - \mathbb{P})}{\beta(s)(1 + \gamma\mathbb{N})} \tag{6}$$

where

$$\mathbb{N} \equiv \int_S \frac{\mathrm{d}s}{\beta(s)} \qquad \mathbb{A} \equiv \int_S \frac{\alpha(s)}{\beta(s)}\mathrm{d}s \qquad \mathbb{P} \equiv \int_S \frac{p(s)}{\beta(s)}\mathrm{d}s. \tag{7}$$

Thus, like in most models of monopolistic competition, the individual demand for a variety

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[8]Our approach is thus consistent with Aw, Batra and Roberts (2001) and Eckel and Neary (2010) who assume that quality is intrinsic to a firm. However, unlike these authors, we allow quality to vary by variety s. This issue has been tackled in a handful of papers (for example, Hallak and Sivadasan, 2013).

(6) depends on a few *market aggregates*, here $\mathbb{N}$, $\mathbb{A}$ and $\mathbb{P}$. Using the spatial interpretation of $\beta(s)$ given above, it is straightforward that a group of varieties r characterized by small (large) values of $\beta(r)$ have a strong (weak) impact on the demand for variety s because consumers are (not) willing to buy much of them, as they (dis)like its horizontal characteristics better than those of r. This explains why $\beta(s)$ appears in the denominator of the aggregates $\mathbb{N}$, $\mathbb{A}$ and $\mathbb{P}$.

Each variety is weighted by the inverse of its taste mismatch $\beta(s)$ to determine the *effective* mass of varieties, given by $\mathbb{N}$. It is $\mathbb{N}$, and not the unweighted mass of varieties N, which affects the consumers' demand for a given variety. Indeed, adding or deleting varieties with bad taste matches does not affect much the demand for the others, whereas the opposite holds when the match is good. Note also that the effective mass of varieties $\mathbb{N}$ may be larger or smaller than the unweighted mass of varieties N in the product market, according to the distribution of taste mismatches. Similarly, the quality and price of a variety are weighted by the inverse of its taste mismatch to determine the effective quality index $\mathbb{A}$ and the effective price index $\mathbb{P}$. In particular, varieties displaying the same quality (or price) may have very different impact on the demand for other varieties according to their taste mismatches. The aggregate indices in (7) show that taste heterogeneity across varieties affects demand and, therefore, the market outcome. This shows that preferences (2) are *asymmetric* and capture several of the main features of the Lancasterian approach to product differentiation, such as different degrees of substitution between varieties, when varieties are asymmetrically located in the product characteristics space.

Note, finally, that (6) implies that the total mass of varieties consumed is given by

$$Q = \frac{\mathbb{A} - \mathbb{P}}{1 + \gamma\mathbb{N}} \tag{8}$$

which shows once more how the utility of a variety depends on the distribution of the taste parameter $\beta(s)$ since all the aggregate indices enter into Q. Incidentally, note that the definition of Q corresponds to the second term in the right-hand side of (6), where it is weighted by the ratio $\gamma/\beta(s)$. Thus, the larger Q, the tougher the competition that each variety s faces and the smaller its demand. For example, competition effects are stronger whenever the aggregate quality $\mathbb{A}$ is higher. As a result, if the aggregate quality goes up this will reduce the demand for each variety. This may lower the WTP for a particular variety by so much that the choke price of this variety falls below its costs, thus driving this variety out of business. This channel of firm-product exit was hitherto missing in models where the level of quality was not included in the competition effects and, therefore, could not affect the exit (or entry) of products.

The above discussion shows that it is possible to introduce asymmetry across varieties in demand in a very simple way. As will be seen, preferences (2) also generate a large array of new effects. The demand for a variety s now depends on its own horizontal and vertical attributes as well as on the effective mass of competing varieties ($\mathbb{N}$), the aggregate effective quality ($\mathbb{A}$) and the effective price index ($\mathbb{P}$). The interplay between these aggregate indices determine how a particular variety *meets the competition.*

Standard definitions of horizontal and vertical differentiation exist for indivisible varieties and with consumers making mutually exclusive choices. But these concepts until now were largely absent in models guiding the majority of empirical works in trade. Therefore, we consider the

verti-zontal preferences particularly useful for those researchers who are interested in measuring and distinguishing horizontal (taste) from vertical (quality) attributes in trade. In contrast, in the standard quadratic utility, the common β assigned to all the varieties affects both price and quantity sold of each variety, which makes it difficult to interpret it as a true parameter of horizontal differentiation. With the new and richer set of preferences introduced here, that distinction can now be made more clearly.

2.4 Heterogeneous consumers

Thus far, we have considered a set I of homogeneous consumers. But now we relax this assumption and allow consumers to be *heterogeneous.* In terms of our beer example, allowing for heterogeneous consumers amounts to assuming that a representative consumer in one country may prefer Budweiser to Heineken, whereas a consumer in another country may prefer Heineken to Budweiser.

Formally this means that we allow the β-distribution to vary with $i \in I$. Thus, from this point forward, the taste-mismatch associated with a variety is consumer-specific. This implies that i must now enter the taste mismatch parameter $\beta(s, i)$ to reflect the heterogeneity of consumers. Thus, *taste mismatch is two-dimensional*: it varies across varieties $s \in S$ as well as across consumers $i \in I$. That $\beta(s, i)$ varies with s means that the same consumer i has different attitudes toward different varieties (preferences are asymmetric), whereas $\beta(s, i)$ varies with i because different consumers have different attitudes toward the same variety s (consumers are heterogeneous).

Our main focus being on international trade, we follow most of this literature and assume that aggregate demands stemming from one country are derived from the maximization of a representative consumer's utility, such as (2). As a consequence, in this paper there is consumer heterogeneity between countries but *not* within countries. Although aggregating consumer preferences within a country is a priori doable, we do not address this issue here for data reasons. Indeed, if the distribution of $\beta(s, i)$ with respect to i were known, we could aggregate individual demands across consumers living in the same country and capture consumer heterogeneity within countries. This is exactly what is accomplished in the discrete choice literature where demand shocks are idiosyncratic to individual consumers, while aggregating demands across individuals yields the market demand when the distribution of shocks is extreme value.[9]

We propose an alternative approach, which is more in line with the standard trade literature. In addition, our model allows for a simple description of consumers buying a variable number of units of each variety, something which is not easy to perform with discrete choice models. Note also that using discrete choice models when preferences across varieties are asymmetric is not an easy task. Most of the existing theoretical literature developed in industrial organization uses the multinomial logit, which assumes symmetry. Using the probit with different covariances turns out to be especially cumbersome, whereas our approach leads to simple and intuitive results. We see this as a strong comparative advantage of the verti-zontal model.

Our model can be used at different levels of demand aggregation, i.e. a household, a city, or

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[9]Using Hotelling's spatial metaphor developed in Appendix A, the distance $\beta(1, i)$ between shop 1 and consumer i's ideal differs from the distance $\beta(1, j)$ to consumer j's ideal.

a country. This makes it a potentially useful tool to address alternative issues, especially when data are available at a very disaggregated level such as barcode data within cities (Handbury and Weinstein, 2011). In what follows, we interpret a consumer as a country's representative consumer. To be precise, we consider $I = \{1, ..., n\}$ as the set of destination countries and S_i as the set of varieties available in country i. In such a context, our approach offers new insights into competition effects. Based on the standard quadratic utility given in (1), country size determines the number of varieties and, therefore, the competition effects. Allowing for consumer heterogeneity and asymmetric preferences across countries, as we do here, adds another dimension of competitiveness, taste mismatch and quality. In Melitz and Ottaviano's (2008) type of models, two countries of similar size and GDP would have identical competition effects. Under the system of preferences we present here, this will not be the case, i.e., it will also depend on the quality of the varieties on offer and on their interaction with local preferences. Even with the same market size, the same number of firms, and the same quality on offer, this could still result in different competition effects because in one country one set of varieties match better local taste than in the others.

Because i is now an index that varies from 1 to n, we will replace $\beta(s, i)$ with $\beta_i(s)$. Prices and quantities will similarly be denoted $p_i(s)$ and $q_i(s)$, whereas the market aggregates $\mathbb{N}_i$, $\mathbb{A}_i$ and $\mathbb{P}_i$ are indexed by i only. This notation is also more convenient in the empirical analysis undertaken in Section 4.

3 Firm optimization and market outcome

Because the vertical and horizontal attributes and the marginal cost ($c(s)$) vary across varieties, firms are heterogeneous along the three dimensions.[10] Firms can be thought of as exporters of a particular country of origin shipping products to destination countries indexed by i. Our analysis holds true when trade costs are incorporated. Indeed, it is sufficient to replace $c(s)$ with $c_i(s) = c(s) + t_i$, where t_i is the cost of shipping one unit of variety s to country i. But we refrain from including trade costs everywhere for the sake of clarity of exposition. Empirically, trade costs will be captured by product-destination specific dummies, which amounts to assuming that trade costs are the same for all varieties of a given product exported from the same country of origin to the same destination, which seems plausible.[11]

3.1 Profit maximization

The operating profits earned from selling variety s in country i can be written as follows:

$$\Pi_i(s) = [p_i(s) - c(s)] \, q_i(s).$$

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[10]Since our model deals with heterogeneity at a firm-product level, firms can be either single product or multi-product. As in Bernard, Redding and Schott (2011), we assume that each firm-product has a different marginal cost that is constant. We leave more complex multi-product issues, such as cannibalization and core competencies studied in Eckel and Neary (2010) and Mayer, Melitz and Ottaviano (2012), for future research.

[11]Variation in fob export prices under verti-zontal preferences is attributed to varying competition effects in the countries of destination. With standard CES preferences, fob export prices only vary with distance when additive rather than iceberg trade costs are assumed (Hummels and Klenow, 2005; Martin, 2012).

Note that in our model markets are segmented, so that $q_i(s)$ and $p_i(s)$ differ according to the destination country the firm exports its variety to.

