

# Demand Uncertainty: Exporting Delays and Exporting Failures

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## Abstract

This paper presents a model of trade that explains why firms wait to export and why many exporters fail. Firms face uncertain demands that are only realized after the firm enters the destination. The model retools the timing of the resolution of uncertainty found in models with heterogeneity of firm productivity. This retooling addresses several shortcomings. First, the imperfect correlation of demands reconciles the sales variation observed in and across destinations. Second, since demands for the firm's output are correlated across destinations, a firm can use previously realized demands to forecast unknown demands in untested destinations. The option to forecast demands causes firms to *delay* exporting in order to gather more information about foreign demand. Third, since uncertainty is resolved after entry, many firms enter a destination and then exit after learning that they cannot profit. This prediction reconciles the high rate of exit seen in the first years of exporting. Finally, when faced with multiple destinations to which they can export, many firms will choose to sequentially export in order to slowly learn more about its chances for success in untested markets.

**Keywords:** firm heterogeneity, trade failures, exporting delay

**JEL Codes:** F12

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## 1. Introduction

Models of international trade incorporating heterogeneity among firms have gained some traction in recent years.<sup>1</sup> Inspired by empirical work documenting the differences between firms that do and do not export, models such as Melitz (2003) plausibly explain why only a fraction of firms export.<sup>2</sup> In these models, high fixed and variable costs of exporting prevent all but the most productive firms from exporting. This mechanism of self-selection has empirical support over other explanations for firm exporting, such as learning-by-exporting.<sup>3</sup>

However, models that heterogenize firms via productivity fail to reconcile several facts that were recently uncovered. For instance, heterogeneity in productivity cannot fully explain the variation of firms sales within a destination. Since productivity is anchored to the firm and translates monotonically to firm sales, these models predict that the variation in productivities for a set of firms selling to a destination should fully explain the variation in sales for that set. Recent work has shown that the variation across firms explains less than half of the variation in total sales within a destination.<sup>4</sup>

Since productivities in Melitz (2003) are realized before the firm supplies to any destination, a firm that begins exporting should export immediately and forever to all destinations. This prediction is inconsistent with evidence that most firms delay entry into exporting, and that many firms stop exporting almost immediately after they begin.<sup>5</sup> As Figure 1 shows, over a third of Colombian firm that exported in the 1980's stopped after only one year, and that the hazard rate of exporting decreases with the time length of exporting.<sup>6</sup> Melitz (2003) is also inconsistent with the pattern of the export expansion of

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<sup>1</sup>Notable examples include Eaton and Kortum (2002), Bernard, Eaton, Jensen, Kortum (2003), Melitz (2003), Bernard, Jensen, Schott (2006), and Bernard, Jensen, Redding, Schott (2007).

<sup>2</sup>Notable works include Aw, Chung, Roberts (2000), Bernard and Jensen (1995, 1999) and Clerides, Lach, Tybout (1998).

<sup>3</sup>See survey by Greenaway and Kneller (2007).

<sup>4</sup>See Eaton, Kortum, Kramarz (2011), Lawless and Whelan (2008), and Munch and Nguyen (2009).

<sup>5</sup>Damijan, Kostevc, and Polanec (2006) find that Slovenian firms supply domestically for two to four years before they start exporting. Eaton, Eslava, Kugler, and Tybout (2007) find that nearly half of Colombian firms who started exporting in 1997 stopped the following year.

<sup>6</sup>Colombian firm data statistics calculated by author from dataset generously provided by Jim Tybout.

Colombian firms, where firms slowly expand the set of destinations to which they export.<sup>7</sup>

Insert Figure 1 here

To reconcile these patterns, I introduce a model of trade akin to Melitz (2003) with two novel contributions. The first is that I allow for the imperfect correlation of firm sales across destinations. I do this by interpreting firm heterogeneity in demand space: firms face perceived quality draws that are firm-destination specific. In Melitz (2003), a model in which the heterogeneity is perfectly correlated across destinations, firms enter all profitable markets simultaneously. In this new model, firms use realized demands in supplied destinations to forecast demands in unsupplied destinations. In a free entry equilibrium, the ability to forecast demands causes firms to *delay* exporting in order to gather more information about foreign demand. This feature of the model reconciles the observed delays in exporting (Damijan, Kostevc, and Polanec 2006). In a multi-country setting, this forecasting ability results in some firms slowly adding countries to their set of exporting destinations, reconciling the pattern that firms export sequentially (Eaton, Eslava, Kugler, and Tybout 2007).

The second difference between this model and Melitz (2003) is the timing of the resolution of uncertainty. A firm in Melitz (2003) realizes its productivity before any supply decisions are made; the firm perfectly forecasts profits as soon as it is born. Those firms that "fail" in Melitz never supply to any destination; they are not firms that we can see in the sales data. In the current model, firms do not know their profits in a destination until after they supply there at least once. This results in some firms garnering negative profits. Those that make negative profit exit the destination the following period. I term this exit a *failure*. If the destination is a foreign country, it is an *exporting failure*. This feature of the model reconciles the high exporting failures seen in Figure 1.

Marketing research points to demand uncertainty as the driver of failures. Table 1

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See Clerides, Lach, Tybout (1998) for data details.

<sup>7</sup>See Eaton, Eslava, Kugler, Tybout (2007)

summarizes the results of marketing studies of product failures. Only one of the eight studies points to unexpected high cost as a cause of failures while all of them attribute failures to over-optimistic forecasts of market demand.<sup>8</sup>

Table 1: Reasons for New Product Failures

	Study							
	1	2	3	4	5	6	7	8
<b>Unexpected high cost</b>						<b>X</b>		
<b>Value to potential buyers was overestimated</b>	<b>X</b>	<b>X</b>	<b>X</b>	<b>X</b>	<b>X</b>	<b>X</b>	<b>X</b>	<b>X</b>
Poor planning	<b>X</b>	<b>X</b>		<b>X</b>	<b>X</b>	<b>X</b>	<b>X</b>	
Timing Wrong	<b>X</b>	<b>X</b>	<b>X</b>	<b>X</b>		<b>X</b>		
Enthusiasm crowded on facts				<b>X</b>	<b>X</b>	<b>X</b>	<b>X</b>	<b>X</b>
Product failed	<b>X</b>	<b>X</b>				<b>X</b>		
Product lacked a Champion					<b>X</b>			
Company politics					<b>X</b>			

1.Abrams (1974), 2.Angelus (1969), 3.Booz, Allen, & Hamilton (1968), 4.Constandse (1971), 5.Diehl (1972), 6.Hopkins & Bailey (1971), 7.MacDonald (1967), 8.Miles (1974)  
 Reproduced from Crawford (1977)

Other papers overcome the imperfect correlation of sales variation across destinations by layering additional sources of heterogeneity such as quality on top of firm-specific productivity.<sup>9</sup> This model is able to reconcile this pattern with a single source of heterogeneity.

The Melitz (2003) model cannot explain the exporting delays and exporting failures present in literature. Recent studies have modeled delays and failures by adding exogenous shocks over time.<sup>10</sup> Firms experiencing these shocks oscillate back and forth across the exporting cutoff. These firms start and stop exporting based on the direction of the shock. This channel certainly explains some of the patterns described above, but has

<sup>8</sup>Marketing studies lament the persistence of high failure rates in light of 75 years of marketing advances. The firm can spend an exorbitant amount of money forecasting market demand only to produce a product that the market ultimately rejects. Recent examples include new Coke and HD-DVD. This points towards a mechanism of failure that cannot be overcome by increasing advertising or other fixed costs.

<sup>9</sup>See for example Eaton, Kortum, Kramarz (2011), Ghironi and Melitz (2005), Das, Roberts, Tybout (2007), Ruhl and Willis (2008), Hallak and Svidasan (2008), or Benedetti and Borota (2010).

<sup>10</sup>See Luttmer (2004), Ghironi and Melitz (2005), Irarrazabal and Opmolla (2005), and Ruhl and Willis (2008).

some shortcomings. The channel is one of exogenous shocks, so extracting implications is more difficult. This paper suggests an orthogonal mechanism by which firms decide to delay and to stop exporting.<sup>11</sup> In addition, time-varying shocks alone cannot reconcile why some exporters are less productive than nonexporters, while destination-varying demand in this paper can.

Instead of varying firm heterogeneity across time, this paper varies it across destinations. Exporting failures arise, not because firms realize a negative shock, but because a firm does not know whether it can succeed in a destination before it is actually in that destination. Exporting delays occur, not because firms realize a positive shock, but because, in equilibrium, forecasts of negative profits discourage new firms from supplying all destinations. New firms are better off by selling at home first. By delaying entry into other destinations, the firm learns more about itself before deciding whether to export. In a multicountry setting, this learning process means some firms will slowly expand their set of export destinations.

