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Global Firms†

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Research in international trade has changed dramatically over the last twenty years, as attention has shifted from countries and industries towards the firms actually engaged in international trade. The now-standard heterogeneous firm model posits measure-zero firms that compete under monopolistic competition and decide whether to export to foreign markets. However, much of international trade is dominated by a few "global firms," which participate in the international economy along multiple margins and account for substantial shares of aggregate trade. We develop a new theoretical framework that allows firms to have large market shares and decide simultaneously on the set of production locations, export markets, input sources, products to export, and inputs to import. Using US firm and trade transactions data, we provide strong evidence in support of this framework's main predictions of interdependencies and complementarities between these margins of firm international participation. Global firms participate more intensively along each margin, magnifying the impact of underlying differences in firm characteristics and increasing their shares of aggregate trade. (*JEL* D22, F14, F23, L60, R32)

1. *Introduction*

Research in international trade has changed dramatically over the last twenty years, as attention has shifted from countries and industries toward firms. An initial wave of empirical research established a series of stylized facts: only some firms export, exporters are more productive than non-exporters, and trade liberalization is accompanied by an increase in aggregate industry productivity. Subsequent theoretical research emphasized

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reallocations of resources within and across firms, as well as endogenous changes in firm productivity in a setting in which measure-zero firms compete under monopolistic competition and self-select into export markets (e.g., Melitz 2003). This new theoretical research generated additional empirical predictions, which in turn led to a further wave of empirical research and an ongoing dialogue between theory and evidence.[1]

In this paper, we argue that this standard paradigm does not go far enough in recognizing the role of "global firms," which we define as firms that participate in the international economy along multiple margins and account for substantial shares of aggregate trade. We develop a new theoretical framework that incorporates a wider range of margins of participation in the international economy than previous research. Each firm can choose production locations in which to operate plants, export markets for each plant, products to export from each plant to each market, exports of each product from each plant to each market, the countries from which to source intermediate inputs for each plant, and imports of each intermediate input from each source country by each plant. Firms that participate so extensively in the international economy are unlikely to be measure zero and, indeed, account for substantial shares of observed trade. Therefore, we allow these global firms to internalize the effects of their pricing and product introduction decisions on market aggregates. Despite allowing for such effects on market aggregates and incorporating a rich range of firm decision margins, our model remains tractable and amenable to empirical analysis. The key contribution of this review, relative to our previous surveys (cited in footnote 1), is that we use this new theoretical framework to derive four sets of key predictions on which we present empirical evidence. Some of this evidence updates previous findings for earlier years, in which case we use our framework to draw out new insights and highlight changes over time. Other evidence is distinctive to this review and relates directly to the predictions of our new theoretical framework.

Our empirical work is organized around the following four sets of theoretical predictions. First, firm decisions for each margin of participation in the international economy are *interdependent*. For example, importing decisions are interdependent across countries, because the decision to incur the fixed costs of sourcing inputs from one country gives the firm access to lower-cost suppliers, which reduces firm production costs and prices. These lower prices in turn imply a larger scale of operation, which makes it more likely that the firm will find it profitable to incur the fixed costs of sourcing inputs from other countries (as in Tintelnot 2017 and Antràs, Fort, and Tintelnot 2017). Exporting and importing decisions are also interdependent with one another because incurring the fixed exporting cost for an additional market increases firm revenue, which makes it more likely that the firm will find it profitable to incur the fixed cost of sourcing inputs from any given country. This interaction between exporting and importing in turn implies that exporting decisions are interdependent across countries. Incurring the fixed exporting cost for an additional market increases firm revenue, which makes it more likely that the firm will find it profitable to incur the fixed cost of importing inputs from another country. This, in turn, reduces variable production costs and prices, and thereby increases revenue, which makes it more likely that the firm will find it profitable to incur the fixed exporting cost for another

[1] For earlier surveys of this theoretical and empirical literature, see Bernard et al. (2007), Bernard et al. (2012), Melitz and Trefler (2012), Melitz and Redding (2014a), and Redding (2011). For broader surveys of firm organization and trade, see Antràs (2015), Antràs and Rossi-Hansberg (2009), and Helpman (2006).

market. More generally, the choices of the set of markets to serve, the set of products to export, and the set of countries from which to source inputs (the "extensive margins") affect variable production costs and prices, which implies that they influence exports of each product to each market and imports of each input from each source country (the "intensive margins"). In a world of such interdependent firm decisions, understanding the effects of a reduction in trade costs on any one margin (e.g., exports of a given product to a given country) requires taking into account its effects on all other margins (through the organization of global production chains that involve imports as well as exports).

Second, firm decisions along multiple margins of international participation *magnify* the effects of differences in exogenous primitives (e.g., exogenous components of firm productivity) on endogenous outcomes (e.g., firm sales and employment). More productive firms participate more intensively in the world economy along each margin. Therefore, small differences in firm productivity can have magnified consequences for firm sales and employment, as more productive firms lower their production costs by sourcing inputs from more countries, and also expand their scales of operation by exporting more products to each market and exporting to more markets. Similarly, small changes in exogenous trade costs can have magnified effects on endogenous trade flows, as they induce firms to serve more markets, export more products to each market, export more of each product, source intermediate inputs from more countries, and import more of each intermediate input from each source country.

Third, firms that participate so intensively in the international economy are unlikely to be measure zero, and hence their choices can affect market aggregates, which gives rise to *strategic market power*. Firms with larger market shares have greater effects on market aggregates, and hence they face lower perceived elasticities of demand, which implies that they charge higher markups of price over marginal cost. This mechanism for variable markups operates across a range of different functional forms for demand, including constant elasticity of substitution (CES) preferences. These variable markups provide a natural explanation for empirical findings of "pricing to market," where firms charge different prices in different markets. Such price differences arise because firm markups vary endogenously across markets, depending on firm sales shares within each market. Variable markups provide a natural rationalization for empirical evidence of "incomplete pass-through," whereby cost shocks are not passed through fully into consumer prices. The reason is that, as cost shocks are transmitted to prices, they result in endogenous adjustments in sales shares, which lead to offsetting changes in firm markups. In addition to this strategic market power, when firms participate in international markets by exporting multiple products, they internalize the cannibalization effects from the introduction of new products on the sales of existing products. Hence, multiproduct firms make systematically different product introduction decisions from single-product firms.

Fourth, the magnification of exogenous differences across firms through multiple, interdependent, and complementary margins of international participation implies that aggregate trade is *concentrated* in the hands of a relatively small number of firms. Therefore, our framework offers new insights for understanding the skewed distribution of sales across firms that has been the subject of much attention in the industrial organization literature (e.g., Sutton 1997 and Axtell 2001). To infer the underlying distribution of firm productivity from the observed distribution of firm sales requires taking into account the multiple, interdependent, and complementary firm decisions (such as to enter export markets, supply products, and source intermediate inputs) that affect firm sales.