Let S_i be the set of varieties available in country i. The benefits of using quasi-linear preferences are reaped here since firms' profits affect only the consumption of the numéraire regardless of their level and the way profits are determined. As a consequence, the analysis of the equilibrium provided below is robust against different modeling entry strategies. For example, S_i could be the set of varieties supplied by the single-product firms that are active at the free-entry equilibrium, as in Melitz and Ottaviano (2008), or the set of varieties supplied by multi-product firms, as in Ottaviano and Thisse (2011). Therefore, how S_i is determined is not critical because our analysis holds for *any* given set S_i of varieties.

Because the variety s is negligible to the market, differentiating $\Pi_i(s)$ with respect to $p_i(s)$ yields:

$$p_i^*(s; \mathbb{P}_i) = \frac{\alpha(s) + c(s)}{2} - \frac{\gamma(\mathbb{A}_i - \mathbb{P}_i)}{2(1 + \gamma\mathbb{N}_i)}. \tag{9}$$

The natural interpretation of (9) is that it represents firm s' best-reply to the market conditions in country i. These conditions are defined by the aggregate behavior of all producers, which is summarized here by the price index $\mathbb{P}_i$. The best-reply function is upward sloping because varieties are substitutes: a rise in the effective price index $\mathbb{P}_i$ relaxes price competition and enables each firm to sell its variety at a higher price. By shifting the best reply downward, a larger effective mass $\mathbb{N}_i$ of firms makes competition tougher and reduces prices.

In contrast, since we do not deal with firms' quality choice, $\mathbb{A}_i$ is exogenously determined by the distributions of quality ($\alpha(s)$) and tastes ($\beta_i(s)$) over S_i. In particular, when the quality index $\mathbb{A}_i$ rises, each firm faces competing varieties which together represent a higher aggregate quality, thus making the market penetration of a particular variety harder. Note also that $\mathbb{A}_i$ affects prices positively, even though it affects each individual variety's price negatively. This implies that an increase in aggregate quality in a country raises price levels, but makes it harder for an individual variety to survive. Thus, through market aggregates, we manage to reconcile weak interactions under monopolistic competition with several of the main features of Hotelling-like models of product differentiation.

Integrating (9) over S_i shows that the equilibrium price index can be expressed in terms of the aggregate indices $\mathbb{A}_i, \mathbb{C}_i$ and $\mathbb{N}_i$:

$$\mathbb{P}_i^* = \mathbb{C}_i + \frac{\mathbb{A}_i - \mathbb{C}_i}{2 + \gamma\mathbb{N}_i} \tag{10}$$

where the cost index $\mathbb{C}_i$ is defined as follows:

$$\mathbb{C}_i \equiv \int_{S_i} \frac{c(s)}{\beta_i(s)} ds.$$

Hence, as in the other market indices, varieties' costs are weighted by the taste distribution in the country of destination. The interpretation is that efficiently produced varieties may have a low impact on the cost index when they have a bad match with local taste. In sum, each destination country is characterized by a different set of market aggregates ($\mathbb{N}_i$, $\mathbb{A}_i$, $\mathbb{C}_i$, and $\mathbb{P}_i$),

which are all weighted by the destination-specific taste distribution.

3.2 Market equilibrium

The market process is described by an aggregative game involving a continuum of players (the variety suppliers) and a single market aggregate $\mathbb{P}_i$ per destination country. The equilibrium outcome is given by a Nash equilibrium, which is determined as follows. Plugging (10) into (9), we obtain the equilibrium price of variety s in country i:

$$p_i^*(s) = \frac{\alpha(s) + c(s)}{2} - \mathcal{T}_i \frac{\bar{\alpha}_i - \bar{c}_i}{2} \tag{11}$$

where $\bar{\alpha}_i$ is the average effective quality in country i of varieties present in this country and $\bar{c}_i$ is the average effective marginal production cost of the varieties present in country i, be they domestically produced or imported:

$$\bar{\alpha}_i \equiv \mathbb{A}_i/\mathbb{N}_i \qquad \bar{c}_i \equiv \mathbb{C}_i/\mathbb{N}_i$$

while

$$\mathcal{T}_i \equiv \frac{\gamma \mathbb{N}_i}{2 + \gamma \mathbb{N}_i} \in [0, 1].$$

Clearly, the equilibrium price of a single variety depends on the market aggregates $\mathbb{A}_i$, $\mathbb{C}_i$ and $\mathbb{N}_i$, which in turn depend on the whole distribution of the taste mismatch parameter $\beta_i(\cdot)$ as well as on the cost ($c_i(\cdot)$) and quality ($\alpha_i(\cdot)$) parameters of the competitors in country i.

As for the parameter $\mathcal{T}_i$, it reflects the *toughness* of competition in country i, which can make the equilibrium price range from perfect competition to pure monopoly. This is an important additional feature of the preferences presented in this paper: it offers the possibility of studying different types of market structure in trade models by varying the toughness of competition. To see this, consider the following example. When $\gamma \mathbb{N}_i$ is arbitrarily small, which means that variety s has only poor substitutes in country i, each variety is supplied at its monopoly price because $\mathcal{T}_i \to 0$. On the other hand, when $\mathcal{T}_i \to 1$, country i is crowded by many good substitutes, which means that the market outcome converges toward perfect competition.

The benefits of assuming that γ is the same between any pair of varieties are reaped by capturing the intensity of competition in a particular country through $\mathcal{T}_i$. In addition, the toughness of competition may vary from one country to another because $\mathcal{T}_i$ depends on the effective mass of competing varieties in each country, which depends itself on the country-specific taste distribution.[12]

It follows from (11) that higher quality results in higher prices, but the opposite need not hold. Prices can rise for other reasons such as higher costs or lower competition. This points at the need to complement unit values with cost controls to properly measure quality at the product level, which is not always possible without access to additional firm-level information.

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[12]This parameter can be nicely related to the existence of different price ranges across sectors observed by Khandelwal (2010). Noting that each variety is characterized by an idiosyncratic quality and cost parameter, we can show that, paraphrasing Khandelwal, it is *the length of the markup ladder* that varies across sectors in our model: the tougher the competition, the shorter the ladder.

Note also that the first term of (11) is variety-specific (the parameters are all indexed s). These variety-specific determinants of prices and per-capita quantities, such as cost and quality, do not vary by destination country and influence prices and quantities in a similar way in all countries. However, the second term in (11) is not variety-specific but depends on destination market aggregates that are identical for all the varieties sold in a particular country i. Since these indices are country-specific variables (all indexed i) we refer to the second term in (11) as a *market effect*.

The (absolute) markup is given by

$$p_i^*(s) - c(s) = \frac{\alpha(s) - c(s)}{2} - \mathcal{T}_i \frac{\bar{\alpha}_i - \bar{c}_i}{2}. \tag{12}$$

As expected, the markup increases (decreases) with $\alpha(s)$ ($c(s)$). More importantly, it also decreases (increases) with $\bar{\alpha}_i$ ($\bar{c}_i$). Hence, when varieties available in country i have a high quality (a low cost) and a good match with country i's consumer tastes, the price at which variety s can be sold in country i is low. By contrast, when the same varieties have a bad match, variety s can be sold at a high price. Therefore, quality as such is not enough for a variety to be successful in a specific country. What (12) tells us is that *the markup of a specific variety is strongly affected by the way competing varieties meet consumers' tastes in country i.*

Last, suppose that the average effective quality $\mathbb{A}_i/\mathbb{N}_i$ increases by $\Delta > 0$. Then, if the quality upgrade Δ_s of variety s is such that

$$\Delta_s > \mathcal{T}_i \Delta$$

its price and markup will increase, even though the quality upgrade Δ_s may be lower than Δ. In contrast, if the quality upgrade of variety s is smaller than $\mathcal{T}_i \Delta$, then its markup and price will decrease, even though the quality upgrade Δ_s is positive. Thus, what matters for the "competitiveness" of a firm is its relative quality at the level of the product market.

Using the properties of linear demand functions, we readily verify that the equilibrium output of each variety is given by

$$q_i^*(s) = \frac{1}{\beta_i(s)} \left[\frac{\alpha(s) - c(s)}{2} - \mathcal{T}_i \frac{\bar{\alpha}_i - \bar{c}_i}{2} \right]. \tag{13}$$

The first term in parentheses on the right-hand side of (13) is variety-specific, whereas the second term shows that quantities shipped can differ across countries due to the market effect that is common to all the varieties present in country i. However, the entire expression in brackets is weighted by the taste parameter $\beta_{s,i}$, which is variety- and country-specific turning (13) into a non-linear expression. The equilibrium quantity equation (13) can be rewritten as a function of its price:

$$q_i^*(s) = \frac{1}{\beta_i(s)} \left[p_i^*(s) - c(s) \right]. \tag{14}$$

Combining (11) and (13) also provides us with a description of the market outcome predicted by our model in terms of the export price and quantity of a variety shipped by a firm to country i.

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The quantity exported $q_i^*(s)$ differs depending on the characteristics of the destination country, which are captured here by a series of market aggregates. Important to realize is that even when countries are identical in terms of their size and the number of varieties sold, they can still have very different demand for variety s due to the taste differences (distribution of $\beta_i(s)$) in different countries.

Using (14) shows that the profits earned on variety s sold in country i are as follows:

$$\Pi_i(s) = \frac{1}{\beta_i(s)} \left[p_i^*(s) - c(s) \right]^2. \tag{15}$$

What this expression shows is that *a variety can be very successful in a particular country while doing poorly on another* for reasons that are both plausible and easy to pin down in our model, i.e., the quality of the match with local tastes, consumer idiosyncrasies across countries, and the toughness of competition within countries. Thus, a firm facing similar markups in two countries may have different profit levels depending on how much its product is liked in each country. In the same vein, (15) also reveals that a variety may be sold at a high markup, thus suggesting that its producer has much market power. However, this variety may generate low profits. As a result, *the level of a markup does not necessarily mean that the corresponding variety is selling well.*

The selection issue in CES-like models requires a fixed costs of exporting. This is different in quadratic utility models. Melitz and Ottaviano (2008) already pointed out that with firm heterogeneity in cost, selection and zero trade flows may result from a cost above the choke price in a country. The model we introduce here sheds additional light on entry issues due to the role of taste. The novelty here is that, in addition to low productivity, low quality and competition effects, exports of a variety may be zero because of its *high taste mismatch in the destination country.* A zero trade flow may thus stem from any of these aforementioned reasons, or combination of them, thus rendering the identification of individual parameters problematic. This differs from standard models in which productivity is the main parameter to explain entry into export markets (Helpman, Melitz and Rubinstein, 2008).