One additional contribution of the model is the ability to reconcile the existence of export-only firms. Approximately one percent of American firms in 1987 and five percent of Colombian firms in the 1980's were export-only.<sup>12</sup> The model shows how export-only firms can arise in a general equilibrium setting.

I present the structure of the model in the following section. It presents an overview of the economy and describes the decisions firms must make each period. I then restrict the model to several simpler cases. I discuss the equilibrium testing strategies of firms in a two country case and show how trade costs and market size can affect the order in which firms test markets. I then discuss the implications of a multiple symmetric country case. Even when there are not trade costs and destinations are identical ex ante, firms will slowly expand their set of supplied destinations. To conclude, I discuss possible extensions.

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<sup>11</sup>There are other explanations of exporting delay, e.g. financial constraints by Bellone, Musso, Nesta, Sahiavo (2010).

<sup>12</sup>For American firms, see Figure 1 in Bernard and Jensen (1995). Colombian firm statistics calculated by author from dataset generously provided by Jim Tybout.

## 2. Model Structure

The world consists a set of  $J = \{1, 2, \dots, |J|\}$  countries and an infinite horizon of discrete time periods  $t$ . Consumers have homothetic preferences over a homogenous good and a differentiated good and allocate constant budget shares to both. The homogenous good is produced with a constant returns to scale technology using labor as the single factor of production. It is traded freely. This equalizes wages across countries, which we normalize to one. We focus the rest of the exposition on the differentiated good. Each country  $j$  spends  $y_{jt}$  of its income consuming varieties of the differentiated good. Preferences over these varieties can be represented by the utility function  $u_j$  over the set of varieties  $\Omega_{jt}$  available to consumers in  $j$  at  $t$ :

$$u_j(\{q_{j\omega t}\}_{\omega \in \Omega_{jt}}) = \int_{\omega \in \Omega_{jt}} \exp\left(\frac{x_{j\omega}}{\theta}\right) (q_{j\omega t})^{\frac{\theta-1}{\theta}} d\omega$$

where  $q_{j\omega t}$  is the quantity of variety  $\omega$  consumed in  $j$  at time  $t$ ,  $\theta > 1$  is a measure of the elasticity of substitution between these varieties, and  $x_{j\omega}$  is a random variable determining  $j$ 's time-invariant *perceived quality* of  $\omega$ .  $x_{j\omega}$  can also be interpreted as the appeal, or popularity, of  $\omega$  in  $j$ .

Each variety  $\omega$  is made by a single firm using a production technology involving both fixed and marginal costs, as popularized by Krugman (1980). As in Chaney (2008), the firm must pay a fixed cost  $f$  for each destination  $j$  to which it supplies.<sup>13</sup> The fixed costs represent, for example, storefront rent, fixed shipping and port fees, or advertising costs. The firm also pays a constant marginal cost  $\tau_{hj}$  for each unit shipped from its home country  $h$  to a destination country  $j$ . The marginal costs represent, for example, variable production, transport, and tariff costs.<sup>14</sup> As is standard in New Trade Theory, firms sell in a monopolistically competitive market and charge a markup over marginal costs. Firm

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<sup>13</sup>This paper considers fixed advertising costs to be constant and exogenous, but others have examined endogenous advertising costs in a partial equilibrium setting (e.g. Arkolakis 2010, Gormsen 2009).

<sup>14</sup>The model has similar export delay/failure predictions if fixed costs, instead of marginal costs, differed across destinations. Both costs affect the cutoffs in Equation 5 similarly.

$\omega$ 's profit  $\pi$  in destination  $j$  in period  $t$  is a function of its perceived quality  $x_{j\omega}$ :

$$\begin{aligned}\pi_{hjt}(x_{j\omega}) &= \frac{\tau_{hj}^{1-\theta} y_{jt}}{\theta \Pi_{jt}} \exp(x_{j\omega}) - f \\ \Pi_{jt} &= \int_{\omega \in \Omega_{jt}} \exp(x_{j\omega}) \tau_{hj}^{1-\theta} d\omega,\end{aligned}\tag{1}$$

where  $\Pi_{jt}$  is the endogenous level of competition in  $j$ . It is large enough to be unaffected by the addition or subtraction of any single variety  $\omega$ .

All variables except for  $x_{j\omega}$  are known to the firm owner at all times. The firm owner observes  $x_{j\omega}$  if and when she supplies  $\omega$  to  $j$ . Once  $x_{j\omega}$  is observed, then  $\pi_{hjt}(x_{j\omega})$  is known for all future periods. If  $x_{j\omega}$  has not been observed, the firm owner can forecast her profits in  $j$  based on her beliefs about  $x_{j\omega}$ .

We examine steady state equilibria in which aggregate market conditions do not change over time. Therefore,  $y_{jt}$  and  $\Pi_{jt}$  can be characterized by  $y_j$  and  $\Pi_j$ . We drop the  $t$  subscript wherever it is superfluous.

### 2.1. The Distribution of Perceived Qualities

This section discusses the random vector  $\mathbf{x}_\omega \equiv [x_{1\omega}, \dots, x_{j\omega}, \dots, x_{|J|\omega}]$  comprising  $|J|$  elements. Each  $x_{j\omega}$  corresponds to the perceived quality of  $\omega$  in  $j$ . For  $j, k \in J, j \neq k$ ,  $x_{j\omega}$  and  $x_{k\omega}$  have joint multivariate normal properties characterized by the moments:<sup>15</sup>

$$E[x_{j\omega}] = E[x_{k\omega}] = 0 \tag{2a}$$

$$VAR[x_{j\omega}] = VAR[x_{k\omega}] = \sigma_0^2 \tag{2b}$$

$$\frac{Cov(x_{j\omega}, x_{k\omega})}{\sigma_0^2} = \rho \tag{2c}$$

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<sup>15</sup>The assumption of normality is not critical for the qualitative results of the model. A normal distribution is used so that the resultant sales are lognormally distributed. The lognormal distribution more closely matches firm size patterns in Bernard, Eaton, Jensen, and Kortum (2003) and Eaton, Kortum, and Kramarz (2004) than the commonly used Pareto distribution. Cabral and Mata (2003) show that firm sizes are distributed lognormally. Axtell (2001) argues that firm sizes are Pareto distributed, but concedes that the tails of the distribution are not Pareto. A truncated lognormal may fit the data best.

where  $\sigma_0^2 > 0$  is the variance of each of the marginal distributions and  $0 < \rho < 1$  is the correlation coefficient. The restriction on  $\rho$  implies that the demands in any two destinations are positively and imperfectly correlated.

Since perceived qualities are correlated across destinations, the owner of firm  $\omega$  forecasts unknown perceived qualities given her set of observed  $x_{j\omega}$ . We model this process using Bayesian updating. We can define firm  $\omega$ 's information set  $I_\omega^t \subseteq J$  such that if  $i \in I_\omega^t$ , then the firm has observed  $x_{i\omega}$  in a period before  $t$ . Firm  $\omega$ 's conditional beliefs about any unknown  $x_{j\omega}, j \notin I_\omega^t$  is then normally distributed with moments:<sup>16</sup>

$$E_\omega [x_{j\omega} | I_\omega^t] = \mu_{I_\omega^t} = \left( \frac{\sum_{i \in I_\omega^t} x_{i\omega}}{|I_\omega^t|} \right) \left( \frac{|I_\omega^t| \rho}{|I_\omega^t| \rho + (1 - \rho)} \right) \quad (3a)$$

$$VAR_\omega [x_{j\omega} | I_\omega^t] = \sigma_{|I_\omega^t|}^2 = \sigma_0^2 \left( 1 - \frac{|I_\omega^t| \rho^2}{|I_\omega^t| \rho + (1 - \rho)} \right). \quad (3b)$$

If  $I_\omega^t$  is empty, the moments in Equation 3 collapse to those in Equation 2. As the number of previous observations  $|I_\omega^t|$  increases, the expected perceived quality  $\mu_{I_\omega^t}$  approaches the sample mean of the observed perceived qualities; the firm owner trusts her own experiences more. As  $|I_\omega^t|$  increases, the conditional variance  $\sigma_{|I_\omega^t|}^2$  also decreases; the firm owner can more precisely predict perceived qualities. Note that the variance  $\sigma_{|I_\omega^t|}^2$  depends on the number of elements in  $I_\omega^t$ , but not the elements specifically.