Our paper is related to the influential line of research that has modeled firm heterogeneity in differentiated product markets following Melitz (2003).[2] In this model, a competitive fringe of potential firms decide whether to enter an industry by paying a fixed entry cost, which is thereafter sunk. Potential entrants face ex ante uncertainty concerning their productivity. Once the sunk entry cost is paid, a firm draws its productivity from a fixed distribution and productivity remains fixed thereafter. Firms produce horizontally differentiated varieties within the industry under conditions of monopolistic competition.[3] The existence of fixed production costs implies that a firm drawing a productivity below the "zero-profit productivity cutoff" would make negative profits from producing and hence chooses instead to exit the industry. Fixed and variable costs of exporting ensure that only those active firms that draw a productivity above a higher "export productivity cutoff" find it profitable to export.[4] Following multilateral trade liberalization, high-productivity exporting firms experience increased revenue through greater export market sales; the most productive non-exporters now find it profitable to enter export markets, increasing the fraction of exporting firms; the least productive firms exit; and there is a contraction in the revenue of surviving firms that only serve the domestic market. Each of these responses reallocates resources toward high-productivity firms and raises aggregate productivity through a change in industry composition.[5]

Our contribution relative to this theoretical research is to develop a framework that incorporates a wider range of firm margins of international participation than in prior research. Each firm chooses the set of export markets to serve (as in Eaton, Kortum, and Kramarz 2011) and the set of products to supply to each export market (as in Bernard, Redding, and Schott 2010, 2011 and Hottman, Redding, and Weinstein 2016).[6] Each firm also chooses the set of countries from which to source intermediate inputs and which inputs to import from each source country (as in Antràs, Fort, and Tintelnot 2017 and Bernard, Moxnes, and Saito forthcoming).[7] We provide the first framework that simultaneously encompasses all of these margins of international participation and we show how this framework can be used to make sense of a number of features of US firm and trade transactions data. As firms that participate in the international economy along all of these margins can account for large shares of sales in individual markets, we allow firms to internalize their effects on market aggregates

[2] See also Bernard, Redding, and Schott (2007) and Melitz and Ottaviano (2008).

[3] For alternative approaches to firm heterogeneity, see Bernard et al. (2003) and Yeaple (2005).

[4] While the original model focuses on exporting, this framework is extended to incorporate foreign direct investment (FDI) as an alternative mode for servicing foreign markets in Helpman, Melitz, and Yeaple (2004).

[5] While firm productivity is fixed in the Melitz (2003) model, subsequent research has incorporated endogenous decisions that affect firm productivity through a variety of mechanisms, including technology adoption (Costantini and Melitz 2008, Bustos 2011, and Lileeva and Trefler 2010), innovation (Atkeson and Burstein 2010; Perla, Tonetti, and Waugh 2015; and Sampson 2016), endogenous changes in workforce composition (Helpman, Itskhoki, and Redding 2010 and Helpman et al. 2017) and endogenous changes in product mix (Bernard, Redding, and Schott 2010, 2011).

[6] Other research on multiproduct firms and trade includes Arkolakis, Muendler, and Ganapati (2016); Dhingra (2013); Eckel and Neary (2010); Feenstra and Ma (2008); Mayer, Melitz, and Ottaviano (2014); and Nocke and Yeaple (2014).

[7] Firm importing is also examined in Amiti and Konings (2007); Amiti and Davis (2012); Blaum, Lelarge, and Peters (2013, forthcoming); Goldberg et al. (2010); De Loecker et al. (2016); and Halpern, Koren, and Szeidl (2015).

when choosing prices, as in Atkeson and Burstein (2008); Eaton, Kortum, and Sotelo (2013); Edmond, Midrigan, and Xu (2015); Gaubert and Itskhoki (2015); Hottman, Redding, and Weinstein (2016); and Sutton and Trefler (2016).[8]

Our research is also related to the large empirical literature that has examined the relationship between firm performance and participation in international markets following Bernard and Jensen (1995). Early empirical studies in this literature used firm and plant-level data to document a number of stylized facts about exporters and non-exporters. In particular, exporters are larger, more productive, more capital intensive, more skill intensive, and pay higher wages than non-exporters within the same industry (see Bernard and Jensen 1995, 1999). Subsequent empirical research has used international trade transactions data to establish additional regularities about firm trade participation following Bernard, Jensen, and Schott (2009). Much of the variation in aggregate bilateral trade flows is accounted for by the extensive margins of the number of exporting firms (see Eaton, Kortum, and Kramarz 2004) and the number of firm product observations with positive trade (see Bernard et al. 2009). While the extensive margins of export firms and products are sharply decreasing in proxies for bilateral trade costs such as distance, the intensive margin of average exports per firm-product observation with positive trade exhibits little relationship with these proxies because of changes in export composition (see Bernard, Redding, and Schott 2011). We show how our theoretical framework accounts for these properties of firm export behavior and for a broader range of features of firm participation in the global economy.

Within this empirical literature on export participation, our paper is related to several studies that have focused on the largest firms in the international economy. Bernard, Jensen, and Schott (2009) document the concentration of activity in the largest exporting and importing firms for the United States and argues that the "most globally engaged" firms are more likely to trade with difficult markets and perform foreign direct investment. Mayer and Ottaviano (2007) establish a set of regularities for European firms and find that the export distribution is highly skewed. Freund and Pierola (2015) examine "export superstars" and find that very large firms shape country export patterns. Among thirty-two countries, the top firm, on average, accounts for 14 percent of a country's total (non-oil) exports; the top five firms make up 30 percent; and the revealed comparative advantage of countries can be created by a single firm.

Although our theoretical framework incorporates a wider range of margins of international participation than in previous research, it is necessarily an abstraction and cannot capture all features of firms' business strategies. In particular, we do not model the formation of individual trading relationships between buyers and sellers, as in the recent literature on networks in international trade, including Bernard, Moxnes, and Saito (forthcoming); Bernard, Moxnes, and Ulltveit-Moe (forthcoming); Chaney (2014, 2018); Eaton et al. (2014); Eaton et al. (2016); and Lim (2016). We also abstract from "carry along trade," in which a firm exports products that it does not produce, as examined in Bernard et al. (forthcoming). Our theoretical framework incorporates multinational activity to rationalize the trade between related parties that we observe in

[8] A related body of research examines the idea that firms can be "granular," in the sense that idiosyncratic shocks to individual firms can influence aggregate business-cycle fluctuations, as in Gabaix (2011) and di Giovanni, Levchenko, and Mejean (2014). For broader arguments for incorporating oligopolistic competition into international trade, see Neary (2003, 2016) and Shimomura and Thisse (2012).

the US trade transactions data. Our paper is therefore related to the large literature on multinational firms, including Arkolakis et al. (forthcoming); Muendler and Becker (2010); Cravino and Levchenko (2017); Helpman, Melitz, and Yeaple (2004); and Ramondo and Rodriguez-Clare (2013) as reviewed in Antràs and Yeaple (2009). However, as discussed further below, a caveat is that we do not have data on the overseas production activity of multinational firms, and we only observe related-party trade when one party to the transaction is located in the United States.

The remainder of the paper is structured as follows. Section 2 develops our theoretical framework. Section 3 introduces the data. Section 4 provides empirical evidence on the key predictions of our theoretical framework. Section 5 concludes.

2. *Theoretical Framework*

We consider a world of many (potentially) asymmetric countries. Firms are heterogeneous in productivity and make three sets of decisions: which markets to serve (typically indexed by m), which countries to produce in (usually denoted by i), and which countries to source inputs from (generally indicated by j). For each destination market, firms choose the range of products to supply to that market (ordinarily referenced by k). For each source country, firms choose the range of intermediate inputs to obtain from that source (most often represented by ℓ). We assume that consumer preferences take the CES form. However, we allow firms to be large relative to the markets in which they sell their products, which introduces variable markups (because each firm internalizes the effect of its pricing choices on market aggregates). We use the firm's profit-maximization problem to derive general properties of a firm's decisions to participate in international markets as a function of its productivity that hold regardless of the way in which the model is closed in general equilibrium.