The market effect implies that fob prices can differ depending on destination countries through the β-weighted market aggregates. However, $\beta_i(s)$ does not enter the price equation (11) directly, whereas it does enter directly in the equilibrium quantity equation (13).[13] This is important for several reasons. First, it offers an opportunity for the identification of parameters $\alpha(s)$ and $\beta_i(s)$ based on the fact that taste affects directly quantities but not prices. Second, it confirms the interpretation of the parameter $\beta_i(s)$ as capturing horizontal differentiation. Also, whereas the price equation (11) is a linear and separable equation, the quantity equation (13) is not. The reason is that $\beta_i(s)$ is both country- and variety-specific.

Note that the equilibrium price of variety s is independent of $\beta_i(s)$ because the price elasticity is independent of this parameter:

$$\epsilon_i(s) = -\frac{p_i(s)}{\alpha(s) - \gamma Q_i - p_i(s)}.$$

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[13]The parameter β does not enter prices because firms in their profit maximization trade-off setting a higher price when taste is strong and having smaller sales, to setting a price independent of taste but getting a large market share when taste is strong.

Since $\beta_i(s)$ does not affect $\epsilon_i(s)$, it has no impact on $p_i(s)$. However, the whole β-distribution matters for the elasticity because it influences the equilibrium value of Q_i, as shown by (8). This shows once more how the variables of the model can be affected differently by the taste mismatch parameter.

We summarize those results as follows.

Proposition 1 *Equilibrium* **prices** *depend on variety-specific cost and quality as well as on the market-specific degree of competitiveness. Market effects, which can be captured by taste-weighted price, quality and cost indices as well as by the effective mass of competitors, vary with the destination country, but are common to all varieties exported there. Thus, export prices of the same variety across countries only vary through market-specific effects.*

Proposition 2 *Equilibrium* **quantities** *(sales) depend on market-specific and variety-specific tastes. Thus, export quantities of the same variety across countries shows additional variability, as compared to prices, because of idiosyncratic tastes.*

These propositions imply that export prices are explained by a combination of firm characteristics (s) and country characteristics (i), whereas we expect this to be less the case for quantities (sales). On the one hand, variety characteristics are the same no matter where a variety is exported to, so they should not account for the variability in prices of the same variety across countries, but they should account for differences between varieties exported to the same country. On the other hand, country characteristics should account for most of the variability of prices of the same variety sold into different countries. When considering several varieties jointly, we would expect the combination of variety characteristics and country characteristics to be important and to give a high goodness-of-fit for prices, but a much lower goodness-of-fit for quantities (sales). This is what we will explore in the next section.

Before proceeding, it is worth noting that the above expressions do not involve income effects within countries because the utility (2) is quasi-linear. However, this does not mean that income effects cannot be dealt with. In Appendix B we show how income differences between countries can be incorporated. Richer destination countries derive a lower marginal utility from consumption than poorer countries, which is then reflected in a different value of the numéraire. Since the numéraire is the basic unit of measurement of all the parameters in the model, income levels are implicitly present in (11) and the other equations, but do not alter them.

3.3 Parameter identification

An interesting feature of our model is that its parameters are identifiable. The model's particular functional form allows researchers to directly measure quality differences between varieties in the same destination country and to estimate the taste mismatch parameter at the country-variety level. The parameter capturing country-variety-specific taste mismatch, i.e. horizontal differentiation is the most easily identifiable. To determine its value, we rewrite equation (14) and show it is the ratio between each variety's markups and its quantities sold, at any given

point in time, t:[14]

$$\beta_{i,t}(s) = \frac{p_{i,t}^*(s) - c_t(s)}{q_{i,t}^*(s)}. \tag{16}$$

However, empirical identification of the "taste mismatch" parameter would require firm-product level information on costs or markups. But this data is not available to us, and will not be pursued here. Instead, in section 4 we use cross-sectional exporters data on prices and volumes of product-level shipments, to determine the plausibility of the verti-zontal model in first instance. As for the parameter capturing variety-specific vertical differentiation, it can be measured in relative terms. Note that $\alpha(s)$ is the value in terms of numéraire attributed by consumers to the vertical characteristics of a particular variety s. In relative terms, quality differentials between any couple of varieties (say, r and s) can be readily obtained by exploiting the property that relative prices of different varieties in a common destination country depend only upon differences in costs and quality since both face the same market effects and thus they drop out when looking at relative quality (as shown in equation (11)):

$$\Delta\alpha_t(s,r) = \alpha_t(s) - \alpha_t(r) = 2\left[p_{i,t}^*(s) - p_{i,t}^*(r)\right] - \left[c_t(s) - c_t(r)\right]. \tag{17}$$

Measuring the distance between the quality of all the varieties, $\alpha_t(s)$, and the quality of the lowest-quality variety, $\alpha_t(0)$, one could identify the relative quality distribution of the varieties present in country i at time t and eventually normalize it to have an idea of the relative distribution of varieties' quality in a country. This means that no additional information or indirect estimation methodology would be needed to capture the relative quality of each variety in a country.

Empirical identification of relative quality in (17) would also require detailed information on firm-product costs, which is not available to us. Instead the main question we aim to address here is whether the data at hand are supportive of the verti-zontal model. Or do the data lean more towards a standard quadratic utility (with or without quality shifters) or towards a standard CES model (with or without quality) as the underlying mechanism to explain firm-product price and quantity variation across countries?

For this purpose we will use a simple goodness-of-fit test of an empirical approximation of both the price and quantity equation estimated on cross-sectional data. This test offers an easy way to discriminate the predictions that arise under verti-zontal preferences from other models.

4   Evidence on taste heterogeneity across countries

4.1   Data

We use data on firm-product-country trade flows of Belgian exporters. The data is composed of fob (free on board) export prices and quantities by destination country. This allows us to compare prices (unit values) and quantities of the same varieties across destinations as well as prices and quantities of different varieties within the same destination. The Belgian export data

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[14]Note that our approach would be consistent with the assumption of both linear or iceberg transport costs, as long as they are product-specific and do not vary by variety.

are obtained from the National Bank of Belgium's Trade Database and are a cross-section of the entire population of recorded annualized trade flows at the firm level by product and destination. Exactly which trade flows are recorded (i.e. whether firms are required to report their trade transactions) depends on their value and destination. For extra-EU trade (trade partner outside the EU borders), all transactions with a minimum value of 1,000 euros or weight of more than 1,000 kg have to be reported. For intra-EU trade, (trade partner inside the EU borders), firms are only required to report their export flows if their total annual intra-EU export value is higher than 250,000 euros. The products are recorded at 8-digit Combined Nomenclature (CN8).[15] In most cases, CN8 output is measured in weight (kilograms), but for a smaller set of products, quantities are also expressed in units (liters, bottles, pairs etc.).[16]

Due to its hierarchical nature, CN8 products can also be classified as products at more aggregate levels. For firms with primary activity in manufacturing, the data includes more than 5,000 exporters and over 7,000 different CN8 products, exported to 220 countries, for a total of more than 200,000 observations. We use cross-sectional export data for the year 2005 from manufacturing firms for which both values and quantities exported are reported. We do not have information on other firm-characteristics.

With the data at hand we can combine a product category at 8-digit level (CN8), say beer, with a firm-identifier such that beers can be distinguished from one another by the firm they are exported by. These firm-product combinations are allowed to enter consumer preferences differently. Even with the very detailed product classifications that we have in our data, one limitation is that it cannot be excluded that there may still be heterogeneity within the 8-digit product category that cannot be observed (e.g., specific brands, distribution channels, and so on). While most 8-digit products have a precise description, for some products this is less the case. But what is important to keep in mind is that, by linking the product to a firm, consumer preferences are now allowed to differ between the various firm-product combinations available in the country. In what follows we define a *variety* as a *firm-product* combination.

We use raw data on unit values and quantities and drop outliers at the 1% of the distribution. The only data restrictions that we impose are that, first, each firm faces some competition in their own CN8 product in a particular destination country and, second, that a variety is exported to more than one country. In practice, we impose a minimum of two firm-CN8 products to be present in the same destination and a minimum of two export markets for each variety. In this way, we can identify a variety- and a destination-specific effect in the regressions. While results are not very sensitive to an increase in the number of competing varieties per destination country, with each additional variety that we require to be present in a country, the number of observations for the regression falls substantially. Table 1 shows how the restricted sample compares to the full sample for both weights and units.

INSERT TABLE 1 HERE.

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[15]The CN classification is equal to the HS classification at the 6 digit levels.

[16]Measurement error that can plague quantity measurement should be lower when output is measured in units be it that the number of observations is much lower. For this purpose we report results both for units and weights.

4.2 Goodness-of-fit test

Equations (11) and (13) show that equilibrium prices and quantities consist of a first term, which is determined by firm-product level cost (c) and quality (α), and a second term, which depends on destination country specific variables (indexed by i). Thus, variety-specific variation (cost and quality) can be captured empirically by firm-product fixed effects, and local competition effects in the destination can be captured by country-product fixed effects.

The following empirical specification where we regress individual firm-product prices ($y_{s,i} = p_{s,i}$) and quantities ($y_{s,i} = q_{s,i}$) on variety and destination dummies allows for an easy way to discriminate between the verti-zontal and the other models:

$$y_{s,i} = \delta_0 + \delta_1 Firm\_Product_s + \delta_2 Country\_Product_i + \epsilon_{s,i} \qquad (18)$$

In the regressions we use alternatively price ($p_{s,i}$) and quantity ($q_{s,i}$) level data as dependent variables.

The equilibrium price equation (11) implies that firm-product quality and cost affect prices in a similar and linear way. So, even without identifying quality and without disentangling quality and cost, a simple OLS regression of export prices on firm-product dummies is expected to capture this variation and to explain an important part of the price data. Since cost and quality are variety-specific, firm-product dummies should account for that.