The probability that  $x_{j\omega} = x$  is denoted as  $g(x | \mu_{I_\omega^t}, \sigma_{|I_\omega^t|}^2)$ , since only  $\mu_{I_\omega^t}$  and  $\sigma_{|I_\omega^t|}^2$  are needed to characterize the distribution. The unconditional pdf is referred to as  $g_0(\cdot)$  (That is,  $g_0(x) = g(x | 0, \sigma_0^2)$ ).

In summary, the firm owner has observed some(or none) of the elements of  $\mathbf{x}_\omega$ , the vector of perceived qualities across potential supply destinations. She uses this information to generate beliefs about her perceived qualities in the remaining destinations. In each time period, the firm owner uses these beliefs to make decisions about which destinations to supply.

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<sup>16</sup>Moments are derived in Appendix A.

## 2.2. Firm Decisions

The owner of firm  $\omega$  maximizes expected lifetime profits not within a destination, but across all destinations. At time  $t = 0$ , her problem is to choose a sequence  $\{J_\omega^t(\cdot)\}_{t=0}^\infty$  to maximize

$$\max_{\{J_\omega^t(\cdot)\}_{t=0}^\infty} E \left[ \sum_{t=0}^{\infty} \sum_{j \in J_\omega^t(\cdot)} (1 - \delta)^t \pi_{hjt}(x_{j\omega}) \right] \quad (4)$$

where  $J_\omega^t(\cdot) \subseteq J$  is the set of destinations to which the firm owner will supply  $\omega$  in  $t$ .  $J_\omega^t(\cdot)$  is contingent on the beliefs about  $x_{j\omega}$  at time  $t$ . The profits in  $j$  are discounted due to an exogenous firm death rate of  $\delta$ . We can simplify this problem by breaking it up into supply decisions within each destination and a sequence of testing decisions across destinations.

In each period  $t$ , the firm owner must decide whether to supply to each of the  $|J|$  destinations, using the information gleaned from having previously supplied to a set of destinations  $I_\omega^t$ . First, for each  $i \in I_\omega^t$  of the previously tested destinations, the firm owner decides whether to *stay* and continue supplying there. Second, for each  $j \in J \setminus I_\omega^t$  untested destination, she decides whether to *test* her variety there. Let's examine each of these decisions.

### 2.2.1. The value of staying in a destination

Consider the firm owner's decision for a destination  $i$  that she supplied to in a period before  $t$  and thus previously observed  $x_{i\omega} = x$ . The firm owner chooses to *stay* in destination  $i$  by supplying  $\omega$  to  $i$  again. The value of staying is the known profits  $\pi_{hjt}(x)$ . She will stay if the value is positive. Rearranging equation (1) shows that  $\pi_{ijt}(x) > 0$  only if  $x > x_{hj}^*$ , where

$$x_{hj}^* = \ln \left( \frac{f\Pi_j\theta}{\tau_{hj}^{1-\theta} y_j} \right) \quad (5)$$

If  $x < x_{hj}^*$ , the firm will not supply  $\omega$  to  $j$  in  $t$  or in any period after  $t$ . This is termed a *failure* of  $\omega$  in  $j$ . The *stay cutoff*  $x_{hj}^*$  is the minimum perceived quality required by firms in country  $h$  to stay in destination  $j$ .

### 2.2.2. The direct value of testing a destination

If the variety  $\omega$  has not previously been supplied to  $j$ , the firm owner must decide whether to supply  $\omega$  to  $j$  for the first time. This is the decision to *test*  $\omega$  in destination  $j$ . The firm owner may test  $j$  for two reasons. First, there is a *direct value* of testing coming from the expected stream of profits garnered by supplying to  $j$  over a lifetime. Second, there is an *indirect value* of testing coming from updating the firm's information set  $I_\omega^t$ .

For a firm  $\omega$  from destination  $h$  testing destination  $j$  in period  $t$ , the direct value of testing  $v_{hjt}$  is a function of the conditional distribution of the perceived quality  $x_{j\omega}$ , as determined by the variables  $\mu_{I_\omega^t}$  and  $\sigma_{|I_\omega^t}^2$ :

$$v_{hjt}(\mu_{I_\omega^t}, \sigma_{|I_\omega^t}^2) = \underbrace{\int_{-\infty}^{\infty} \pi_{hjt}(x) g(x|\mu_{I_\omega^t}, \sigma_{|I_\omega^t}^2) dx}_{\text{Expected testing period profits}} + \underbrace{\sum_{t'=t+1}^{\infty} (1-\delta)^{t'}}_{\text{Discounted sum}} \underbrace{\left( \int_{x_{hj}^*}^{\infty} \pi_{ij}(x) g(x|\mu_{I_\omega^t}, \sigma_{|I_\omega^t}^2) dx \right)}_{\text{Expected future period profits}}. \quad (6)$$

The direct value of testing  $v_{hjt}$  comprises the profits the firm expects in the first supply period  $t$  and the discounted sum of expected profits in the future, should the firm observe a favorable perceived quality. It is easier to work with  $v_{hjt}(\mu_{I_\omega^t}, \sigma_{|I_\omega^t}^2)$  by combining Equations 1, 5 and 6 to produce a direct value of testing  $v_{hjt}(\mu_{I_\omega^t}, \sigma_{|I_\omega^t}^2) = v(\mu_{I_\omega^t}, \sigma_{|I_\omega^t}^2; x_{hj}^*)$ :

$$\begin{aligned} v(\mu_{I_\omega^t}, \sigma_{|I_\omega^t}^2; x_{hj}^*) &= f \int_{-\infty}^{\infty} \exp(x - x_{hj}^*) g(x|\mu_{I_\omega^t}, \sigma_{|I_\omega^t}^2) dx - f \\ &\quad + \frac{(1-\delta)}{\delta} f \int_{x_{hj}^*}^{\infty} (\exp(x - x_{hj}^*) - 1) g(x|\mu_{I_\omega^t}, \sigma_{|I_\omega^t}^2) dx. \end{aligned} \quad (7)$$

Equation 7 shows that the market variable  $x_{hj}^*$  along with its information set-specific  $\mu_{I_\omega^t}$  and  $\sigma_{|I_\omega^t}^2$  completely characterize firm  $\omega$ 's direct value of testing destination  $j$ .

**Theorem 1.** *The direct value of testing  $v(\mu_{I_\omega^t}, \sigma_{|I_\omega^t}^2; x_{hj}^*)$  has the following properties:*

- a.  $\frac{dv(\mu_{I_\omega^t}, \sigma_{|I_\omega^t|}^2; x_{h_j}^*)}{d\mu_{I_\omega^t}} > 0$ ,  $\frac{dv(\mu_{I_\omega^t}, \sigma_{|I_\omega^t|}^2; x_{h_j}^*)}{dx_{h_j}^*} < 0$ ,  $\frac{dv(\mu_{I_\omega^t}, \sigma_{|I_\omega^t|}^2; x_{h_j}^*)}{d\sigma_{|I_\omega^t|}^2} > 0$
- b. For constant  $\sigma_{|I_\omega^t|}^2 = \sigma_{|I|}^2$ , there exists a unique  $\mu_{h_j|I}^+ < x_{h_j}^*$  exists such that  $\mu > \mu_{h_j|I}^+ \Rightarrow v(\mu, \sigma_{|I|}^2; x_{h_j}^*) > 0$ .
- c. For two destinations  $j$  and  $k : x_{h_j}^* > x_{h_k}^* \Rightarrow \mu_{h_j|I}^+ > \mu_{h_k|I}^+$
- d. For two sets  $I$  and  $I' : |I| < |I'| \Rightarrow \mu_{h_j|I}^+ < \mu_{h_j|I'}^+$ .

**Proof.** See Appendix B. ■

The direct value of testing increases with the firm's expected perceived quality and decreases with the stay cutoff. Although not immediately intuitive, the direct value of testing also increases with the conditional variance. Firms gain more from testing an unknown market when the variance is large, because they can take advantage of high realizations of  $x_{j\omega}$ . As  $|I_\omega^t|$  increases, the conditional variance  $\sigma_{|I_\omega^t|}^2$  decreases via Equation 3b, so firms that have tested many markets are reluctant to test more markets. For each nonnegative integer  $|I| < |J|$ , there is a set of firms in  $h$  with  $|I_\omega^t| = |I|$ . Of these firms, those with  $\mu_{I_\omega^t} > \mu_{h_j|I}^+$  expect a positive direct value of testing  $j$ . The value of  $\mu_{h_j|I}^+$  is termed the *direct testing cutoff* for a firm from  $h$ , considering destination  $j$ , with  $|I|$  previous observations. Destinations with higher stay cutoffs will have higher direct testing cutoffs, and firms with more known perceived qualities require a higher forecast in order to test a destination.