2.1 *Preferences*

We consider a nested structure of demand as in Hottman, Redding, and Weinstein (2016). Preferences in each market m are a Cobb–Douglas aggregate of the consumption indices (C^G_{mg}) of a continuum of sectors indexed by g:

$$(1) \qquad \ln U_m = \int_{g\in\Omega^G} \lambda^G_{mg} \ln C^G_{mg}\, dg, \qquad \int_{g\in\Omega^G} \lambda^G_{mg}\, dg = 1,$$

where λ^G_{mg} determines the share of market m's expenditure on sector g; and Ω^G is the set of sectors.[9] The consumption index (C^G_{mg}) for each sector g in each market m is defined over consumption indices (C^F_{mif}) for each final good firm f from each production country i:

$$(2) \qquad C^G_{mg} = \left[\sum_{i\in\Omega^N}\sum_{f\in\Omega^F_{mig}} \left(\lambda^F_{mif} C^F_{mif}\right)^{\frac{\sigma^F_g-1}{\sigma^F_g}}\right]^{\frac{\sigma^F_g}{\sigma^F_g-1}},$$

$$\sigma^F_g > 1, \quad \lambda^F_{mif} > 0,$$

where σ^F_g is the elasticity of substitution across firms for sector g; Ω^N is the set of countries; λ^F_{mif} is a demand shifter ("firm appeal") that captures the overall appeal of the consumption index supplied by firm f to market m from production country i; and Ω^F_{mig} is the set of firms that supply market m from production country i within sector

[9] For expositional clarity, we use the superscripts G, F, and K to denote sector, firm, and product-level variables. We use the subscripts m, i, and j to index the values of variables for individual markets, production countries, and source countries respectively. We use the subscripts g, f, and k to index the values of variables for individual sectors, firms, and products respectively.

g.[10] The consumption index (C^F_{mif}) for each firm f from production location i in market m within sector g is defined over the consumption (C^K_{mik}) of each final product k:

$$(3)\quad C^F_{mif} = \left[\sum_{k \in \Omega^K_{mif}} \left(\lambda^K_{mik} C^K_{mik} \right)^{\frac{\sigma^K_g - 1}{\sigma^K_g}} \right]^{\frac{\sigma^K_g}{\sigma^K_g - 1}},$$

$$\sigma^K_g > 1, \quad \lambda^K_{mik} > 0,$$

where σ^K_g is the elasticity of substitution across products within firms; λ^K_{mik} is a demand shifter ("product appeal") that captures the appeal of product k supplied to market m from production country i; and Ω^K_{mif} is the set of products supplied by firm f to market m from production country i.

There are a few features of this specification worth noting. First, we allow firms to be large relative to sectors (and hence internalize their effects on the price index for the sector). However, we assume that each firm is of measure zero, relative to the economy as a whole (and hence takes aggregate expenditure E_m and wages w_m as given). Second, the assumption that the upper level of utility is Cobb–Douglas implies that no firm has an incentive to try to manipulate prices in one sector to influence behavior in another sector. The reason is that each firm is assumed to be small relative to the aggregate economy (and hence cannot affect aggregate expenditure) and sector expenditure shares are determined by the Cobb–Douglas parameters λ^G_{mg} alone. Therefore, the firm problem becomes separable by sector, which implies that the divisions of a firm that operate in multiple sectors can be treated as if they were separate firms. The firm's overall size, performance, and participation in international markets is determined by the aggregation of its decisions across all of the sectors in which it is active. When we present our empirical results below, we report both results for the firm as a whole and for the firm's separate activities for each sector and product. To simplify the exposition throughout the rest of this theoretical section, we refer to the divisions of multi-sector firms that operate in different sectors as, simply, firms.

Third, our framework incorporates multinational activity because we allow firms to simultaneously choose the set of markets to serve, the set of countries in which to produce, and the set of countries from which to source inputs. Multinational activity occurs whenever a firm locates a production facility in a foreign country. We allow for such multinational activity to rationalize the trade between related parties that we observe in the US trade transactions data. However, a caveat is that we only observe such trade when one party to the transactions is located in the United States, because we do not have data on the overseas production activity of multinational firms or related-party trade between pairs of foreign production facilities.

Fourth, we allow for horizontal differentiation across both firms f and production locations i, because the appeal parameter for each firm f in market m (λ^F_{mif}) is allowed to depend on the production location i from which that market is served. Therefore, a given firm's products supplied from different production locations are imperfect substitutes, which enables the model to rationalize a firm supplying a given market from multiple

[10] Much of the existing empirical literature in international trade and industrial organization refers to any shifter of demand conditional on price (such as λ^F_{mif}) as "quality," as in Shaked and Sutton (1983), Berry (1994), Schott (2004), Khandelwal (2010), Broda and Weinstein (2010), Hallak and Schott (2011), Manova and Zhang (2012), and Feenstra and Romalis (2014). But this demand shifter can also capture more subjective differences in taste, as discussed in Di Comite, Thisse, and Vandenbussche (2014). We use the term "appeal" to avoid taking a stand as to whether the shift in demand arises from vertical quality differentiation or subjective differences in consumer taste.

production locations. We allow the strength of consumer preferences for the firm's products to depend on the production location in which they are produced. For example, Canadian consumers can have different preferences for Toyota cars depending on whether those Toyotas are produced in Canada or Japan.

Fifth, since preferences are homogeneous of degree one in appeal, firm appeal (λ^F_{mif}) cannot be defined independently of product appeal (λ^K_{mik}). We therefore need a normalization. It proves convenient to make the following normalizations: we set the geometric mean of product appeal (λ^K_{mik}) across products within each firm and production country equal to one and the geometric mean of firm appeal (λ^F_{mif}) across firms within each sector equal to one:

$$(4) \qquad \left(\prod_{k\in\Omega^K_{mif}} \lambda^K_{mik}\right)^{\frac{1}{N^K_{mif}}} = 1,$$

$$\left(\prod_{i\in\Omega^N}\prod_{f\in\Omega^F_{mig}} \lambda^F_{mif}\right)^{\frac{1}{N^F_{mg}}} = 1,$$

where $N^K_{mif} = \left|\Omega^K_{mif}\right|$ is the number of products supplied by firm f from production country i to market m and $N^F_{mg} = \left|\left\{\Omega^F_{mig} : i \in \Omega^N\right\}\right|$ is the total number of firms supplying market m from all production countries i within sector g.