According to the verti-zontal model, the other determinants of export prices are all country effects indexed by i in (11). These country effects affect all varieties (firm-CN8) competing in the same country-product in the same way and also enter the price equation in a linear way. Since our trade data holds information on destinations, we can approximate country effects through country-product dummies. Based on the theory, the joint inclusion of firm-product and country-product dummies is expected to yield a good fit in a regression on individual firm-product prices.

In the verti-zontal model, the same set of variables is expected to perform less well in explaining variation of quantities across countries. In addition to quality, taste differences between consumers also matter. This is expected to result in a very different fit between price and quantity regressions where we expect quantity regressions have a consistently lower R^2.

The reason is that quantities are not just a function of firm-product cost and quality and country-level competition effects, but are also determined by idiosyncratic taste $\beta_{s,i}$ that makes the quantity equation (13) a non-linear one.

We do not log-linearize prices and quantities in (18), as for example Bastos, Silva and Vehoogen (2013) or Hallak and Sivadasan (2013) do. That is because in our case, by using the raw data for unit values and output, we impose a stricter test of the model since linearity of demand is one of the specific implications of our model and it is what distinguishes the price from the quantity regressions in (18). Furthermore, taking logs would have been useful if we had been interested in interpreting the specific regression coefficients, but this is not what we are after. Instead we focus on the value of the R^2 as a measure of the goodness-of-fit in the regressions

As we will show in the regressions, the systematically lower R^2 for quantities than for prices in almost every product, industry and destination that we consider, is suggestive that quantities

do not depend on the same fundamentals as prices. Based on our theory, we consider taste heterogeneity to be the underlying reason.

Unfortunately, a formal test on the significance of differences in R^2 does not exist. Therefore, complementary to a goodness-of-fit test, we also present a correlation test (section 4.5). Propositions 1 and 2 can also be formulated in terms of price and quantity correlations across countries. The advantage of using correlations is that a formal test statistic exist which allows us to formulate and test the prediction of weaker quantity correlation across countries. While the evidence is overwhelmingly in favour of our model, we refrain from considering it as conclusive that "taste" is the only missing source of variation.

4.3 Predictions from verti-zontal versus other Models

What do we a priori expect to be the goodness-of-fit of an empirical approximation of both the price and quantity equation in (18) estimated on cross-sectional data? And how do the predictions under verti-zontal preferences differ from other models?

Let us start by considering the case of a standard CES model where productivity is the only source of heterogeneity, as in Melitz (2003). In such a model, prices are expected to differ between varieties but not for the same variety across countries. Under a standard CES, fob export prices are the same independently of the destination to which the product is shipped. Therefore, we would expect a variety-fixed effect, which accounts for cost heterogeneity between firms, to account for all variation in prices. This also applies to a CES model with consumer taste draws, as in Bernard, Redding and Schott (2011).

A CES model with taste draws by variety-country and a discrete choice model with a different taste distribution per destination country are closest to the verti-zontal model in rationalizing the stronger quantity variability that we and others find in the data. However, they cannot explain the joint variability of prices and quantities described below. A CES model with taste draws in terms of prices would predict that export prices do not vary by destination country, while our data clearly shows they do. In a discrete choice model, a stronger taste for a product would also result in a higher price for that product, which would result in strong price volatility and would render the goodness-of-fit of (18) for prices as low as for quantities, which is not what we observe in the data.

Thus, based on a standard CES model (with or without taste draws), we would not expect additional variability in fob prices to come from country-fixed effects or, alternatively, from more narrowly defined country-product fixed effects.

Instead, for quantities a standard CES model assigns a role to country effects, driven by income differences across countries. A standard CES would explain a similar part of variation as in the price regression. But country-fixed effects would also explain some of the variation in quantities. Thus, in a CES model we would expect country dummies to raise the goodness-of-fit in the quantity regressions, but not in the price regression. In other words, a CES model would predict a higher goodness-of-fit for quantities.

In a CES model augmented with quality, as in Baldwin and Harrigan (2011), the variety-fixed effect would now account for both productivity and quality differences between firm-products. While the use of variety-FE does not allow us to separate cost from quality heterogeneity, it

does allow us to distinguish the type of quality differentiation that firms are making. If firms ship the same quality to all destination countries, then the variety-fixed effect would take up all the variation in prices. In such a world, adding country-fixed effects to the regression would yield no additional explanatory power for prices, while it would for quantities, as in the standard CES. But should firms ship a different quality of the same variety to different countries, this would correspond to a parallel demand shifter that varies by country. In such a model, we would expect this quality variation to be absorbed by country-fixed effects both for prices and quantities. Country-fixed effects in the quantity regression would additionally also absorb income differences between countries.

Thus, based on a CES model, irrespective of whether quality is intrinsic to a variety or depends on the destination country, we would not expect a lower goodness-of-fit of (18) in the quantity regression compared to the price regression. Thus, the prediction from a CES model is quite different from Proposition 1 derived from the verti-zontal model.

What about a standard quadratic utility, as in Melitz and Ottaviano (2008)? In such a model, both the equilibrium prices and quantities are a linear combination of a variety-specific effect and a country-effect. The variety effect captures heterogeneity in costs across firm-products, while a country-effect captures competition effects that vary by destination country. Based on a standard quadratic utility, price and quantity variation should both be equally well explained by a combination of variety-(firm-product) fixed effects and country-fixed effects. Thus, in contrast to the verti-zontal model, a standard quadratic utility would predict both price and quantity dummy regressions on variety and country fixed effects to give *an equally high* goodness-of-fit measured by the R^2.

A quadratic utility model augmented with quality, as in Kneller and Yu (2008), would give a similar prediction as a standard quadratic utility model. Quality acts as a parallel demand shifter between varieties and possibly even within varieties across countries. But this should not alter the equality in goodness-of-fit between a price and a quantity dummy regression.[17] Therefore, even in a quadratic utility model with quality differentiation, we would continue to expect *an equally good fit* for price and quantity regressions in dummy regressions on variety and country fixed effects. Thus, the verti-zontal model is the only model that predicts a systematically lower R^2 in quantity regressions than in price regressions when variety and destination effects are accounted for.

Under verti-zontal preferences, equilibrium quantities are determined by a non-linear combination of variety- and country-variety-specific variables. This non-linearity in output is driven by the presence of variety-country specific idiosyncratic taste, which can be seen from (13). However, we continue to have a linear equilibrium price equation, but the taste parameter does not enter directly, leaving all the variability to be explained by the simple sum of variety characteristics and country characteristics. Therefore, to capture the variation in firm-product-country prices (unit values) with a linear combination of variety-and country fixed effects is expected to yield a high goodness-of-fit in the price equation. In contrast, trying to fit a linear model on a combination of variables that are expected to behave in a non-linear way, as in the case of firm-

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[17]In a standard quadratic utility, quantities are given by $\left[\frac{1}{\beta}(p-c)\right]$, but since β is now a constant it should not affect the R^2, so we would expect an equally good fit in the quantity regression as in the price regression.

product-country quantities, is expected to yield a much lower goodness-of-fit. This result is not affected by selection issues because variety characteristics are intrinsic to each variety in every destination market while country characteristics affect all the varieties present in a particular country in a symmetric way.[18] A simple test where we approximate firm-product variation and country-product variation through a set of dummies for each provides an easy and direct way of discriminating between all the models discussed above.

Before discussing the results of the specification (18), we first consider the within data variation explained by firm, product and country-level effects alone. The highly disaggregate nature of our trade data at the 8-digit CN level enables us to examine heterogeneity of within-firm, within firm-product and within country-product unit values and output across countries and to compare results to earlier findings in the literature.

4.4 Results

4.4.1 Heterogeneity across firms, products and countries

In our dataset, quantities can expressed in weight (kilograms) or alternatively in units (pairs, liters, and so on). In Table 2a we present the results when weight is used for measuring quantities for which we have most observations.

In column 1 we include firm-fixed effects (FE) to see how much data variation in prices and quantities is explained by firm heterogeneity. Including firm-FE is equivalent to assuming that there is only one source of heterogeneity in the data and it works at the firm level, for example when cost and quality differences are small between products of the same firm but are significant between products of different firms. The results in column (1) do not confirm this assumption. The inclusion of firm-FE alone explains about a third (38%) of the variation in prices. This finding is comparable to Munch and Nguyen (2010) and others.[19] But while previous studies looked at sales variation, we separate price from quantity variation. For quantities, firm-specific effects explain much less of the variation. Only 16% to 19% are explained depending on whether we measure output as "quantity per capita of the destination country" or "quantity per dollar of GDP of the destination country." The variation that firm-FE explain of simple quantities is 17% and lies between the other two output measures.

What about product-FE? In other words, how much of the variation in firm-product-country prices is driven by the type of product. Product-FE (columns 2 to 5) in the weight regressions, explain about 30% of price variability, but this varies substantially with the level of detail at which we define a product. At the most disaggregate level (CN2-FE) of a product definition products explain 18% of price variation and about 4% of quantity variation. At the most detailed product definition (CN8-FE), products explains 40% of price variation and about $12 - 15\%$ of quantity variation, depending on how we measure quantities.

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[18]We cannot run a selection model, like a Heckman two-stage model, since the second stage does not allow us to compute a meaningful measure of the goodness-of-fit which is the measure we need to compare the variability explained in the price and quantity regressions. But in the theory we show that our results do not depend on selection issues.

[19]Munch and Nguyen (2012) find that firm-specific effects explain 31% of unconditional export sales variation of Danish firms. Eaton, Kortum and Kramarz (2010) France finds that variation of sales conditional upon entry explains 39% of variation. Lawless and Whelan (2008) for Irish firms find firm-specific effects to account for 41% of firm destination sales variation.

Clearly, for a given product, export unit values exhibit substantial variation. But the remaining variability is large and either comes from different firm-level costs and quality or from different destination countries served by the firms selling the same product.