Equation 7 collapses the firm owner's decisions within market  $j$  into a time-invariant function  $v(\mu_{I_\omega^t}, \sigma_{|I_\omega^t|}^2; x_{h_j}^*)$ . The firm's sequence problem can now be reformulated into a problem of maximizing the discounted sum of the direct values of testing:

$$\max_{K_t \subseteq J \setminus I_\omega^t} E \left[ \sum_{t=0}^{\infty} \sum_{k \in K_t} (1 - \delta)^t v(\mu_{I_\omega^t}, \sigma_{|I_\omega^t|}^2; x_{h_k}^*) \right], \quad (8)$$

subject to  $I_\omega^t = \cup_{t'=0}^{t-1} K_{t'}$ . So  $K_t$  is the set of new destinations firm  $\omega$  tests in period  $t$ . Although  $v(\cdot)$  is time-invariant, its inputs depend on past events. The probability distributions in Equation 7 change with  $I_\omega^t$ , so the firm must consider both the direct values of testing a destinations  $k \in K_t$  as well as the indirect effect that testing  $K_t$  has

on  $v(\cdot)$  in the future. A firm may test  $k$  when  $\mu_{I_\omega^t} < \mu_{hk|I}^+$  because testing  $k$  allows the firm to observe  $x_{k\omega}$  and update her information set  $I_\omega^{t+1} = I_\omega^t \cup \{k\}$ . This is a recursive problem we tackle next.

### 2.2.3. The forecast value of testing

The optimization problem 8 can be solved via dynamic programming. First, let's define the firm's state. The firm's direct value of testing  $v(\mu_{I_\omega^t}, \sigma_{|I_\omega^t|}^2; x_{hk}^*)$  depends only on  $\mu_{I_\omega^t}$  and  $\sigma_{|I_\omega^t|}^2$  given steady state equilibrium values of  $x_{hk}^*$ . The firm's possible testing destinations are determined by  $I_\omega^t$ . Equation 3b shows that  $\sigma_{|I_\omega^t|}^2$  is also determined by  $I_\omega^t$ . Therefore, the pair  $(\mu_{I_\omega^t}, I_\omega^t)$  sufficiently describes the firm's state at a point in time.

Given a state  $(\mu_{I_\omega^t}, I_\omega^t) = (\mu, I)$ , a firm's *forecast value*  $V_h(\mu, I)$  can be written as the Bellman equation:

$$V_h(\mu, I) = \max_{K \subseteq J \setminus I} \left[ \overbrace{\sum_{k \in K} v(\mu, \sigma_{|I|}^2; x_{hk}^*)}^{\text{The direct values of testing}} + \underbrace{(1 - \delta) E_I^K V_h(\mu', I')}_{\text{The indirect value of testing}} \right] \quad (9a)$$

$$I' = I \cup K \quad (9b)$$

$$\mu' \sim \mathcal{N} \left( \mu, \sigma_0^2 \left( \frac{|K| \rho}{|I'| \rho + 1 - \rho} \right)^2 \left( 1 - \frac{|I| \rho^2}{|I'| \rho + (1 - \rho)} \right) \right). \quad (9c)$$

The control variable  $K$  is the set of new destinations in which the firm will test  $\omega$ . Testing  $K$  generates a direct value of testing  $v(\mu, \sigma_{|I|}^2; x_{hk}^*)$  for each  $k \in K$  and an indirect value via updating the state to  $(\mu', I')$ . Since the probability distribution  $\mu'$  is affected by both  $I$  and  $K$ , we use the conditional expectation  $E_I^K$ . The transition function for  $\mu$  is derived from conditional moments 3a of  $x_{k\omega}$  for  $|I|$  and  $|I'|$  observations.<sup>17</sup> We can now describe the forecast value for any firm in  $h$  with state  $(\mu, I)$ . We define  $K_h^*(\mu, I)$  as the optimal testing policy that satisfies Equation 9.

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<sup>17</sup>We can show this by letting  $\varepsilon \sim \mathcal{N}(0, 1)$  and derive  $\mu' = (\sum_{i \in I'} x_{i\omega}) \left( \frac{\rho}{|I'| \rho + (1 - \rho)} \right) = \left( \frac{|I| \rho + (1 - \rho)}{\rho} \mu + \sum_{k \in K} x_{k\omega} \right) \left( \frac{\rho}{|I'| \rho + (1 - \rho)} \right) = \left( \frac{|I| \rho + (1 - \rho)}{|I'| \rho + (1 - \rho)} \mu + \frac{\rho}{|I'| \rho + (1 - \rho)} \sum_{k \in K} (\mu + \sigma_{|I|} \varepsilon) \right) = \mu + \frac{\sigma_{|I|} \rho K}{|I'| \rho + (1 - \rho)} \varepsilon$

We can describe some characteristics of the forecast value.  $V_h(\mu, I)$  is bounded from below by zero since the firm can just choose to not test any more destinations (i.e.  $K_h^*(\mu, I) = \emptyset \Rightarrow V_h(\mu, I) = 0$ ). At the other end of the spectrum, when there are no more destinations to test, the forecast value is also zero ( $V_h(\mu, J) = 0$ ).

If the firm sells to all remaining markets in some period, then there is nothing to learn for any subsequent period. Hence, the firm must have passed the direct testing cutoff in each of the remaining markets. But  $\mu > \mu_{hj|I}^+$  does not guarantee that  $j \in K_h^*(\mu, I)$ . For example, suppose  $x_{hj}^* \gg \mu > \mu_{hj|I}^+ \gg \mu_{hk|I}^+$  for untested destinations  $j, k$  and  $\delta$  is close to zero such that there is only an infinitesimal loss in lifetime profit due to delaying entry into  $j$ . The firm owner may then want to test  $k$  first in order to reduce uncertainty about profits in  $j$ . It is not sufficient to just compare  $\mu$  to  $\mu_{hj|I}^+$ . To determine  $K_h^*(\mu, I)$  and  $V_h(\mu, I)$ , we must evaluate the right hand side of Equation 9a for all possible  $K$ . In the numerical exercise in Section 4.1, we examine a situation where a firm has  $\mu > \mu_{hj|I}^+ \forall j \in J \setminus I$ , but does not test all the remaining destinations.

### 2.3. Equilibrium

The initial state of the dynamic programming problem described by Equation 9 is  $(\mu, I) = (0, \emptyset)$ , when the firm has not yet tested any destinations. These new firms all share the same initial forecast value  $V_h(0, \emptyset)$ . We consider steady state equilibria where a new firm's forecast value is zero. An equilibrium of this type is defined as the vector of stay cutoffs  $\mathbf{x}^* = (x_{11}^*, \dots, x_{hj}^*, \dots, x_{|J||J|}^*)$  and optimal testing policy  $K_h^*(\mu, I)$ , such that:

1.  $K = K_h^*(\mu, I)$  satisfy Equation 9 for all countries  $h \in J$ .
2.  $V_h(0, \emptyset) = 0$ .

The first condition states that all firms will choose testing destinations to maximize the value of testing given the firm's current set of tested countries and expected perceived quality in untested countries. The second conditions states that, ex ante, all firms expect to make zero lifetime profit from introducing a brand new product to the world.

### 3. Two Countries

We can discuss the main implications of the model by examining a version consisting of two countries  $H$  (*ome*) and  $F$  (*oreign*) with market sizes  $y_{Ht}$  and  $y_{Ft}$ . Intranational marginal costs are normalized:  $\tau_{HH} = \tau_{FF} = 1$ , and international marginal costs reflect iceberg trade costs:  $\tau_{HF} = \tau_{FH} = \tau > 1$ .