Under these normalizations, product appeal (λ^K_{mik}) determines the relative expenditure shares of products within a given firm from a given production country, while firm appeal (λ^F_{mif}) determines the relative expenditure shares of firms from a given production country within a given sector and market; the Cobb–Douglas expenditure shares (λ^G_{mg}) determine the relative expenditure shares of sectors within a given market; and aggregate expenditure (E_m) captures the overall level of expenditures in a given market. The corresponding sectoral price index dual to (2) is:

$$(5) \quad P^G_{mg} = \left[\sum_{i\in\Omega^N}\sum_{f\in\Omega^F_{mig}} \left(\frac{P^F_{mif}}{\lambda^F_{mif}}\right)^{1-\sigma^F_g}\right]^{\frac{1}{1-\sigma^F_g}},$$

and the corresponding firm price index dual to (3) is:

$$(6) \quad P^F_{mif} = \left[\sum_{k\in\Omega^K_{mif}} \left(\frac{P^K_{mik}}{\lambda^K_{mik}}\right)^{1-\sigma^K_g}\right]^{\frac{1}{1-\sigma^K_g}}.$$

An important property of these CES preferences, which we use below, is that elasticity of the price index with respect to a price of a variety is that variety's expenditure share. Therefore the expenditure share of firm f from production country i in market m within sector g is:

$$(7) \quad S^F_{mif} = \frac{\left(P^F_{mif}/\lambda^F_{mif}\right)^{1-\sigma^F_g}}{\sum_{i\in\Omega^N}\sum_{o\in\Omega^F_{mig}}\left(P^F_{mio}/\lambda^F_{mio}\right)^{1-\sigma^F_g}} = \frac{\partial P^G_{mg}}{\partial P^F_{mif}}\frac{P^F_{mif}}{P^G_{mg}},$$

and the expenditure share of product k from production country i in market m within firm f is:

$$(8) \quad S^K_{mik} = \frac{\left(P^K_{mik}/\lambda^K_{mik}\right)^{1-\sigma^K_g}}{\sum_{n\in\Omega^K_{mif}}\left(P^K_{min}/\lambda^K_{min}\right)^{1-\sigma^K_g}} = \frac{\partial P^F_{mif}}{\partial P^K_{mik}}\frac{P^K_{mik}}{P^F_{mif}}.$$

The corresponding level of expenditure on product k is:

$$(9) \quad E^K_{mik} = \left(\lambda^F_{mif}\right)^{\sigma^F_g-1}\left(\lambda^K_{mik}\right)^{\sigma^K_g-1}\left(\lambda^G_{mg}w_m L_m\right) \times \left(P^G_{mg}\right)^{\sigma^F_g-1}\left(P^F_{mif}\right)^{\sigma^K_g-\sigma^F_g}\left(P^K_{mik}\right)^{1-\sigma^K_g},$$

where we have used the Cobb–Douglas upper tier of utility, which implies that sectoral expenditure is a constant share of aggregate expenditure ($E^{G}_{mg} = \lambda^{G}_{mg} E_m$). We have also used the fact that aggregate expenditure equals aggregate income ($E_m = w_m L_m$), where labor is the sole primary factor of production with wage w_m and inelastic supply L_m.

2.2 *Final Goods Production Technology*

A final-goods firm f is defined by its productivity (φ_{if}) in each potential country of production i, consumers' perceptions of the overall appeal of the firm from that production country in market m (λ^{F}_{mif}), and consumers' perceptions of the appeal of each product k supplied by that firm from that production country to that market (λ^{K}_{mik}). Each product k is produced using labor and a continuum of intermediate inputs indexed by $\ell \in [0,1]$, which are modeled following Eaton and Kortum (2002) and Antràs, Fort, and Tintelnot (2017).[11] A firm f with productivity φ_{if} that locates a plant in production country i and uses L^{K}_{ik} units of labor and an amount $Y^{K}_{ik}(\ell)$ of each intermediate input ℓ can produce the following output (Q^{K}_{ik}) of product k:

$$(10)\ Q^{K}_{ik} = \varphi_{if}\left(\frac{L^{K}_{ik}}{\alpha_g}\right)^{\alpha_g}\left(\frac{\int_0^1 Y^{K}_{ik}(\ell)^{\frac{\eta_g-1}{\eta_g}}d\ell}{1-\alpha_g}\right)^{\frac{(1-\alpha_g)\,\eta_g}{\eta_g-1}},$$

$$0 < \alpha_g < 1, \quad \eta_g > 1,$$

where α_g is the share of labor in final production costs; η_g is the elasticity of substitution across intermediate inputs for sector g; and more productive firms (with higher φ_{if}) generate more output for given use of labor (L^{K}_{ik}) and intermediate inputs $Y^{K}_{ik}(\ell)$. We characterize below the properties of the final goods firm's profit maximization problem as a function of its productivity (φ_{if}), regardless of the functional form of the distribution from which that productivity is drawn. Therefore, we are not required to impose a particular functional form for the distribution of final goods productivity.

To open a plant in production country i, firm f must incur a fixed production cost of $F^{P}_{i} > 0$ units of labor. We also assume that the firm must incur a fixed exporting cost of $F^{X}_{mi} > 0$ units of labor to export to market m from production country i, after which it can supply that market subject to iceberg variable trade costs of $d^{X}_{mi} \geq 1$, where $d^{X}_{mi} > 1$ for $m \neq i$ and $d^{X}_{mm} = 1$. Additionally, we assume that the firm must incur fixed sourcing costs of $F^{I}_{ij} > 0$ units of labor to obtain intermediate inputs in production country i from source country j, after which it can obtain these inputs subject to iceberg variable trade costs of $d^{I}_{ij} \geq 1$, where $d^{I}_{ij} > 1$ for $i \neq j$ and $d^{I}_{ii} = 1$. The fixed costs of production, exporting, and sourcing (F^{P}_{i}, F^{X}_{mi}, and F^{I}_{ij}) are incurred in terms of labor in country i and must be paid irrespective of the number of products exported or the number of inputs used. To rationalize firms only exporting a subset of their products to some markets, we also assume a fixed product exporting cost (F^{K}_{mik}) for each product k exported from production country i to market m. We allow the variable trade costs to differ between final and intermediate goods ($d^{X}_{mi} \neq d^{I}_{mi}$). For simplicity, we assume that the final goods variable trade costs (d^{X}_{mi}) are the same across products k, and the intermediate inputs variable trade costs (d^{I}_{ij}) are the same across inputs ℓ, although it is possible to relax both of these assumptions. Consistent with a large empirical literature, we assume that fixed and variable trade costs are sufficiently high that only a subset of firms from each production country i export to foreign markets $m \neq i$ and that only a subset of these firms from production country i import intermediate inputs from foreign source countries $j \neq i$.

[11] See also Bernard, Moxnes, and Saito (forthcoming); Rodríguez-Clare (2010); and Tintelnot (2017).

2.3 *Intermediate Input Production Technology*

Intermediate inputs are produced with labor according to a linear technology under conditions of perfect competition. If a final-goods firm f in production country i has chosen to incur the fixed importing costs for source country j, the cost of sourcing an intermediate input ℓ from country j for product k is:

$$(11) \qquad a_{ijfk}(\ell) \;=\; \frac{w_j d_{ij}^I}{z_{ijfk}(\ell)},$$

where, recall that w_j is the wage in country j and $z_{ijfk}(\ell)$ is a stochastic draw for intermediate input productivity. We assume that intermediate input productivity is drawn independently for each final-good firm f, product k, intermediate input ℓ, production country i, and source country j from a Fréchet distribution:

$$(12) \qquad G_{ijfk}(z) \;= e^{-T_{jk}^K z^{-\theta_k^K}},$$

where T_{jk}^K is the Fréchet scale parameter that determines the average productivity of intermediate inputs from source j for product k and θ_k^K is the Fréchet shape parameter that determines the dispersion of intermediate input productivity for product k.