With country-product FE, the explained variability for quantities is substantially higher (columns 6 to 9). For weights (Table 2a), at the most detailed product-level (country-CN8), 55% of export price variability and 32% to 48% of quantity variability are explained. The R^2 for price and quantities in general are closer together when country-product fixed effects are considered. This is not a surprise and is consistent with both the verti-zontal and CES models. In the verti-zontal model country-product dummies which capture destination country-effects affect both prices and quantities. But country-product effects, at least in part, also capture taste heterogeneity since taste varies across countries. Taste is inherently non-linear, therefore we expect the country-dummies, which are parallel shifters, to capture quantity variation in part. This is especially true when we consider "quantities per dollar of GDP of the destination country" where we already divide the dependent variable output by a country-specific variable.

With firm-product FE as the sole regressors (columns 10 to 13), the variability explained is also high compared to firm-level FE. This supports the assumptions made earlier in Sections 2 and 3 that most variation in quality and unit cost was at firm-product level. This assumption allowed making predictions independent of the single or multiple product nature of firms. Empirically, however, that assumption needs to be verified. At the most detailed level (firm-CN8), the explained price variability of observations in weight is now about 67%, while for quantities, the explained variability with the inclusion of firm-product FE explains about 33%, depending on how quantities are measured. Thus, the inclusion of a firm-product FE explains much more variability in both the price and quantity regressions than either firm- FE or product-FE. This justifies a theoretical approach that allows demand to vary by firm-product rather than by firm or by product only.[20]

In Table 2b we show the results for units. The number of observations and varieties are much lower and all FE explain more of the variation in the data. For prices ("unit values per unit") all types of FE give a higher fit in the regressions with units than with weights. But more importantly, the difference in R^2 between the price and the quantity regression is consistently present with a lower R^2 in the quantity regressions. For observations in units, which are arguably less subject to measurement error than weights, the difference of goodness-of-fit between prices and quantity regressions is even larger.

Single-attribute models, like the one in Table 2, leave a substantial amount of variability unexplained, as also pointed out by Hallak and Sivadasan (2013). But the F-tests at the bottom of the Table 2 that test for the relevance of the single-attribute regressors, are all significant. This suggests that firm-product and country-product are both important regressors to include since each one explains a significant part of the variation in the firm-product-country data. The F-tests for the price regressions are typically more than double those for quantities, which is suggestive that the linear functional form that we impose by including the dummies is more suited to explain prices than quantities.

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[20]Munch and Nguyen (2012) using Danish export data also point out that the firm-product dimension is important to explain data variation.

INSERT TABLE 2 HERE.

However, from the single-attribute models in Table 2, we do not know how important firm-product FE versus country-product FE are in explaining data variability since a comparison of R^2 across different models is not meaningful.[21] Firm-product and country-product FE models both result in a high R^2, especially with observations in units (Table 2b). A variance decomposition analysis will help us to determine the relative role of firm-product FE and country-product FE when included jointly in the regression. At the same time, it will also help us to discriminate quadratic utility models from CES models. Quadratic utility models predict that country effects are an important determinant of prices, while CES type of models see no role for country-effects to explain prices.

In the ANOVA Table 3, we consider a combined attribute model of firm-CN8 and country-CN8, since the R^2 of the stand-alone regressors in Table 2 were highest at this most detailed product definition, thus raising most doubt on the need for a combined attribute model. The ANOVA decomposition should tell us if a combined model is justified. Since the inclusion of firm-CN8 FE involves a larger number of dummies (degrees of freedom) than in the case of country-CN8 dummies, we may wrongly conclude that firm-product FE explain more of the data variation. The ANOVA analysis takes this different number of dummies into account such that we get a better idea about the relative importance of each regressor.

The results are shown in Table 3 where the top panel shows the results for the price regressions and the bottom panel for the quantity regressions. We report the Mean Sum of Squares (MS), which is the outcome of dividing the Partial Sum of Squares of each regressor (not shown for brevity) by its degrees of freedom from the regressions. As such the MS gives the explanatory power of each regressor per degree of freedom. Measured this way, firm-CN8 FE and country-CN8 FE account for a relatively even part of the variation explained, be it that the relative importance of the regressors alternates between specifications. In the quantity regressions, the importance of variety- verus country-FE is about even, while in the price regressions, the country-FE appear to be more important per degree of freedom. We do not explore this further since the relative importance of variety- verus country-specific effects is beyond this paper's objectives. More importantly, the ANOVA analysis confirms that the inclusion of both variety-effects and country-effects seem warranted explaining price and quantity variation.[22]

INSERT TABLE 3 HERE.

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[21]Only when the regressors are orthogonal and completely uncorrelated does the increase in the R^2 tell us what the contribution of each regressor is. But this is unlikely here.

[22]Munch and Nguyen (2012) argue that an ANOVA analysis in an unbalanced dataset may bias results, which means we cannot draw too strong conclusions on the relative importance of variety-versus country-effects, other than that both seem needed.

4.4.2 Combining variety and country dummies

The F-tests on the single-attribute models in Table 2 suggest that firm-product and country-product dummies in isolation are relevant regressors while the variance decomposition in Table 3 suggests that the combination of the two is necessary to explain the data variability.

The results of combining variety and country dummies to explain price and quantity variation are shown more systematically and for different product-level definitions in Table 4. In this Table we show the results of regressions where we pool data over all product categories, essentially assuming a single market in which all goods compete and insert firm-product and country-product dummies. We progressively narrow the definition of a product-market starting with firm-CN2 and move towards firm-CN8.

Independent of the product-market definition, we see that the variability explained in the price regression is always higher than in the quantity regressions. In the weights regressions, the difference between price and quantity regressions' R^2 is about 20% to 40%, while for the units' regressions in the bottom panel the difference is closer to around 40%. In the units' regressions, the variation in the quantity regression explained is typically less than half of what is explained by the same two sets of dummies in the price equation. It is worth noting that the finer the firm-product and country-product definition, the better the goodness-of-fit for both the price and quantity regressions. But this can be attributed to the fact that more dummies also imply less residual degrees of freedom in the regression which tends to raise the R^2.

INSERT TABLE 4 HERE.

Two important insights emerge from the combined-attribute models in Table 4. First, while price variability is pretty much pinned down by a combination of variety and country dummies, quantity variability is less so. This is in sharp contrast to models that predict that prices and quantities should be perfectly correlated as they are supposedly determined by the same sources of variability, as in the standard quadratic utility setting. In addition it is in contrast with models predicting that destination-specific characteristics are the only additional source of variability when moving from prices to quantity equations, such as the CES. But our data seem to suggest that different sources of variability are at work, being destination-variety specific and affecting quantities rather than prices. Second, the empirical results show that the linear functional form that we imposed in (18) gives a good fit for prices but a consistently lower fit for quantities. This is in line with what we expect since the verti-zontal theory suggests that a linear form applies to prices but not to quantities which are inherently non-linear.

4.4.3 Regressions by products and industries

Pooling all the data, as we did until now, is similar to considering the product market as one integrated market which may hide heterogeneity between industries. For this reason in Table 5 we report results for (18) based on product-level regressions.

Based on the results thus far we can say that including both variety- and country-FE at the most detailed product (CN8)-level is the specification that works most against our results since the price and quantity regressions for this most detailed definition of a product market lie closest

to each other. Therefore we will work with this specification to give the data most chance to overthrow our theory.

In Table 5, we first consider all firm-CN8 varieties belonging to the same CN2 and exported to the same country to be in competition with each other in every country they are exported to. Put differently, we start by considering CN2 as the relevant product market where all goods are substitute products. This results in about 90 different CN2 product markets for weights and about 45 different CN2 industries for units. For each of these industries we run separate regressions of price and output on variety- and country-product FE.[23]

Column 1 of Table 5 reports the weighted average R^2 across all CN2 industries which is 65% for prices and about 36% for simple quantities. The corresponding numbers for the units' regressions is an average R^2 of 74% for prices and around 37% for simple quantities regressions.[24] Column 2 shows the percentage of times that the goodness-of-fit in the price regressions exceeds that of the quantity regressions, which is around 93% for weight and 82% for units' regressions when considering simple quantities.[25] We subsequently narrow the definition of a relevant product market from CN4, CN6 to CN8. Even in the most narrow product market definition, where we consider 1,701 separate regressions for each of the CN8 industries considered (weights), we find the weighted average R^2 for prices to be 66% and for simple quantities to be 46%. Column (3) shows that in 77% of the 1,701 regressions that we ran, the goodness-of-fit in the price regression is strictly higher than that of the simple quantity regressions. Results are qualitatively the same when considering varieties in units. Results do not differ much when we measure output in a different way, although R^2 tend to go up slightly when considering quantity per capita or quantity per dollar of GDP.

Regressions at product-level thus confirm our prediction that a linear model, like the one in (18), appears to have less predictive power in quantity regressions. While this holds for the large majority of products that we consider, from column (3) in Table 5 it is clear that there are instances where there is not always a positive difference between price and quantity R^2. Our theory does not rule out the existence of products where taste differences are not very important or where business-to-business sales are more important than business-to-consumer.[26] Put differently, in the case of intermediate products the cost-minimizing combination of inputs in production functions may differ from the utility-maximizing consumption bundle of consumers. Our model is more likely to explain price and quantity variation of final consumption goods than of intermediate goods.

To have a first indication for which industries taste differences seem to matter less, we report in Table 6 industry-level regressions, where we group the CN2 products by the sections to which they belong in the RAMON Eurostat classification.

For the fourteen so-obtained industries, the regressions for weights do not reject our model.

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[23]In the product-level regressions we define the country-product at country-CN2 in the CN2 regressions, at country-CN4 in the CN regressions and so forth.

[24]For each CN product category averages are weighted by the number of observations, but results are very similar for weighted and simple averages.

[25]Results are very similar for the unweighted averages and will be suppressed. They are available upon request.

[26]Similar R^2 in prices and quantities could point at the absence of taste heterogeneity. A higher R^2 in the quantity regression than in the price regressions corresponds with predictions of a quality augmented CES model with quality differences for the same product by destinations.

The R^2 for prices is typically 20% to 30% higher than for quantities. Only for exports in units for "Minerals and Chemicals" the quantity regression shows a stronger goodness-of-fit. This may suggest that taste effects are not important in this industry or that "Minerals and Chemicals" is more of a business-to-business industry for which our model may not apply.