The two country case greatly simplifies the search for the optimal testing policy  $K_h^*(\mu, I)$ . In equilibrium, the direct value of testing must be negative for both destinations, or else the zero expected profit condition would not hold. New firms will start by testing the destination with the higher direct value of testing. By Theorem 1,  $dv\left(\mu_{I_\omega^t}, \sigma_{|I_\omega^t|}^2; x_{hj}^*\right) / dx_{hj}^* < 0$ , so a new firm in  $H$  will test  $H$  first if  $x_{HH}^* < x_{HF}^*$ . By manipulating Equation 5, we can see that:

$$x_{HH}^* < x_{HF}^* \Leftrightarrow \frac{y_F}{y_H} < \tau^{\theta-1} \frac{\Pi_F}{\Pi_H}. \quad (10)$$

Some predictions of the model can be gleaned from the relationship in (10). First, if the two countries are symmetric ( $y_F = y_H$ ,  $\Pi_F = \Pi_H$ ), then firms will always test the domestic destination first. Trade costs encourage firms to *delay* exporting to the more expensive foreign destination. Second, we can show that  $\Pi_F/\Pi_H$  is bounded from above, so for any  $\tau$ , we can find a ratio  $y_F/y_H$  that reverses the inequalities in (10).<sup>18</sup> For scenarios where  $y_F/y_H > \tau^{\theta-1} \Pi_F/\Pi_H$ , equilibrium is characterized by all firms testing the *Foreign* destination first. The demand in  $F$  is so large that even firms in  $H$  are willing to risk exporting first. This may be the case for small countries exporting to the US. Firms could start up in those countries with the sole purpose of selling to US customers. Since  $\tau$  increases the required  $y_F/y_H$  ratio, this scenario is less likely for remote destinations.

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<sup>18</sup>We show  $\Pi_F/\Pi_H$  is bounded from above in Appendix C.

#### 4. More than two Countries

As seen in the two country case, trade costs and market sizes can differentiate destinations by profitability and determine the order of entry. However, even without this exogenous ordering, the current model can generate exporting delays. In a multi-country setting, the firm sequentially tests markets to learn more about its perceived quality in untested markets. We show this by examining a version of the model consisting of  $|J| > 2$  symmetric countries with no trade costs ( $\tau_{hj} = 1$ ). The rest of the structure laid out in Section 2 remains the same. Since the costs of supplying  $\omega$  are equal across destinations, the term "exporting" is adjusted slightly. We define a firm's first destination to which it supplies as its domestic destination, and any additional destinations as export destinations. For exposition purposes, consider a representative firm  $\omega$  using the labor from country  $h$  which has not yet supplied to any destinations in period 0.

The ex ante symmetry of destinations simplifies much of the model. The stay cutoffs  $x_{hj}^* = x^*$  are the same for all destinations. All  $I$  with identical cardinality  $|I|$  affect the forecast value  $V_h(\mu, I)$  identically. The same is true for  $K$ . Solving for  $V_h(\mu, I)$  now only involves calculating  $E_I^K V_h(\mu', I')$  for  $|J| - |I|$  possibilities. We assume the firm chooses the  $|K|$  destinations randomly.

Calculating  $E_I^K V_h(\mu', I')$  still involves determining the conditional distribution of  $\mu'$ . We can simplify the task via the Tauchen (1986) process by discretizing  $\mu$  into  $M$  nodes  $\mu^1 < \mu^2 < \dots < \mu^M$  and calculating transition probabilities using transition Equation 9c. A departure from Tauchen (1986) arises because the distribution of  $\mu'$  is conditional on the choice  $K$  as well as the state  $(\mu, I)$ . Therefore, we need to calculate transition probabilities  $p_{mn}^{|I||K|} = \Pr[\mu' = \mu^m | (\mu, |I|, |K|) = (\mu^m, |I|, |K|)]$  for each  $mn |I| |K|$  quadruple.

Given these simplifications, the forecast value can be rewritten as a function of the expected perceived quality  $\mu^m$  and number of tested destinations  $|I|$ :

$$V_h(\mu^m, |I|) = \max_{|K|} \left[ |K| \cdot v(\mu^m, \sigma_{|I|}^2; x^*) + (1 - \delta) \sum_{n=1}^M p_{mn}^{|I||K|} V_h(\mu^n, |I| + |K|) \right], \quad (11)$$

where  $|K| \leq |J| - |I|$ .

#### 4.1. Numerical Predictions

To solve for the optimal  $|K^*|$  for each state  $(\mu, |I|)$ , we define a set  $\{\mu^m\}_{m=1}^M$  of nodes with corresponding transition probabilities  $p_{mn}^{|I||K|}$ . We begin our solution algorithm with an initial guess of  $x^* = \tilde{x}^1$ . We work backwards from  $|I| = |J|$ , since we know  $V_h(\cdot, |J|) = 0$ . At each step  $i = [1, \dots, |J|]$ , we solve for  $V_h(\mu^m, |I| - i)$  using equation 11 and previously solved  $\{V_h(\mu^n, |I| - i) : i < i\}$ . The firm's initial condition is characterized by  $(\mu, |I|) = (0, 0)$ , so this algorithm finds  $V_h(0, 0)|_{x^* = \tilde{x}^1}$ . We revise our guess, with the aim to find  $\tilde{x}^* : V_h(0, 0)|_{x^* = \tilde{x}^*} = 0$ .

We report findings for an economy comprising  $|J| = 5$  countries and  $M = 21$  nodes. We choose  $\delta = 0.11$  to match the long run hazard rate of US imports at a 10-digit Harmonized System aggregation (Besedes and Prusa 2006). Different values of  $\rho$  were tried; we report results for  $\rho = 0.7$ . The apriori  $\sigma_0^2$  only magnifies the equilibrium stay cutoff  $\tilde{x}^*$ . Therefore, we use  $\sigma_0^2 = 1$  and discuss  $\tilde{x}^*$  as a multiple of  $\sigma_0^2$ .<sup>19</sup> We use a simple bisectional method to find  $\tilde{x}^*$  since the solution usually converges within 10 iterations. Tables 2 and 3 show the equilibrium values of  $V_h$  and  $|K^*|$  for states  $(\mu^m, I)$  in this economy:

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<sup>19</sup>The last parameter  $f$  only magnifies the values in Table 2 via its effect on  $v(\cdot)$  in Equation 7. The Matlab code which finds the equilibrium for any  $\rho, |J|$ , and  $M$  is available from the author. Findings are robust to the choice of other parameters, which can be altered in the code.

Table 2: Forecast Values  $V_h(\mu^m, |I|)$  in a 5 country economy.<sup>a</sup>

$\mu^m$	Number of tested destinations $ I $					
	<b>0</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
<b>-2.80</b>	0.00	0.00	0.00	0.00	0.00	0.00
<b>-2.52</b>	0.00	0.00	0.00	0.00	0.00	0.00
<b>-2.24</b>	0.00	0.00	0.00	0.00	0.00	0.00
<b>-1.96</b>	0.00	0.00	0.00	0.00	0.00	0.00
<b>-1.68</b>	0.00	0.00	0.00	0.00	0.00	0.00
<b>-1.40</b>	0.00	0.00	0.00	0.00	0.00	0.00
<b>-1.12</b>	0.00	0.00	0.00	0.00	0.00	0.00
<b>-0.84</b>	0.00	0.00	0.00	0.00	0.00	0.00
<b>-0.56</b>	0.00	0.00	0.00	0.00	0.00	0.00
<b>-0.28</b>	0.00	0.00	0.00	0.00	0.00	0.00
<b>0.00</b>	0.001	0.00	0.00	0.00	0.00	0.00
<b>0.28</b>	(9.67)	0.00	0.00	0.00	0.00	0.00
<b>0.56</b>	(25.25)	0.00	0.00	0.00	0.00	0.00
<b>0.84</b>	(48.51)	12.14	4.20	0.91	0.00	0.00
<b>1.12</b>	(84.48)	35.68	22.02	13.14	6.11	0.00
<b>1.40</b>	(141.23)	69.46	47.30	29.99	14.47	0.00
<b>1.68</b>	(214.16)	113.52	77.88	49.64	24.11	0.00
<b>1.96</b>	(305.67)	164.34	111.54	70.66	34.22	0.00
<b>2.24</b>	(417.46)	219.12	145.48	91.00	43.72	0.00
<b>2.52</b>	(549.77)	273.58	176.24	108.43	51.57	0.00
<b>2.80</b>	(700.68)	322.81	200.89	121.44	57.16	0.00

<sup>a</sup> Values in ( ) in Column **0** are hypothetical because all firms start with  $(\mu^m, |I|) = (0.00, 0)$

To understand Tables 2 and 3, we can trace the path of a firm  $\omega$  that begins its life with the state  $(\mu^m, |I|) = (0, 0)$  in period 1. Table 2 indicates its forecast value  $V_h(0.00, 0) = 0.001$  (just above zero), and Table 3 indicates its optimal testing policy  $|K^*| = 1$  destination. Firm  $\omega$  tests 1 destination in period 1 and observes, for example,  $x_{1\omega} = 1.60$ . Using Equation 3a, we can update  $\mu^m$  to 1.12. This new state  $(\mu^m, |I|) = (1.12, 1)$  has a forecast value of 35.68 (in Table 2) and an optimal strategy of testing 2 additional destinations (in Table 3). So firm  $\omega$  tests two more destinations in period 2, observing two more  $x_{j\omega}$  and updating  $\mu^m$  and  $|I|$  again. If the firm's state after testing three destinations is  $(0.56, 3)$ , then it has an updated forecast value of 0 and will not test any more destinations.