Although intermediate input productivity $(z_{ijfk}(\ell))$ is specific to a final-goods firm, we assume that all intermediate input firms within source country j have access to this productivity, which ensures that intermediate inputs are produced under conditions of perfect competition.[12] Although intermediate input productivity draws are assumed to be independent, we allow the scale parameter T_{jk}^K to vary across both products and countries. Therefore, if source country j has a high value of T_{jk}^K for product k and also has a high value of T_{jn}^K for another product $n \neq k$, this variation in the Fréchet scale parameters will induce a correlation between intermediate input productivity draws for products k and n.

2.4 *Exporting and Importing Decisions*

Firm decisions in this framework involve the organization of global production chains.[13] Each final-goods firm chooses the set of production countries in which to operate plants, taking into account the location of these facilities relative to final-goods markets and their location relative to sources of intermediate inputs. Each final-goods firm also chooses the set of markets to supply from each plant, the range of products to export from each plant to each market, the set of countries from which to source intermediate inputs for each product in each plant, and imports of each input for each product in each plant.

We analyze the final-goods firm's optimal exporting and importing decisions in two stages. First, for given sets of countries for which the fixed production costs (F_i^P), fixed exporting costs (F_{mi}^X), and fixed sourcing costs (F_{ij}^I) have been incurred, and for a given set of products for which the product fixed exporting costs (F_{mik}^K) have been incurred for each production location and market, we characterize the firm's optimal decisions

[12] We thus abstract from issues of incomplete contracts and hold-up with relationship-specific investments, as considered in Antràs (2003), Antràs and Helpman (2004), and Helpman (2006). Within our framework, final-goods firms are indifferent whether to source intermediate inputs within or beyond the boundaries of the firm.

[13] The determinants and implications of global production chains are explored in Antràs and Chor (2013); Alfaro et al. (forthcoming); Baldwin and Venables (2013); Costinot, Vogel, and Wang (2013); Dixit and Grossman (1982); Grossman and Rossi-Hansberg (2008); Johnson and Noguera (forthcoming); Melitz and Redding (2014b); and Yi (2003).

of which intermediate inputs to source from each country, how much of each intermediate input to import from each source country, and how much of each product to export to each market. Second, we characterize the firm's optimal choices of the set of countries for which to incur these fixed production, exporting, and sourcing costs.

2.4.1 *Importing Decisions for a Given Set of Locations*

We begin with the final-goods firm's sourcing decisions for intermediate inputs. Suppose that firm f has chosen the set of production countries i in which to locate plants ($\Omega_f^{NP} \subseteq \Omega^N$), the set of markets m to which to export from each plant ($\Omega_{if}^{NX} \subseteq \Omega^N$), the set of source countries j from which to obtain intermediate inputs for each plant ($\Omega_{if}^{NI} \subseteq \Omega^N$), and the set of products k to export from each plant to each market (Ω_{mif}^{K}). Given these sets of countries and products, we now characterize the firm's optimal intermediate input sourcing decisions for these sets. Using the monotonic relationship between the price of intermediate inputs ($a_{ijfk}(\ell)$) and intermediate input productivity ($z_{ijfk}(\ell)$) in (11) and the Fréchet distribution of this productivity (12), the firm f in production country i faces the following distribution of prices for intermediate inputs for each product k from each source country $j \in \Omega_{if}^{NI}$:

$$(13) \quad G_{ijfk}(a, \Omega_{if}^{NI}) \; = \; 1 - e^{-T_{jk}^{K}(w_j d_{ij}^{I})^{-\theta_k^K} a^{\theta_k^K}}, \qquad j \in \Omega_{if}^{NI}.$$

The firm sources each intermediate input for each product from the lowest-cost supplier within its set of source countries $j \in \Omega_{if}^{NI}$. Since the minimum of Fréchet-distributed random variables is itself Fréchet distributed, the corresponding distribution of minimum prices across all source countries $j \in \Omega_{if}^{NI}$ is:

$$(14) \quad G_{ifk}(a, \Omega_{if}^{NI}) \; = \; 1 - e^{-\Phi_{ifk}\left(\Omega_{if}^{NI}\right) a^{\theta_k^K}},$$

$$\Phi_{ifk}\left(\Omega_{if}^{NI}\right) \; \equiv \sum_{j \in \Omega_{if}^{NI}} T_{jk}^{K}(w_j d_{ij}^{I})^{-\theta_k^K}.$$

Given this distribution for minimum prices, the probability that the firm f in production country i sources an intermediate input for product k from source country $j \in \Omega_{if}^{NI}$ is:

$$(15) \quad \mu_{ijfk}(\Omega_{if}^{NI}) = \frac{T_{jk}^{K}(w_j d_{ij}^{I})^{-\theta_k^K}}{\sum_{h \in \Omega_{if}^{NI}} T_{hk}^{K}(w_h d_{ih}^{I})^{-\theta_k^K}}.$$

The variable-unit cost function dual to the final-goods production technology (10) is:

$$(16) \quad \delta_{ifk}^{K}(\varphi_{if}, \Omega_{if}^{NI}) = \frac{1}{\varphi_{if}} w_i^{\alpha_g} \left[\int_0^1 a_{ifk}(\ell)^{1-\eta_g} d\ell\right]^{\frac{1-\alpha_g}{1-\eta_g}}.$$

Using the distribution for intermediate input prices (14), variable unit costs can be expressed as:

$$(17) \quad \delta_{ifk}^{K}(\varphi_{if}, \Omega_{if}^{NI}) = \frac{1}{\varphi_{if}} w_i^{\alpha_g} \left(\gamma_k^K\right)^{1-\alpha_g} \left[\Phi_{ifk}\left(\Omega_{if}^{NI}\right)\right]^{-\frac{1-\alpha_g}{\theta_k^K}},$$

where

$$\gamma_k^K \; = \; \left[\Gamma\left(\frac{\theta_k^K + 1 - \eta_g}{\theta_k^K}\right)\right]^{\frac{1}{1-\eta_g}},$$

$\Gamma(\cdot)$ is the Gamma function, and we require $\theta_k^K > \eta_g - 1$.

We refer to $\Phi_{ifk}\left(\Omega_{if}^{NI}\right)$ as *firm supplier access* because it summarizes a final-goods firm's access to intermediate inputs around the globe as a function of its choice of the set of source countries (Ω_{if}^{NI}). Other things equal, firm supplier access is decreasing in the number of source countries: $N_{if}^{I} = \left|\Omega_{if}^{NI}\right|$. Firm supplier access also depends on wages (w_j) and intermediate input productivity (T_{jk}^{K}) in each source country $j \in \Omega_{if}^{NI}$ and the variable trade costs of importing intermediate inputs from those source countries (d_{ij}^{I}). The firm's total cost function (including fixed sourcing costs and taking into account the firm's output choice) for product k is:

$$(18) \quad \Lambda\left(\varphi_{if}, \Omega_{if}^{NI}, Q_{ik}^{K}\right) = \frac{w_i^{\alpha_g}\left(\gamma_k^K\right)^{1-\alpha_g}\left[\Phi_{ifk}\left(\Omega_{if}^{NI}\right)\right]^{-\frac{1-\alpha_g}{\theta_k^K}}}{\varphi_{if}} Q_{ik}^{K} + \sum_{j\in\Omega_{if}^{NI}} w_i F_{ij}^{I},$$

where Q_{ik}^{K} is total firm output of product k in country i, which is the sum of output produced for each market m (Q_{mik}^{K}) across all markets: $Q_{ik}^{K} = \sum_{m\in\Omega_{if}^{NX}} Q_{mik}^{K}$. Firms that incur the fixed sourcing costs (F_{ij}^{I}) for more source countries j have higher total fixed costs, but lower variable costs, because of improved firm supplier access $\Phi_{ifk}\left(\Omega_{if}^{NI}\right)$.