More detailed industry studies will likely reveal where taste heterogeneity is strong and where it is not or where other factors are at play. In any case, all the evidence presented above seems to suggest that in the large majority of products and industries, taste heterogeneity matters since that is today the only model which can explain consistently lower R^2 of specification (18) in quantity regressions than in price regressions.

4.5   Robustness: correlations and remote destinations

A legitimate concern is whether our results are not driven by the fact that the most important trading partners for Belgium are European, which may have a dampening effect on price differences. If the high goodness-of-fit in the price regressions is the result of arbitrage or lack of border controls, this could drive the results. Therefore, as a consistency check, we investigate whether this trade orientation towards European destinations may have affected our results.

We do so by looking at a set of heterogeneous and remote countries (Australia, Brazil, Canada, China, India, Japan, South Africa, Turkey, and US)[27] together with the three main trading partners of Belgium (France, Netherlands and Germany). For these countries we consider pairwise bilateral correlations for each country-pair of Belgian export prices and quantities shipped. An advantage of using correlations is that differences can be statistically tested for. But for pairwise correlations to be meaningful, we exclude zero trade flows here and only consider those varieties that are present in all countries. This results in a balanced panel of 87 varieties and 1,044 observations.[28]

These pairwise correlations all lie around 90%, which is the average of all the bilateral price rank correlations considered and is indicated by the solid line at the top of Figure 1. Proposition 1, which predicts that the price rankings of varieties within destination countries will not be affected by country effects, is confirmed by the high price correlation we find. Therefore, we would expect stable price rankings amongst a set of varieties exported even when the destination countries are remote and heterogeneous compared to the country of origin.

In contrast, the bilateral quantity ranking correlations given by the triangle dots in Figure 1, can be as low as 50% as indicated by the dashed horizontal line segment, which is what we expect on the basis of Proposition 2. The four most correlated country pairs in terms of quantity ranks correspond to the three EU member states considered (France, Netherlands and Germany) and Turkey, a candidate EU member country. Of all the countries included, the ones with the highest pairwise quantity rank correlations are the three European countries. This can clearly be seen from Figure 1 where EU countries are circled. Figure 1 thus suggests that taste

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[27]The criteria for choosing these countries included a maximum distance from Belgium, including as many different continents as possible and conditioning on the fact that countries received the same set of varieties exported from Belgium.

[28]The lower quantity correlations, which we find in this balanced sample, are in line with the goodness-of-fit results obtained on the unbalanced sample in the previous section. This confirms that selection issues are not driving our results.

differences are smallest in the three EU countries included, which seems quite plausible given their proximity. All the quantity correlations are lower than price correlations in a statistically significant way at a 1% confidence level.

INSERT FIGURE 1 HERE.

The evidence in Figure 1 also shows that measurement error in quantities as an alternative explanation for our findings is unlikely. Measurement error would result in random variability in quantities, but Figure 1 clearly shows that quantity variation is lower in nearby countries. This makes an explanation like "taste" more plausible as a source of quantity variation than measurement error. Figure 1 also suggests that taste and distance to destination may be highly correlated, which raises some doubts on the correct specification of many gravity models where distance typically features as the prominent explanation explaining bilateral trade flows but which may in part capture taste effects that run along similar dimensions. This is another reason why future research should be focusing on separating taste effects in trade from other potential explanations at work.

5   Conclusions

This paper departs from standard specifications of preferences used in trade models by enriching the demand side. We deviate from the assumption that all substitute varieties within the same country face the same demand, and instead we allow for two important aspects of taste heterogeneity. First, varieties sold in the same country are allowed to be vertically differentiated as well as to have a different match with local consumers' tastes. Second, the same variety sold in different countries is allowed to face a different demand depending on the interactions between local tastes and competition effects. This leads to a new and tractable framework in which taste heterogeneity interacts with cost and quality heterogeneity. We call it a verti-zontal model to stress its vertical and horizontal attributes. Our model displays enough versatility to be applied to a wide range of new issues.

An important prediction arising from taste heterogeneity is that firm-product-country exports can be idiosyncratic and display additional variability even after controlling for firm-product specific productivity and parallel demand shifters. Detailed firm-product-country data for Belgian exporting firms confirm this prediction, which the model rationalizes as the outcome of taste differences unrelated to destination market size or income differences. This missing source of variation cannot be rationalized by any type of preferences used in models based on productive efficiency nor by models with a combination of efficiency and quality, but can be captured by the new preferences we propose here. When empirically controlling for country-level differences, we still find quantity variation, which the theory we put forward rationalizes as taste differences.

However, we do not claim that taste heterogeneity is the only possible explanation for the sales variation of firm-products across countries. Other potential sources of quantity variability, such as variation in distribution networks (Arkolakis, 2010) or demand build-up over time (Fos-

ter, Haltiwanger, Svyerson, 2012) exist and future research should be aimed at disentangling the role of taste versus other explanations. But this calls for a more dynamic analysis of panel data and may prove difficult as such alternatives may be highly correlated with taste factors, which are less directly observable. For example, the absence of a distribution network for a given variety may stem from the mismatch between the variety and local tastes. All that we claim here is that *asymmetric preferences and heterogeneous tastes across countries* can rationalize the data as a potential source of quantity variation.

Future research can be directed towards the empirical identification of the demand parameters involved in the verti-zontal model such as the identification of the taste parameter, clearly distinguished from the quality parameter. This calls for an external validation similar to the approach of Crozet, Head and Mayer (2012) who use an external classification of champagne to calibrate the productivity and quality parameters using CES preferences. The quality and taste parameters arising from the verti-zontal model would then become available for a much wider set of product markets, including those for which external quality and taste indicators do not exist. Also, the empirical identification of the demand parameters can then be used to strip price indices from quality and taste changes to get bett er estimates of GDP growth indicators as currently also pursued by Feenstra and Romalis (2012) who use a different model.

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Appendix A. The micro-foundations of taste mismatch

To show how $\beta(s)$ can be interpreted as a *taste mismatch* between variety s and the consumer's ideal, we use a spatial metaphor based on the Hotelling (1929) model that has been used extensively in the industrial organization and marketing literature. In this metaphor, consumers are located on a unit line segment with a shop located at each end. The consumer's location on the line determines the distance she has to walk to the shop where she buys one unit of a good. The distance travelled corresponds to the consumer's taste mismatch between her ideal variety, given by the consumer's location and the variety on offer in the shop. In Figure 2, we depict such a setting in which two varieties/shops, indexed $s = 1, 2$, are located at the endpoints 0 and 1. Normalizing the transport rate at 1, $\beta_1 \equiv \beta(1)$ is the distance between the consumer and shop 1. In other words, a high (low) value of β_1 amounts to saying that the consumer is far from (close to) shop 1. The further the consumer is from the shop, the lower her utility from consuming the good, due to the disutility of traveling a long distance. Moreover, $\beta_2 \equiv \beta(2) = 1 - \beta_1 > 0$ is the distance between our consumer and shop 2. When preferences are symmetric, the consumer is located at $\beta_1 = \beta_2 = 1/2$.

We now show that this distance in the Hotelling spatial model corresponds with the parameter $\beta(s)$ in the quadratic preferences. When preferences exhibit a *love-for-variety* as in (2), consumers may visit several shops and can buy several units (see Hart, 1985, and Chen and Riordan, 2007) of different varieties of a good. To facilitate the analogy between the Hotelling model and the quadratic preferences in (2), we make a simplifying assumption where we limit the number of goods in (2) to two and where we assume that $\alpha(1) = \alpha(s) = \alpha$. Under this assumption, the consumer's willingness-to-pay (WTP) is equal to α.

This allows us to draw an analogy between Hotelling's spatial model, where consumers are heterogeneous in one dimension, i.e. their location, and the preferences in (2) in which varieties can differ along several dimensions.

To explain this link we turn to Figure 2 and consider to what the new preferences in (2) correspond to. Assume first that a particular consumer i on the line considers buying variety 1. Because $\beta_1 < 1 - \beta_1$, the consumer located at β_1 is willing to buy variety 1 first if her distance to shop 1 is smaller than α. For this to happen, the interval $[1 - \alpha, \alpha]$ must be non-empty. In

other words, the WTP for the differentiated good must be sufficiently large. When $\beta_1 < \alpha$, the consumer visits shop 1.

While Hotelling's story stops here because consumers make mutually exclusive purchases, this is not the case in *love-for-variety* preferences. As long as α exceeds $1/2$,[29] there is a segment $[1 - \alpha, \alpha]$ in which both $\alpha - \beta_1$ and $\alpha - (1 - \beta_1)$ are positive for any $\beta_1 \in [1 - \alpha, \alpha]$. Since consumers have a love for variety, consumer i wants to visit both shops if she is located in the segment $[1 - \alpha, \alpha]$. However, for this to happen, when turning to shop 2 we must account that the consumer has already acquired one unit of the good so that her WTP is now shifted downward by $\gamma/2$. Therefore, the segment over which both shops are actually visited is narrower than $[1 - \alpha, \alpha]$ and given by $[1 - \alpha + \gamma/2, \alpha - \gamma/2]$. Consequently, when the consumer is located at $\beta_1 < 1 - \alpha + \gamma/2$ ($\beta_1 > \alpha - \gamma/2$), she visits shop 1 (2) only, whereas she chooses to visit both shops when her location belongs to $[1 - \alpha + \gamma/2, \alpha - \gamma/2]$. For this to be possible, however, this interval must be non-empty, that is, the condition

$$2\alpha > 1 + \gamma$$

must hold. This is so when the desirability of the differentiated good is high, the substitutability between the two varieties is low, or both. Conversely, it is readily verified that, regardless of her location, the consumer acquires a single variety if and only if

$$\gamma > 2\alpha - 1.$$

In other words, when varieties in (2) are very good substitutes, consumers choose to behave like in the Hotelling model: despite their love for variety, they visit a single shop because the utility derived from buying from the second shop is overcome by the cost of visiting this shop.

The foregoing argument shows how the spatial model can cope with consumers buying one or two varieties of the differentiated good and how consumers' decisions to buy one or two varieties are related to the taste mismatch with each variety. While we develop the example for two varieties on offer, this can be extended to any number of varieties. In particular, when consumers' ideal varieties are described by means of n-dimensional vectors with $n > 1$, it is readily verified that what we have said above can be extended by considering $n + 1$ varieties in R^n.