Table 3: Number of additional destinations  $|K^*|$  to test, in a 5 country economy.<sup>a</sup>

$\mu^m$	Num. of tested dest. $ I $					$p_{mn}^{01}$
	0	1	2	3	4	
<b>[-2.80,-0.28]</b>	0	0	0	0	0	42.1%
<b>0.00</b>	1	0	0	0	0	15.9%
<b>0.28</b>	(1)	0	0	0	0	14.7%
<b>0.56</b>	(1)	0	0	0	0	11.6%
<b>0.84</b>	(1)	1	1	1	0	7.8%
<b>1.12</b>	(5)	2	2	2	1	4.5%
<b>1.40</b>	(5)	4	3	2	1	2.2%
<b>1.68</b>	(5)	4	3	2	1	0.9%
<b>1.96</b>	(5)	4	3	2	1	0.3%
<b>2.24</b>	(5)	4	3	2	1	0.1%
<b>2.52</b>	(5)	4	3	2	1	0.0%
<b>2.80</b>	(5)	4	3	2	1	0.0%

<sup>a</sup>The  $|K^*|$  for  $\mu \in [-2.8, -0.28]$  are compressed to one row. Values in () in Column **0** are hypothetical because all firms start with  $(\mu^m, |I|) = (0.00, 0)$ . The last column  $p_{mn}^{01}$  are the probabilities of transitioning to state  $(\mu^m, 1)$  given initial state  $(0, 0)$  and testing 1 destination.

Since all new firms begin with  $(\mu, |I|) = (0, 0)$ , each tests a single (domestic) market and draws a single  $x_{j\omega}$ . Table 3 lists the probabilities of  $\mu^m$  after this first draw. This first draw will determine the firm's export strategy. Approximately 7.8% of new firms realize a  $\mu^m = 0.84$  and will test one (export) destination. Another 4.5% will simultaneously test two (export) destinations. Those 3.5% of firms drawing  $\mu^m \geq 1.40$  will test all four remaining destinations, because their first observed  $x_{j\omega}$  gave them enough confidence to do so. In total, 15.8% of new firms export at least once. This prediction is in line with findings that between 4-21% of firms export (see Bernard and Jensen (1995, 1999), Bernard, Eaton, Jensen, Kortum (2003), and Bernard, Jensen, Redding, Schott (2007)).

The stay cutoff for this economy is  $\hat{x}^* = 0.93$ . Using the distribution described in Equation 3, we can show that 82% of new firms fail. This prediction is in line with the estimates in Crawford (1977). Of the 15.8% that export at least once, 32% experience an exporting failure. This matches the one year exporting failure rates in Colombia shown in Figure 1.

Only firms with their first  $\mu^m \geq 1.40$  will test all remaining destinations. Those with  $\mu^m = 0.84$  forecast positive profits in all remaining destinations, but choose to test only one additional destination. Even firms that forecast an average perceived quality greater than the stay cutoff will not test all remaining markets simultaneously. The risk of negative profits convinces firms to try fewer destinations while they learn more about their perceived qualities.

## 5. Conclusions

In this paper, I propose a model of heterogeneous firms that reconcile two new patterns of trade: firms wait to export, and firms fail at exporting. To do so, I retool the standard firm heterogeneity model to allow for imperfect correlation of firm heterogeneity across destinations. This retooling endogenizes the delay in exporting and the failures of exporters. When demand is imperfectly correlated across destinations, firms will use known demands in tested destinations to forecast unknown demands in untested destinations. This leads to a richer story of how firms decide when and where to sell.

This is a model of learning, as opposed to a model of evolution like the time-varying productivity models discussed in the introduction. Firms are static in the sense that their perceived qualities are time-invariant. In models where productivity evolves over time, firms will receive their next period productivity shock no matter what they do. In this model, firms make the endogenous choice whether to learn more about themselves. Due to this static nature, the predicted failure rate of firms in the first period of exporting is much higher than in later periods. An amalgam of this learning model and a productivity evolution model would have firm heterogeneity change with time and destinations. This amalgamation would smooth out the drop in hazard rate so that the model predictions would more resemble the data. However, even without time-varying shocks, this model is able to endogenize the drop in hazard rates.

When faced with more than two possible destinations, firms will slowly expand their set of export destinations to learn. Another extension would heterogenize the demand correlations across destinations. This would make some destinations more attractive than

others, depending on the sign and magnitude of the correlation. Even without an a priori ranking of destinations, many firms will test a subset of untested destinations even though they forecast negative profits in some of those destinations. Firm owners know they have a tiny chance of success. But the hope of future profits entices firms to enter destination markets even though they know they will probably fail. This is the motivation for many new business ventures.

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# APPENDICES

## A. Derivation: Moments of $\mathbf{x}_\omega$

The  $J$  element vector  $\mathbf{x}_\omega$  is normally distributed:

$$\mathbf{x}_\omega \sim N_J(0_J, \Xi)$$

$$\Xi = \sigma_0^2 \begin{bmatrix} 1 & \rho & \cdots & \rho \\ \rho & 1 & \cdots & \rho \\ \cdots & \cdots & \cdots & \cdots \\ \rho & \rho & \cdots & 1 \end{bmatrix}$$

The marginal distribution of any two elements can be described by Equation 2. Let's partition  $\mathbf{x}_\omega$  by defining  $\mathbf{x}_\omega = [x_{1\omega}, \mathbf{x}_\omega^I]$ , with corresponding  $\Xi^I = \begin{bmatrix} 1 & \Xi_{1I} \\ \Xi_{I1} & \Xi_{II} \end{bmatrix}$  where  $\mathbf{x}_\omega^I$  is vector with  $J - 1$  element known and  $x_{1\omega}$  is a single element. Greene (2008) shows that the conditional distribution of  $x_{1\omega}$  given  $\mathbf{x}_\omega^I$  is normal with

$$E[x_{1\omega} | \mathbf{x}_\omega^I] = \Xi_{1I} \Xi_{II}^{-1} \mathbf{x}_\omega^I$$

$$VAR[x_{1\omega} | \mathbf{x}_\omega^I] = \sigma_0^2 - \Xi_{1I} \Xi_{II}^{-1} \Xi_{I1}$$

It is simpler if we simplify  $\Xi_{1I} \Xi_{II}^{-1}$  as in Paltseva (2010).

$$\Xi_{1I} \Xi_{II}^{-1} = \frac{\begin{bmatrix} \rho & \cdots & \cdots & \rho \end{bmatrix}}{(1 - \rho)(1 + (I - 1)\rho)} \begin{bmatrix} 1 + (I - 2)\rho & -\rho & \cdots & -\rho \\ -\rho & 1 + (I - 2)\rho & \cdots & -\rho \\ \cdots & \cdots & \cdots & \cdots \\ -\rho & -\rho & \cdots & 1 + (I - 2)\rho \end{bmatrix}$$

$$= \frac{\rho}{(1 + (I - 1)\rho)} \begin{bmatrix} 1 & \cdots & \cdots & 1 \end{bmatrix}$$

so that

$$\begin{aligned}\Xi_{1I}\Xi_{II}^{-1}\mathbf{x}_\omega^I &= \frac{\rho\sum_{i=1}^I\mathbf{x}_{i\omega}^I}{(1+(I-1)\rho)} \\ \sigma_0^2 - \Xi_{1I}\Xi_{II}^{-1}\Xi_{I1} &= \sigma_0^2\left(1 - \frac{I\rho^2}{(1+(I-1)\rho)}\right)\end{aligned}$$

## B. Proof: Theorem 1.

Part a. We can use the moments of truncated normal distributions (Greene 2008, p. 866-867) to rewrite Equation 7 as

$$v(\mu, \sigma^2; x_{hj}^*) = f \exp\left(\mu + \frac{\sigma^2}{2} - x_{hj}^*\right) - f + \frac{(1-\delta)}{\delta} f \vartheta$$

where

$$\vartheta = \int_{x_{hj}^*}^{\infty} (\exp(x - x_{hj}^*) - 1) g(x|\mu, \sigma^2) dx.$$