Finally, an implication of the Fréchet assumption for intermediate input productivity is that the average prices of intermediate inputs conditional on sourcing those inputs from a given source country are the same across all source countries. Therefore, the probability ($\mu_{ijfk}(\Omega_{if}^{NI})$) that a firm f in production country i obtains an input for product k from source country j (15) also corresponds to its share of expenditure on inputs from that source country in its total expenditure on inputs for that product.

2.4.2 *Exporting Decisions for a Given Set of Locations*

Given the final-goods firm f's choice of sets of production countries i (Ω_f^{NP}), markets m (Ω_{if}^{NX}), input sources j (Ω_{if}^{NI}), and sets of products exported to each market (Ω_{mif}^{K}), we now characterize its optimal exporting decisions. Firm f from production country i chooses the price (P_{mik}^{K}) for each product k for each market m within sector g to maximize its profits subject to the downward-sloping demand curve (9) and taking into account the effects of its choices on market price indices:

$$(19) \quad \max_{\left\{P_{mik}^{K}: m\in\Omega_{if}^{NX}, k\in\Omega_{mif}^{K}\right\}} \Pi_{igf}^{F} = \Bigg\{ \sum_{m\in\Omega_{if}^{NX}} \sum_{k\in\Omega_{mif}^{K}} \Bigg[P_{mik}^{K} Q_{mik}^{K}\left(P_{mik}^{K}\right) - \frac{d_{mi}^{X} w_i^{\alpha_g}\left(\gamma_k^K\right)^{1-\alpha_g}\left[\Phi_{ifk}\left(\Omega_{if}^{NI}\right)\right]^{-\frac{1-\alpha_g}{\theta_k^K}}}{\Phi_{if}} Q_{mik}^{K}\left(P_{mik}^{K}\right) \Bigg] - \sum_{m\in\Omega_{if}^{NX}} \sum_{k\in\Omega_{mif}^{K}} w_i F_{mik}^{K} - \sum_{m\in\Omega_{if}^{NX}} w_i F_{mi}^{X} - \sum_{j\in\Omega_{if}^{NI}} w_i F_{ij}^{I} - w_i F_i^{P} \Bigg\},$$

where, recall that $d_{mi}^{X} > 1$ for $m \neq i$ are iceberg variable trade costs for final goods.

Under our assumption of nested CES demand, each final-goods firm f from production country i internalizes that it is the monopoly supplier of the firm consumption index (C_{mif}^{F}) to market m within a given sector, and hence chooses a common markup (μ_{mif}^{F}) of price over marginal cost across all products within that market and sector, as in Hottman, Redding, and Weinstein (2016):

$$(20) \quad P_{mik}^{K} = \mu_{mif}^{F} \frac{d_{mi}^{X} w_i^{\alpha_g}\left(\gamma_k^K\right)^{1-\alpha_g}\left[\Phi_{ifk}\left(\Omega_{if}^{NI}\right)\right]^{-\frac{1-\alpha_g}{\theta_k^K}}}{\varphi_{if}}.$$

The size of this markup (μ_{mif}^{F}) depends on the perceived elasticity of demand (ε_{mif}^{F}) for the firm consumption index in market m:

$$(21) \qquad \mu_{mif}^{F} = \frac{\varepsilon_{mif}^{F}}{\varepsilon_{mif}^{F} - 1},$$

where this perceived elasticity of demand depends on the firm's market share:

$$(22) \qquad \varepsilon_{mif}^{F} = \sigma_{g}^{F} - \left(\sigma_{g}^{F} - 1\right) S_{mif}^{F}$$

$$= \sigma_{g}^{F}\left(1 - S_{mif}^{F}\right) + S_{mif}^{F},$$

where S_{mif}^{F} is the share of firm f from production country i in sectoral expenditure in market m.[14]

Our framework generates these variable markups with CES demand by departing from the assumption of monopolistic competition, instead allowing firms to internalize the effects of their decisions on sectoral price indices in each market, as in Atkeson and Burstein (2008); Eaton, Kortum, and Sotelo (2013); Edmond, Midrigan, and Xu (2015); Hottman, Redding, and Weinstein (2016); and Sutton and Trefler (2016). More productive firms have larger market shares, so that their pricing decisions have a larger effect on sectoral price indices, which implies that they have a lower perceived elasticity of demand.[15]

An alternative approach to generating variable markups would have been to assume non-CES demand, as in the quasi-linear preferences of Melitz and Ottaviano (2008), the constant absolute risk aversion preferences of Behrens and Murata (2012), and the indirectly additive preferences of Bertoletti, Etro, and Simonovska (2016). Our approach allows size differences between firms to affect markups across a wide range of different functional forms for demand (including CES) because firms internalize that their decisions affect sectoral aggregates within each market. From equations (21) and (22), as a firm's market share becomes small within a sector and market ($S_{mif}^{F} \rightarrow 0$), its markup converges to that for the special case of monopolistic competition.

Our framework's prediction of variable markups receives support from a substantial empirical literature in industrial organization, including Trajtenberg (1989), Goldberg (1995), Nevo (2001), De Loecker and Warzynski (2012), and De Loecker et al. (2016), as reviewed in Bresnahan (1989). From equations (21) and (22), the markup charged by each firm differs across markets, depending on its share of expenditure within the sector in that market. This property of the model is consistent with the literature on *pricing to market*, where firms charge different prices for the same good across markets, including Krugman (1987), Bergin and Feenstra (2001), Atkeson and Burstein (2008), Goldberg and Hellerstein (2013), and Fitzgerald and Haller (2014), as reviewed in De Loecker and Goldberg (2014). Finally, the variable markup in equations (21) and (22) implies that an increase in marginal costs is not fully passed on to consumers in the form of a higher price, because the fall in market share induced by a higher price leads to a fall in markup. A large body of empirical research confirms such *incomplete pass-through*, as reviewed in Goldberg and Knetter (1997), with implications for

[14] Although we assume that firms choose prices under Bertrand competition, it is straightforward to consider the alternative case in which firms choose quantities under Cournot competition. In this alternative specification, firms again charge variable markups that are common across products within a given sector and market, but the expression for the perceived elasticity of demand differs, as shown in Atkeson and Burstein (2008) and Hottman, Redding, and Weinstein (2016).

[15] Although firms can be large relative to sectors within markets, and therefore internalize the effect of their decisions on sectoral price indices, we assume that firms remain small relative to each market as a whole, and hence take aggregate expenditure and wages as given. In this sense, firms are large in the small and small in the large, as in Neary (2003, 2016).

monetary policy and the international transmission of shocks, as examined in Smets and Wouters (2007); Gopinath and Itskhoki (2010); Berman, Martin, and Mayer (2012); and Amiti, Itskhoki, and Konings (2014).