Appendix B. How income matters

In the text, income had no impact on the demand for the differentiated good. Yet, it is reasonable to expect consumers with different incomes to have different WTP. When the product under consideration accounts for a small share of their total consumption and the numéraire is interpreted as a Hicksian composite good representing a bundle of all the other products, we may capture this effect by slightly modifying consumer i's utility function. Specifically, in (2) we

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[29]When $\alpha < 1/2$, a consumer located in the central area does not shop at all because both her desirability of the differentiated good is low and her taste mismatch is high. In the standard Hotelling framework, this corresponds to the case in which the price of the good plus the transport cost borne by the consumer exceeds her reservation price.

replace q_0 with $q_{0,i} = \delta_i q_0$ where $\delta_i > 0$ measures consumer i's marginal utility of income. Because this typically decreases with the consumer's income, we may rank consumers by decreasing order of income, and thus $\delta_1 < \delta_2 < ... < \delta_n$ where $\delta_1 = 1$ and $q_{0,1} = q_0$ by normalization.

Consumer i's inverse demand for variety s becomes

$$p_i(s) = \max \left\{ \frac{\alpha(s) - \beta_i(s)q(s) - \gamma Q_i/2}{\delta_i}, 0 \right\}$$

where $p_i(s)$ is expressed in terms of the numéraire of the richest consumer: the lower δ_i, the more the inverse demand is shifted upward. Thus, we indirectly capture the impact of income on demand. In addition, though we find it convenient not to assume any a priori relation between the quality of variety s, $\alpha(s)$, and its taste mismatch with a particular destination market, $\beta_i(s)$, we acknowledge that the relation between these parameters is likely to be correlated with income or other related variables (Gabszewicz and Thisse,1979). Hence what we show is that a quasi-linear model like ours can deal with income differences across countries but cannot deal with income inequality within countries. Still, to work with a representative consumer model seems a reasonable assumption in view of the current data availability. Most available trade data, like ours, only have one observation per firm-product-country which does not allow analysis of consumer differences within countries.

Figure 1: Pairwise rank correlations for a sample of the 12 relevant export markets selected from across the globe
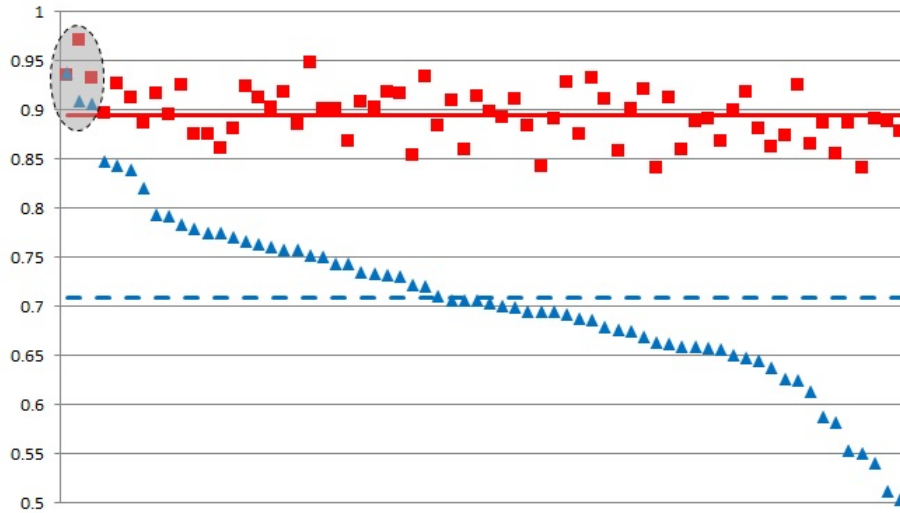
Notes: The countries considered are: France, Netherlands, Germany, US, Canada, Brasil, South Africa, Australia, Turkey, China, India, Japan. The square dots indicate price rank correlations for all the 66 country pair combinations, triangle dots indicate pairwise quantity rank correlations. The horizontal line segments refer to the averages: the solid one refers to prices, the dashed one to quantities. Note that for illustrative purposes country pairs have been sorted in decreasing quantity rank correlation order. The shaded area covers the three most correlated country pairs in terms of quantity ranks: France-Netherlands; Germany-France; Germany-Netherlands.

Figure 2: The spatial metaphor of verti-zontal preferences
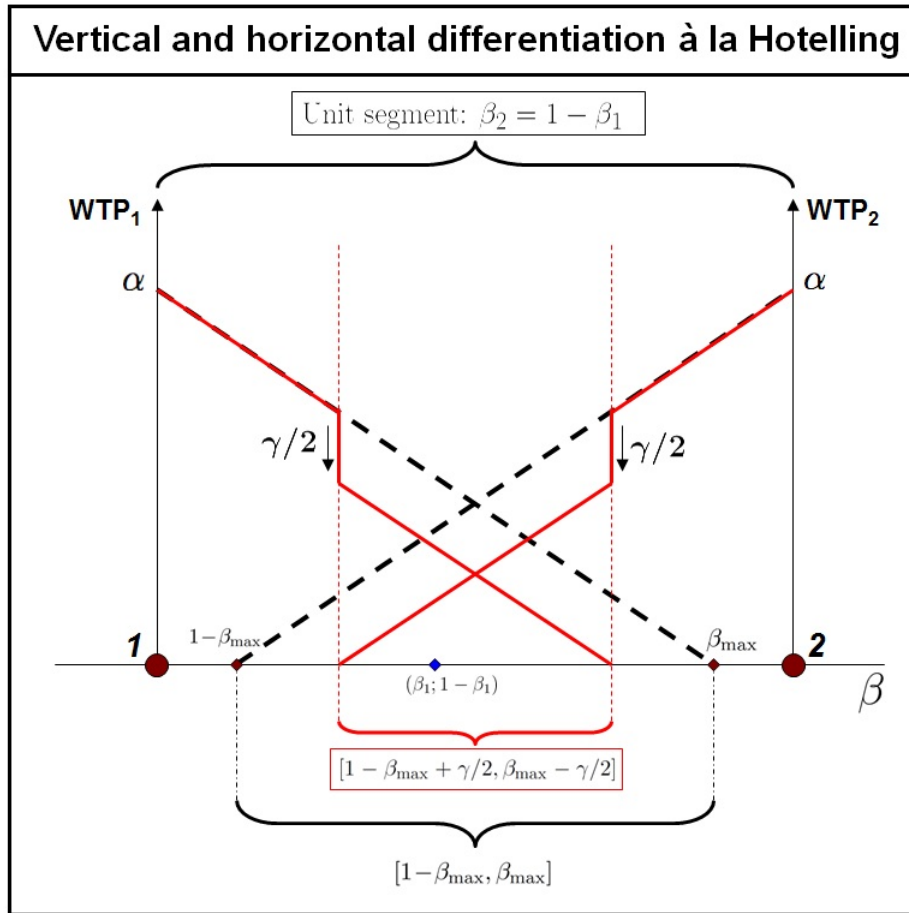
Table 1: The Full and Restricted Data Sample of Belgian Firm-Product-Country Exports.

	WEIGHT		UNITS	
	(1)	(2)	(3)	(4)
	Full sample	Restricted sample	Full sample	Restricted sample
Observations	239,127	111,876	52,227	20,929
Firms	5,386	3,528	2,521	1,067
CN2 Products	95	89	56	46
CN4 Products	1,159	755	315	182
CN6 Products	4,122	1,999	1,161	494
CN8 Products	7,051	2,691	1,922	604
Firm-CN2 Combinations	20,358	8,835	4,844	1,748
Firm-CN4 Combinations	36,709	13,333	7,000	2,320
Firm-CN6 Combinations	50,234	17,759	10,243	3,454
Firm-CN8 Combinations	62,355	19,612	12,842	3,703
Destinations	220	139	206	108
CN2-Destination Combinations	8,283	3,646	3,236	1,214
CN4-Destination Combinations	38,924	13,089	9,404	2,544
CN6-Destination Combinations	78,997	23,738	19,500	4,908
CN8-Destination Combinations	107,681	28,343	26,538	5,548
Trade volume (bill. euros)	88.10	27.02	23.91	8.78
Destinations per firm-CN8:				
Mean	3.84	5.71	4.07	5.65
Median	1	3	1	4
Min	1	1	1	1
Max	160	67	118	60
Firms per CN8-destination:				
Mean	2.22	3.95	1.97	3.77
Median	1	3	1	3
Min	1	2	1	2
Max	235	192	113	76

Notes: "We use raw data on unit values and quantities dropping outliers at the 1% of the distribution. To be able to identify a variety-specific and a market-specific effect in the regressions, in the restricted sample we impose a minimum number of two markets for each firm-CN8 product and a minimum of two firms for each country-CN8 market."

Table 2a: Single-attribute Models and Goodness-of-fit for Pooled Observations in Weight (Kgs).