Now,  $\frac{dv(\mu, \sigma^2; x_{hj}^*)}{d\mu} = f \exp\left(\mu + \frac{\sigma^2}{2} - x_{hj}^*\right) + \frac{(1-\delta)}{\delta} f \frac{d\vartheta}{d\mu}$ . Since  $\exp(\cdot) > 0$ , we only have to show that  $\frac{d\vartheta}{d\mu} > 0$  and Define  $z \equiv \frac{x-\mu}{\sigma}$ . Now

$$\vartheta = \int_{\frac{x_{hj}^* - \mu}{\sigma}}^{\infty} (\exp(\sigma z + \mu - x_{hj}^*) - 1) \phi(z) dz$$

where  $\phi$  is the standard normal pdf. Since  $\sigma z + \mu - x_{hj}^* > 0 \forall z > \frac{x_{hj}^* - \mu}{\sigma}$ ,

$$\frac{d\vartheta}{d\mu} = \int_{\frac{x_{hj}^* - \mu}{\sigma}}^{\infty} \exp(\sigma z + \mu - x_{hj}^*) \phi(z) dz > 0.$$

Similarly,  $\frac{dv(\mu, \sigma^2; x_{hj}^*)}{d\sigma^2} = \frac{f}{2} \exp\left(\mu + \frac{\sigma^2}{2} - x_{hj}^*\right) + \frac{(1-\delta)}{\delta} f 2\sigma \frac{d\vartheta}{d\sigma} > 0$  because

$$\frac{d\vartheta}{d\sigma} = \int_{\frac{x_{hj}^* - \mu}{\sigma}}^{\infty} z \exp(\sigma z + \mu - x_{hj}^*) \phi(z) dz > 0$$

and finally,

$$\begin{aligned} \frac{dv(\mu, \sigma^2; x_{hj}^*)}{dx_{hj}^*} &= - \int_{-\infty}^{\infty} \exp(x - x_{hj}^*) g(x | \mu_{I\omega}^t, \sigma_{I\omega}^2) dx \\ &\quad - \frac{(1-\delta)}{\delta} f \int_{x_{hj}^*}^{\infty} (\exp(x - x_{hj}^*) - 1) g(x | \mu, \sigma^2) dx \\ &< 0 \end{aligned}$$

Part b. We can show that  $v(x_{hj}^*, \sigma^2; x_{hj}^*) = f \left( \exp\left(\frac{\sigma^2}{2}\right) - 1 \right) > 0$  and  $\lim_{\mu \rightarrow -\infty} v(\mu, \sigma^2; x_{hj}^*) = -f$ . Therefore, by the intermediate value theorem, there exists a  $\mu_{hj|I}^+ < x_{hj}^*$  such that  $v(\mu_{hj|I}^+, \sigma^2; x_{hj}^*) = 0$ . Since  $\frac{dv(\mu, \sigma^2; x_{hj}^*)}{d\mu} > 0$ ,  $\mu_{hj|I}^+$  must be unique.

Part c. If  $x_{hj}^* > x_{hk}^*$  then  $v(\mu_{hj|I}^+, \sigma^2; x_{hk}^*) < 0$  from part a and the definition of  $\mu_{hj|I}^+$ .  $v(\mu_{hk|I}^+, \sigma^2; x_{hk}^*) = 0 > v(\mu_{hj|I}^+, \sigma^2; x_{hk}^*) \Rightarrow \mu_{hk|I}^+ > \mu_{hj|I}^+$ .

Part d. If  $|I| < |\hat{I}|$ , then  $v(\mu_{hj|I}^+, \sigma_{|\hat{I}|}^2; x_{hj}^*) < 0$  from part a and the definition of  $\mu_{hj|I}^+$ .  $v(\mu_{hj|\hat{I}}^+, \sigma_{|\hat{I}|}^2; x_{hj}^*) = 0 > v(\mu_{hj|I}^+, \sigma_{|\hat{I}|}^2; x_{hj}^*) \Rightarrow \mu_{hj|\hat{I}}^+ > \mu_{hj|I}^+$ .

### C. Proof: $\Pi_F/\Pi_H$ has an upper bound.

$y_F$  and  $y_H$  are exogenous parameters of the model, so  $\frac{y_F}{y_H} \in (0, \infty)$ . We will show that there exists a sufficient cutoff  $\frac{\Pi_{F,UB}}{\Pi_{H,LB}}$  such that  $\frac{\Pi_F}{\Pi_H} < \frac{\Pi_{F,UB}}{\Pi_{H,LB}}$ . Therefore, there exists  $\left(\frac{y_F}{y_H}\right)^* = \tau^{\theta-1} \frac{\Pi_{F,UB}}{\Pi_{H,LB}}$  such that if  $\frac{y_F}{y_H} > \left(\frac{y_F}{y_H}\right)^*$ ,  $\frac{y_F}{y_H} > \frac{\Pi_F}{\Pi_H}$ .

First, we can define  $\Pi_{F,UB}$ , an upper bound for  $\Pi_F$ .  $\Pi_F$  is maximized when all firms

test  $F$  first. In this case,

$$\begin{aligned}\Pi_F &= M_F \left( \int_{-\infty}^{\infty} \exp(x) g_0(x) dx + \frac{1-\delta}{\delta} \int_{x_{FF}^*}^{\infty} \exp(x) g_0(x) dx \right) \\ &\quad + M_H \tau^{1-\theta} \left( \int_{-\infty}^{\infty} \exp(x) g_0(x) dx + \frac{1-\delta}{\delta} \int_{x_{HF}^*}^{\infty} \exp(x) g_0(x) dx \right)\end{aligned}$$

where  $M_h$  is the mass of new varieties from country  $h$  each period. Since  $\tau > 1$  and  $\int_a^{\infty} \exp(x) g_0(x) dx < \int_{-\infty}^{\infty} \exp(x) g_0(x) dx \forall a > -\infty$ , we can show that

$$\Pi_F < \Pi_{F,UB} = (M_F + M_H) \frac{1}{\delta} \exp\left(\frac{\sigma_0^2}{2}\right).$$

Similarly, we can define a lower bound for  $\Pi_H$ . Suppose only firms that obtain an  $X_{F\omega} > \frac{1}{\rho} \mu_{hH1}^+$  test the  $H$  destination. Then, the level of competition in  $H$  is

$$\begin{aligned}\Pi_H &= M_H (1-\delta) \int_{\frac{1}{\rho} \mu_{FH1}^+}^{\infty} \left( \int_{-\infty}^{\infty} \exp(z) g(z|\rho x, \sigma_1^2) dz + \frac{1-\delta}{\delta} \int_{x_{FH}^*}^{\infty} \exp(z) g(z|\rho x, \sigma_1^2) dz \right) g_0(x) dx \\ &\quad + M_F \tau^{1-\theta} (1-\delta) \int_{\frac{1}{\rho} \mu_{HH1}^+}^{\infty} \left( \int_{-\infty}^{\infty} \exp(z) g(z|\rho x, \sigma_1^2) dz + \frac{1-\delta}{\delta} \int_{x_{HH}^*}^{\infty} \exp(z) g(z|\rho x, \sigma_1^2) dz \right) g_0(x) dx\end{aligned}$$

and we can define a lower bound for it:

$$\Pi_H > (M_H + M_F \tau^{1-\theta}) (1-\delta) \int_{\frac{1}{\rho} \mu_{FH1}^+}^{\infty} \left( \int_{-\infty}^{\infty} \exp(z) g(z|\rho x, \sigma_1^2) dz \right) g_0(x) dx.$$

Using the properties of the lognormal, we find that

$$\begin{aligned}\int_{-a}^{\infty} \exp(u) g(z|\rho x, 1) dz &= \exp(\rho x) \int_{-a}^{\infty} \exp\left(z\sqrt{(1-\rho^2)}\right) g(z) dz \\ &= \exp(\rho x) \exp\left(\frac{(1-\rho^2)\sigma_0^2}{2}\right) \Phi\left((1-\rho^2)s - \frac{a}{s}\right)\end{aligned}$$

and use that result to continue manipulating the inequality:

$$\begin{aligned}
\Pi_H &> (M_H + M_F \tau^{1-\theta}) (1 - \delta) \int_{\frac{1}{\rho} \mu_{H1}^+}^{\infty} \exp(\rho x) \exp\left(\frac{(1 - \rho^2) \sigma_0^2}{2}\right) g_0(x) dx \\
&> (M_H + M_F \tau^{1-\theta}) (1 - \delta) \exp\left(\frac{(1 - \rho^2) \sigma_0^2}{2}\right) \int_{\frac{1}{\rho} \mu_{H1}^+}^{\infty} \exp(\rho x) g_0(x) dx \\
&> (M_H + M_F \tau^{1-\theta}) (1 - \delta) \exp\left(\frac{(1 - \rho^2) \sigma_0^2}{2}\right) \exp\left(\frac{\rho^2 \sigma_0^2}{2}\right) \Phi\left((1 - \rho^2) s - \frac{\mu_{H1}^+}{\rho s}\right) \\
&> (M_H + M_F \tau^{1-\theta}) (1 - \delta) \exp\left(\frac{\sigma_0^2}{2}\right) \Phi\left((1 - \rho^2) s - \frac{\mu_{H1}^+}{\rho s}\right) \\
&> (M_H + M_F \tau^{1-\theta}) (1 - \delta) \exp\left(\frac{\sigma_0^2}{2}\right) \Phi\left((1 - \rho^2) s - \frac{x_{HH}^*}{s}\right) \tag{12}
\end{aligned}$$