The property that the final-goods firm charges a common markup across all products within a given sector and market is a generic feature of nested demand systems. The intuition for this result can be garnered by thinking about the firm's profit-maximization problem in two stages. First, the firm chooses the price index (P_{mif}^{F}) to maximize the profits from supplying its consumption index (C_{mif}^{F}), which implies a markup at the firm level within a given sector and market over the cost of supplying its real consumption index. Second, the firm chooses the price for each product to minimize the cost of supplying its real consumption index (C_{mif}^{F}), which requires setting the relative prices of these products equal to their relative marginal costs. Together, these two results ensure the same markup across all products supplied by the firm within a given sector and market. Nonetheless, firm markups vary across markets within a given sector (with the firm market share in those markets). As the firm's profit maximization problem is separable across sectors, firm markups also vary across sectors within a given market (with the firm market share and elasticity of substitution across products within those sectors).[16]

Using the equilibrium pricing rule (20) in the firm problem (19), equilibrium profits for final goods firm f from production location i within sector g can be written in terms of sales from each product k in each market, the common markup across products within each market, and the fixed costs:

$$(23) \quad \Pi_{igf}^{F} = \Bigg\{ \sum_{m \in \Omega_{if}^{NX}} \sum_{k \in \Omega_{mif}^{K}} \left(\frac{\mu_{mif}^{F} - 1}{\mu_{mif}^{F}} \right) E_{mik}^{K} - \sum_{m \in \Omega_{if}^{NX}} \sum_{k \in \Omega_{mif}^{K}} w_i F_{mik}^{K} - \sum_{m \in \Omega_{if}^{NX}} w_i F_{mi}^{X} - \sum_{j \in \Omega_{if}^{NI}} w_i F_{ij}^{I} - w_i F_{i}^{P} \Bigg\}.$$

Using the markup (21) and our assumption of constant marginal costs to recover variable costs from sales (as $E_{mik}^{K}/\mu_{mif}^{F}$), and using the share of each source country in variable costs (15), imports of intermediate inputs for product k by firm f from production location i within sector g from source country j are:

$$(24) \quad M_{ifkj}^{K} = \frac{T_{jk}^{K} (w_j d_{ij}^{I})^{-\theta_k^K}}{\sum_{h \in \Omega_{if}^{NI}} T_{hk}^{K} (w_h d_{ih}^{I})^{-\theta_k^K}} \left[\sum_{m \in \Omega_{if}^{NX}} \frac{E_{mik}^{K}}{\mu_{mif}^{F}} \right].$$

Finally, using the equilibrium pricing rule (20) in the revenue function (9), sales of each product (E_{mik}^{K}) depend on firm supplier access (Ω_{if}^{NI}) through variable production costs:

$$(25) \quad E_{mik}^{K} = \left(\lambda_{mif}^{F}\right)^{\sigma_g^F - 1} \left(\lambda_{mik}^{K}\right)^{\sigma_g^K - 1} \times \left(\lambda_{mg}^{G} w_m L_m\right) \left(P_{mg}^{G}\right)^{\sigma_g^F - 1} \left(P_{mif}^{F}\right)^{\sigma_g^K - \sigma_g^F} \times \left(\mu_{mif}^{F} \frac{d_{mi}^{X} w_i^{\alpha_g} \left(\gamma_k^K\right)^{1-\alpha_g} \left[\Phi_{ifk}\left(\Omega_{if}^{NI}\right)\right]^{-\frac{1-\alpha_g}{\theta_k^K}}}{\varphi_{if}} \right)^{1-\sigma_g^K}.$$

As in Antràs, Fort, and Tintelnot (2017), incurring the fixed sourcing cost for a new source country (expanding Ω_{if}^{NI}) has two effects on imports from existing source countries for each product. On the one hand, the addition of the new source country reduces imports from existing source countries through a substitution effect (from the expenditure shares (15)). On the other hand, the addition of the new source country improves supplier access (Φ_{ifk}), which reduces production costs and expands firms' sales (from the revenue function (25)), which raises imports from existing source countries

[16] As long as the elasticity of substitution across products within firms (σ_g^K) is greater than the elasticity of substitution across firms (σ_g^F), firms face cannibalization effects such that the introduction of a new product cannibalizes the sales of existing products, as examined in Hottman, Redding, and Weinstein (2016).

through a production scale effect. Which of these two effects dominates, and whether source countries are substitutes or complements, depends on whether $\left(\sigma_g^K - 1\right) \times \left(1 - \alpha_g\right)/\theta_k^K$ is less than or greater than one, respectively.

We now examine the properties of final-goods firm variables with respect to productivity using the firm expenditure share (7), price index (6), and pricing rule (20). We derive these results from the firm's profit-maximization problem. We hold constant wages (w_m) and aggregate expenditure (E_m) in all countries m and the set of production countries in which plants are located for each firm $f(\Omega_f^{NP})$, the set of markets for each plant in each production country i (Ω_{if}^{NX}), the set of products exported from each plant in each production country i to each market m in each sector g (Ω_{mif}^{K}), and the set of input sources for each plant (Ω_{if}^{NI}). These choice sets and wages are themselves endogenous. Therefore, these results should be interpreted as partial derivatives of firm variables with respect to productivity, holding constant these choice sets and wages.[17] Finally, we also hold fixed all other model parameters, including firm appeal (λ_{mif}^{F}), product appeal (λ_{mik}^{K}), and intermediate input productivities (T_{jk}^{K}).

PROPOSITION 1: *Given wages (w_m) and aggregate expenditure (E_m) in all countries m, the set of production countries in which plants are located for each final-goods firm f (Ω_f^{NP}), the set of markets for each plant in each production country i (Ω_{if}^{NX}), the set of products exported from each plant in each production country i to each market m in each sector g (Ω_{mif}^{K}), and the set of source countries for intermediate inputs for each plant (Ω_{if}^{NI}), an increase in final goods firm productivity (φ_{if}) implies:*

(*i*) *higher expenditure shares within each market* (S_{mif}^{F})

(*ii*) *lower prices* (P_{mik}^{K}) *for each product k and higher markups* (μ_{mik}^{K}) *within each market*

(*iii*) *higher sales* (E_{mik}^{K}) *and output* (Q_{mik}^{K}) *of each product within each market*

PROOF:

See the appendix.

Higher final goods firm productivity reduces prices in each market, which leads to higher sales and output of each product in each market, and hence higher total sales and output of each product across all markets. This higher total output for each product in turn implies higher imports of intermediate inputs for each product. Therefore, a key empirical prediction of the model is that higher final goods firm productivity leads to an expansion of the intensive margins of exports of each product and imports of each input. The expansion of firm sales in each market in turn implies a reduction in the firm's perceived elasticity of demand in each market and, hence, higher firm markups. Thus, there is "incomplete pass-through" of the higher firm productivity to consumers in the form of lower prices.