	(1) $y = p, q$	(2) $y = p, q$	(3) $y = p, q$	(4) $y = p, q$	(5) $y = p, q$	(6) $y = p, q$	(7) $y = p, q$	(8) $y = p, q$	(9) $y = p, q$	(10) $y = p, q$	(11) $y = p, q$	(12) $y = p, q$	(13) $y = p, q$
Firm FE	YES												
Product (CN2) FE		YES											
Product (CN4) FE			YES										
Product (CN6) FE				YES									
Product (CN8) FE					YES								
Country-CN2 FE						YES							
Country-CN4 FE							YES						
Country-CN6 FE								YES					
Country-CN8 FE									YES				
Firm-CN2 FE										YES			
Firm-CN4 FE											YES		
Firm-CN6 FE												YES	
Firm-CN8 FE													YES
Price reg. R^2	38.3%	18.5%	33.4%	37.9%	40.0%	23.6%	45.7%	52.7%	55.6%	53.2%	62.9%	66.5%	67.9%
Quantity reg. R^2	17.4%	4.2%	8.8%	11.2%	12.6%	9.1%	19.6%	28.1%	32.6%	22.0%	26.2%	30.1%	32.5%
Q. per capita reg. R^2	16.6%	4.2%	8.8%	10.9%	12.5%	14.2%	26.5%	34.9%	39.3%	21.7%	25.6%	29.1%	31.8%
Q. per GDP reg. R^2	18.9%	4.4%	11.3%	13.5%	15.6%	25.1%	38.6%	46.0%	48.9%	24.9%	28.8%	31.9%	34.3%
F-test p reg.	19.05	288.36	73.80	33.56	27.02	9.15	6.34	4.14	3.69	13.25	12.55	10.51	9.94
F-test q reg.	6.48	55.40	14.23	6.93	5.84	2.97	1.84	1.45	1.43	3.30	2.62	2.28	2.27
F-test qpc reg.	6.09	56.38	14.16	6.70	5.78	4.91	2.72	1.99	1.91	3.24	2.55	2.18	2.19
F-test qpGDP reg.	7.17	59.01	18.68	8.60	7.47	9.94	4.74	3.16	2.83	3.86	2.99	2.49	2.46

Notes: The results in this table are based on the restricted sample as described in Table 1, for quantities expressed in weight (kilograms).

Table 2b: Single-attribute Models and Goodness-of-fit for Pooled Observations in Units.

	(1) $y = p, q$	(2) $y = p, q$	(3) $y = p, q$	(4) $y = p, q$	(5) $y = p, q$	(6) $y = p, q$	(7) $y = p, q$	(8) $y = p, q$	(9) $y = p, q$	(10) $y = p, q$	(11) $y = p, q$	(12) $y = p, q$	(13) $y = p, q$
Firm FE	YES												
Product (CN2) FE		YES											
Product (CN4) FE			YES										
Product (CN6) FE				YES									
Product (CN8) FE					YES								
Country-CN2 FE						YES							
Country-CN4 FE							YES						
Country-CN6 FE								YES					
Country-CN8 FE									YES				
Firm-CN2 FE										YES			
Firm-CN4 FE											YES		
Firm-CN6 FE												YES	
Firm-CN8 FE													YES
Price reg. R^2	70.3%	37.1%	70.9%	76.5%	81.3%	43.5%	79.7%	84.8%	86.7%	81.1%	86.1%	89.9%	91.8%
Quantity reg. R^2	18.1%	5.1%	7.7%	10.2%	11.3%	12.9%	20.0%	28.0%	32.8%	20.8%	23.5%	26.3%	28.7%
Q. per capita reg. R^2	20.3%	6.6%	9.6%	11.7%	12.6%	20.2%	30.4%	37.1%	40.4%	23.5%	25.9%	28.7%	30.1%
Q. per GDP reg. R^2	20.1%	6.8%	10.9%	13.9%	14.8%	34.8%	42.3%	50.3%	52.1%	23.1%	25.8%	30.1%	30.7%
F-test p reg.	44.11	273.33	279.82	134.80	146.54	12.54	28.37	18.15	18.13	47.16	49.77	45.27	52.35
F-test q reg.	4.13	24.69	9.58	4.69	4.31	2.41	1.80	1.27	1.35	2.88	2.47	1.81	1.87
F-test qpc reg.	4.73	32.80	12.15	5.48	4.88	4.12	3.16	1.93	1.88	3.38	2.80	2.04	2.00
F-test qpGDP reg.	4.68	34.00	13.96	6.69	5.88	8.66	5.30	3.31	3.02	3.29	2.79	2.18	2.06

Notes: The results in this table are based on the restricted sample as described in Table 1, for quantities expressed in units (litres, bottles, pairs etc).

Table 3: Analysis of Variance (ANOVA) in dummy regressions.

	(1) Price Regression $y = p$	
	Mean Sum of Squares	
	weight	units
Firm-CN8 FE	7,401	923,217
Country-CN8 FE	14,510	3,285,966
	Quantity Regression $y = q$	
	Mean Sum of Squares	
Firm-CN8 FE	3.0467e+11	1.0277e+11
Country-CN8 FE	4.1216e+11	1.1867e+11

Notes: The results in this table are based on the restricted sample as described in Table 1, for quantities expressed in weight and units. The results refer to the dummy regressions including firm-CN8 and country-CN8 FE.

Table 4: Goodness-of-fit of the Verti-zontal Model for Weight and Units.

	(1) $y = p, q$		(2) $y = p, q$		(3) $y = p, q$		(4) $y = p, q$	
Firm-CN2 FE	YES							
Firm-CN4 FE			YES					
Firm-CN6 FE					YES			
Firm-CN8 FE							YES	
Country-CN2 FE	YES							
Country-CN4 FE			YES					
Country-CN6 FE					YES			
Country-CN8 FE							YES	
	weight	units	weight	units	weight	units	weight	units
Price regression R^2	55.7%	83.1%	70.9%	91.2%	76.9%	95.1%	79.1%	96.0%
Quantity regression R^2	28.6%	31.3%	40.3%	39.7%	50.7%	48.9%	56.7%	54.8%
Q per capita regression R^2	31.6%	36.7%	43.5%	46.6%	53.4%	54.6%	59.1%	58.5%
Q per GDP regression R^2	39.6%	44.5%	51.7%	52.5%	60.0%	62.9%	63.7%	64.7%
Number of observations	111876	20929	111876	20929	111876	20929	111876	20929
Number of dummies	12482	2963	26423	4865	41498	8363	47956	9252

Notes: The results in this table are based on the restricted sample as described in Table 1, for quantities expressed in weight (kilograms) and units (litres, bottles, pairs etc).

Table 5: Product-level Regressions and Goodness-of-fit for Weight and Units.

	(1) Weighted averages		(2) How often price R^2>quantity R^2		(3) Number of products	
	weight	units	weight	units	weight	units
by CN2						
Price R^2	**65.3%**	**74.0%**	.	.	89	46
Quantity R^2	36.3%	36.9%	93.3%	82.6%	89	46
Q per capita R^2	37.5%	40.6%	87.6%	84.8%	89	46
Q per unit of GDP R^2	42.4%	44.7%	84.3%	80.4%	89	46
by CN4						
Price R^2	**65.4%**	**69.5%**	.	.	740	178
Quantity R^2	39.4%	41.4%	83.2%	79.8%	740	178
Q per capita R^2	42.5%	45.8%	81.8%	78.7%	740	178
Q per unit of GDP R^2	46.2%	49.6%	78.5%	78.7%	740	178
by CN6						
Price R^2	**65.7%**	**71.4%**	.	.	1,930	482
Quantity R^2	44.3%	47.7%	77.5%	78.6%	1,930	482
Q per capita R^2	48.7%	51.3%	75.2%	75.9%	1,930	482
Q per unit of GDP R^2	51.5%	55.2%	73.4%	74.1%	1,930	482
by CN8						
Price R^2	**66.4%**	**71.4%**	.	.	2,541	589
Quantity R^2	46.5%	49.9%	77.2%	78.6%	2,541	589
Q per capita R^2	50.6%	53.2%	74.9%	76.2%	2,541	589
Q per unit of GDP R^2	53.1%	56.5%	72.6%	74.4%	2,541	589

Notes: The results in this table are based on the restricted sample as described in Table 1, for quantities expressed in weight (kilograms) and units (litres, bottles, pairs etc). the only additional restriction, per CN product, is that the number of regressors for ech type of dummy is lower than the number of observations to ensure some variability in the sample. The regressors included are firm-CN8 and country-CN FE, for the different CN product categories. For each CN product category, averages of all the CN products are weighted by their number of observations.

Table 6: Industry-level Regressions and Goodness-of-fit for Weight and Units.

INDUSTRIES (CN2 product codes)	Exports in weight			Exports in units		
	(1) R-squared price regression	(2) R-squared quantity regression	(3) Obs. # (model degrees of freedom)	(4) R-squared price regression	(5) R-squared quantity regression	(6) Obs. # (model degrees of freedom)
Agriculture	81.5%	35.5%	6,821	.	.	.
CN2 codes 1 to 15			(1,420)			.
Food and beverages	78.9%	33.6%	11,625	62.0%	44.4%	1,204
CN2 codes 16 to 24			(2,047)			(271)
Minerals and chemicals	76.8%	37.1%	16,277	36.2%	55.5%	344
CN2 codes 25 to 38			(2,649)			(129)
Plastics and rubber	56.7%	34.3%	16,641	65.1%	36.2%	583
CN2 codes 39 and 40			(2,760)			(183)
Leather, skins and wood	78.5%	42.3%	2,353	91.6%	34.3%	1,220
CN2 codes 41 to 46			(562)			(299)
Articles of paper	50.4%	37.5%	5,843	83.3%	59.8%	16
CN2 codes 47 to 49			(1,257)			(12)
Textile articles	86.9%	35.8%	13,544	89.0%	26.8%	12,276
CN2 codes 50 to 63			(2,679)			(2,165)
Footwear and accessories	73.3%	48.1%	322	71.1%	35.5%	356
CN2 codes 64 to 67			(97)			(106)
Construction materials	75.5%	45.9%	2,757	76.8%	42.8%	1,114
CN2 codes 68 to 70			(612)			(245)
Base metals and jewelry	75.5%	40.6%	10,859	77.3%	32.5%	274
CN2 codes 71 to 83			(2,395)			(88)
Mechanical appliances	59.4%	29.0%	17,672	85.4%	38.1%	2,884
CN2 codes 84 and 85			(3,369)			(731)
Transport equipment	75.8%	40.2%	2,160	95.3%	52.8%	330
CN2 codes 86 to 89			(492)			(129)
Precision instruments	62.7%	30.9%	2,128	86.8%	36.9%	550
CN2 codes 90 to 93			(498)			(169)
Furniture and toys	68.6%	27.1%	5,162	69.1%	27.0%	299
CN2 codes 94 to 96			(980)			(85)

Notes: The results in this table are based on the restricted sample as described in Table 1, for quantities expressed in weight (kilograms) and units (litres, bottles, pairs etc). As regressors we include firm-CN8 and country-industry FE. The industry "Agriculture" has been dropped from the sample because it had only 4 observations and the same number of dummies.