We need to substitute in for the endogenous  $x_{HH}^*$ . In equilibrium, we know  $0 > v(0, \sigma_0^2; x_{HH}^*)$ . Therefore,

$$\begin{aligned}
0 > v(0, \sigma_0^2; x_{HH}^*) &= f \left( \begin{array}{c} \int_{-\infty}^{\infty} \exp(x - x_j^*) g_0(x) dx - 1 \\ + \frac{(1-\delta)}{\delta} \int_{x_{HH}^*}^{\infty} (\exp(x - x_j^*) - 1) g_0(x) dx \end{array} \right) \\
&= f \left( \begin{array}{c} \exp\left(\frac{\sigma_0^2}{2} - x_{HH}^*\right) - 1 + \frac{(1-\delta)}{\delta} \exp\left(\frac{\sigma_0^2}{2} - x_{HH}^*\right) \\ - \frac{(1-\delta)}{\delta} \Phi\left(\sigma_0 - \frac{x_{HH}^*}{\sigma_0}\right) \end{array} \right) \\
\exp\left(\frac{\sigma_0^2}{2} - x_{HH}^*\right) &> \delta + (1 - \delta) \Phi\left(\sigma_0 - \frac{x_{HH}^*}{\sigma_0}\right) \\
\frac{\exp\left(\frac{\sigma_0^2}{2} - x_{HH}^*\right) - \delta}{(1 - \delta)} &> \Phi\left(\sigma_0 - \frac{x_{HH}^*}{\sigma_0}\right) \\
\exp\left(\frac{\sigma_0^2}{2} - x_{HH}^*\right) &> \delta \\
\frac{\sigma_0^2}{2} - x_{HH}^* &> \ln \delta \\
(1 - \rho^2) \sigma_0 - \frac{x_{HH}^*}{\sigma_0} &> \frac{\ln \delta}{\sigma_0} + (1 - \rho^2) \sigma_0 - \frac{\sigma_0}{2}
\end{aligned}$$

We can plug this result into Inequality 12 to define

$$\Pi_H > \Pi_{H,LB} = (M_H + M_F \tau^{1-\theta}) (1 - \delta) \exp\left(\frac{\sigma_0^2}{2}\right) \Phi\left(\frac{\ln \delta}{\sigma_0} + (1 - \rho^2) \sigma_0 - \frac{\sigma_0}{2}\right)$$

Now we know that

$$\frac{\Pi_F}{\Pi_H} < \frac{\Pi_{F,UB}}{\Pi_{H,LB}} = \frac{\tau^{\theta-1}}{\delta (1 - \delta) \Phi\left(\frac{\ln \delta}{\sigma_0} + (1 - \rho^2) \sigma_0 - \frac{\sigma_0}{2}\right)}$$

We can now define a sufficient condition for an equilibrium where firms test their varieties in the foreign destination first.

$$\begin{aligned} \frac{y_F}{y_H} &> \frac{\tau^{2\theta-2}}{\delta (1 - \delta) \Phi\left(\frac{\ln \delta}{\sigma_0} + (1 - \rho^2) \sigma_0 - \frac{\sigma_0}{2}\right)} \\ &\Rightarrow \\ \frac{y_F}{y_H} &> \tau^{\theta-1} \frac{\Pi_F}{\Pi_H} \end{aligned} \tag{13}$$

## D. Figures

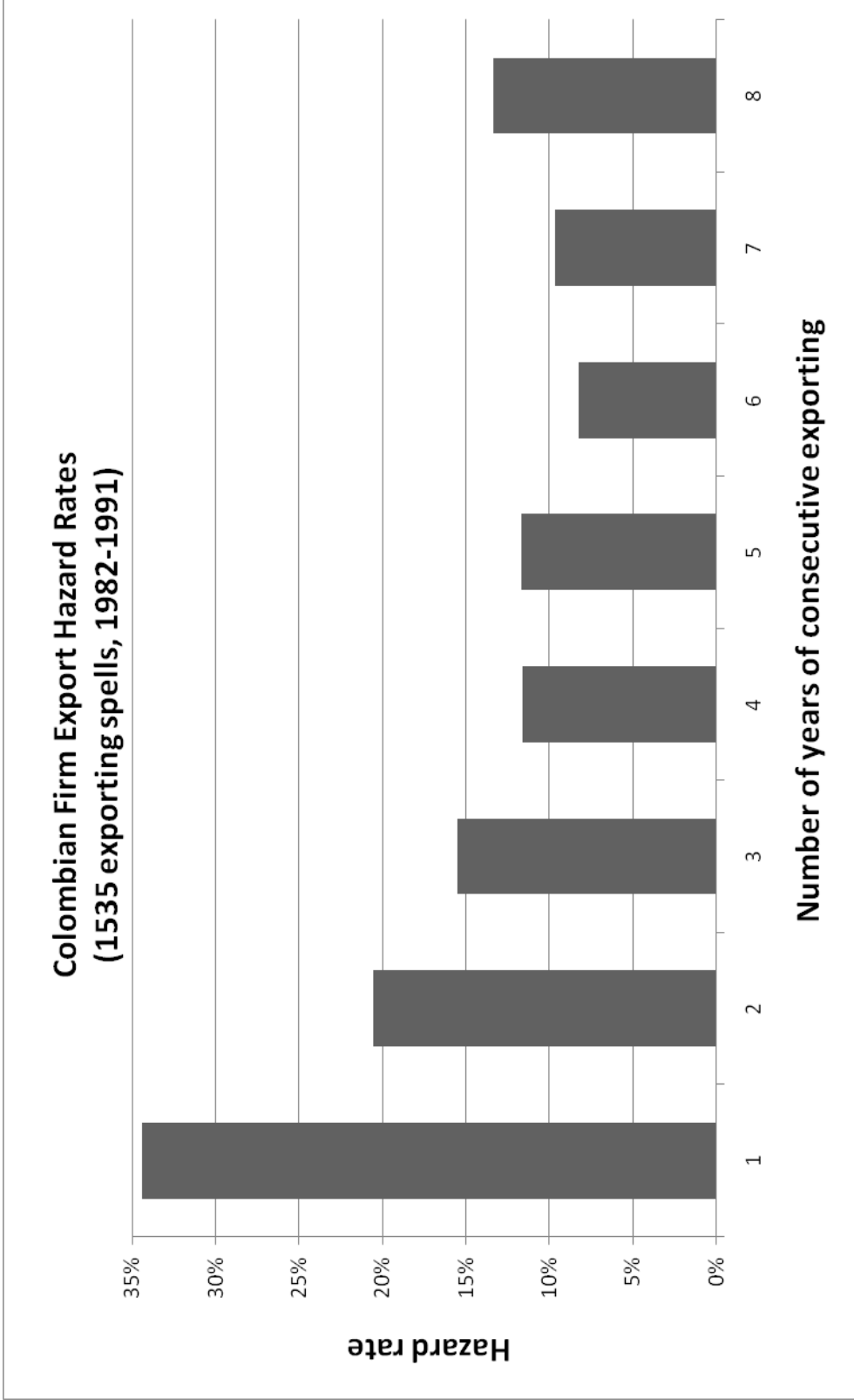


Figure 1: Hazard rates for Colombian firm exporting spells. An exporting spell is defined as the number of years of consecutive exporting. 1981 exporting status was used to determine whether a spell started in 1982. 1991 exporting status was used to determine the number of firms that survived, but not the number of firms that stopped. For example, there were 166 spells of 2 years that started in 1982 or after and ended in 1990 or before. There were 643 spells of lengths 3 or more that started in 1982 or after, including those that still exported in 1991. Therefore, the hazard rate at spells of 2 years =  $\frac{166}{166+643} = 21\%$ . The uptick at 8 years could be small sample error; only 6 firms failed after 8 years. No firms had exporting spells of exactly 9 years (1982-1990).