2.4.3 *Optimal Sets of Locations*

We now turn to the final-goods firm's optimal choice of the sets of production countries in which to locate plants (Ω_f^{NP}), markets for each plant (Ω_{if}^{NX}), source countries for each plant (Ω_{if}^{NI}), and products exported from each plant to each market served (Ω_{mif}^{K}). Firm f chooses these sets of countries

[17] As the derivations are particularly direct, we state our results in terms of partial derivatives of the profit function, but complementarities in firm decisions also can be established by showing that the firm profit function is supermodular in these decisions, as in Mrázová and Neary (forthcoming).

and products to maximize its equilibrium profits (23):

$$(26)\quad \left\{\hat{\Omega}_{f}^{NP}, \hat{\Omega}_{if}^{NX}, \hat{\Omega}_{if}^{NI}, \hat{\Omega}_{mif}^{K}\right\} = \underset{\{\Omega_f^{NP}, \Omega_{if}^{NX}, \Omega_{if}^{NI}, \Omega_{mif}^{K}\}}{\operatorname{argmax}} \left\{ \sum_{i \in \Omega_f^{NP}} \left[\sum_{m \in \Omega_{if}^{NX}} \sum_{k \in \Omega_{mif}^{K}} \left(\frac{\mu_{mif}^{F}-1}{\mu_{mif}^{F}}\right) E_{mik}^{K} - \sum_{m \in \Omega_{if}^{NX}} \sum_{k \in \Omega_{mif}^{K}} w_i F_{mik}^{K} - \sum_{m \in \Omega_{if}^{NX}} w_i F_{mi}^{X} - \sum_{j \in \Omega_{if}^{NI}} w_i F_{ij}^{I} - w_i F_i^{P} \right] \right\},$$

where sales (E_{mik}^{K}) and the markup (μ_{mif}^{F}) in each market are determined from the CES revenue function for each product (9), the firm expenditure share (7), and the firm equilibrium pricing rule (20).

This expression for the final-goods firm's problem has an intuitive interpretation. For each set of production, market, and source countries and each set of products exported, the firm first solves for its equilibrium variable profits as determined in the previous subsection (in terms of the markup (μ_{mif}^{F}) and sales (E_{mik}^{K})). Having computed this solution for each set of production, market, and source countries and each set of products exported, the firm then searches over all possible combinations of production, market, and source countries and products exported for the combination that maximizes total profits.

Although conceptually straightforward, this firm problem is highly computationally demanding. First, the choice set is high dimensional (for each production location i, the firm chooses sets of export markets and intermediate input sources from N countries and chooses its sets of products for each market). Second, the choices of these sets of production locations, markets, source countries, and products are interdependent. One dimension of this interdependence is in importing decisions across source countries. Incurring the fixed sourcing cost (F_{ij}^{I}) for an additional source country j increases firm supplier access ($\Phi_{ifk}(\Omega_{if}^{NI})$) and hence reduces variable unit costs (17) and prices (20). These lower prices in turn imply higher output from the revenue function (9), which makes it more likely that the firm will find it profitable to incur the fixed sourcing costs for another country $h \neq j$. Another aspect of this interdependence is between exporting and importing decisions. Incurring the fixed exporting cost (F_{mi}^{X}) for an additional export market m increases firm output. This increased output makes it more likely that the firm will find it profitable to incur the fixed sourcing cost (F_{ij}^{I}) for any given source country j. Finally, this interaction between exporting and importing makes exporting decisions interdependent across markets. Incurring the fixed exporting cost (F_{mi}^{X}) for an additional market m increases firm revenue, which makes it more likely that the firm will find it profitable to incur the fixed importing cost (F_{ij}^{I}) for any given source country j. This, in turn, reduces variable production costs and prices, and thereby increases revenue, which makes it more likely that the firm will find it profitable to incur the fixed exporting cost for another market $h \neq m$. Our framework thus captures the idea that importing can facilitate exporting, and exporting to one market can promote exporting to another market.

Providing a general characterization of the solution to (26) becomes all the more demanding, once the final-goods firm's problem is embedded in general equilibrium, which requires solving for the endogenous sets of firms and values for wages. However, without explicitly solving for the full general equilibrium, we can again establish some properties of the firm's profit-maximization problem that hold regardless of the way this problem is embedded in general equilibrium. We begin with the firm's decisions of the set of products to export to each market (Ω_{mif}^{K}). We again examine partial derivatives, holding constant wages in all countries m (w_m), the sets of production countries (Ω_{f}^{NP}), markets (Ω_{if}^{NX}), and sources of supply (Ω_{if}^{NI}), and all other model parameters besides productivity (including other firm characteristics such as firm appeal (λ_{mif}^{F}) and product appeal (λ_{mik}^{K})).

A final-goods firm f from production country i will expand the set of products k exported to a given market m within a given sector g from Ω_{mif}^{K} to $\tilde{\Omega}_{mif}^{K}$ (where $\Omega_{mif}^{K} \subset \tilde{\Omega}_{mif}^{K}$) if the resulting increase in variable profits exceeds the additional product fixed costs:

$$(27) \quad \sum_{k \in \left\{\tilde{\Omega}_{mif}^{K} \backslash \Omega_{mif}^{K}\right\}} \left(\frac{\mu_{mif}^{F} - 1}{\mu_{mif}^{F}}\right) E_{mik}^{K} - \sum_{k \in \left\{\tilde{\Omega}_{mif}^{K} \backslash \Omega_{mif}^{K}\right\}} w_i F_{mik}^{K} \geq 0.$$

From proposition 1, an increase in final goods firm productivity (φ_{if}) implies higher sales (E_{mik}^{K}) of each product and higher markups (μ_{mif}^{F}) within each market for any given values of $\{w_m, \Omega_{f}^{NP}, \Omega_{if}^{NX}, \Omega_{if}^{NI}, \Omega_{mif}^{K}\}$. Therefore, this increase in productivity implies greater variable profits from expanding the set of products from Ω_{mif}^{K} to $\tilde{\Omega}_{mif}^{K}$ in (27).

PROPOSITION 2: *Given wages (w_m) and aggregate expenditure (E_m) in all countries m, the set of production countries in which plants are located for each final-goods firm f (Ω_{f}^{NP}), the set of markets for each plant in each production country i (Ω_{if}^{NX}), and the set of source countries for intermediate inputs for each plant (Ω_{if}^{NI}), an increase in final goods firm productivity (φ_{if}) increases the variable profits from an expansion in the set of products supplied to each market from Ω_{mif}^{K} to $\tilde{\Omega}_{mif}^{K}$ (where $\Omega_{mif}^{K} \subset \tilde{\Omega}_{mif}^{K}$).*

PROOF:

See the appendix.

We next consider the final-goods firm's decision of the set of export markets (Ω_{if}^{NX}), holding constant wages in all countries $m (w_m)$, the sets of production locations (Ω_{f}^{NP}), source countries (Ω_{if}^{NI}), and products exported to each market (Ω_{mif}^{K}), and all model parameters besides firm productivity. A firm f from production country i will expand the set of markets served from Ω_{if}^{NX} to $\tilde{\Omega}_{if}^{NX}$ (where $\Omega_{if}^{NX} \subset \tilde{\Omega}_{if}^{NX}$) if the resulting increase in variable profits exceeds the additional fixed exporting costs:

$$(28) \quad \sum_{m \in \left\{\tilde{\Omega}_{if}^{NX} \backslash \Omega_{if}^{NX}\right\}} \sum_{k \in \Omega_{mif}^{K}} \left(\frac{\mu_{mif}^{F} - 1}{\mu_{mif}^{F}}\right) E_{mik}^{K} - \sum_{m \in \left\{\tilde{\Omega}_{if}^{NX} \backslash \Omega_{if}^{NX}\right\}} \sum_{k \in \Omega_{mif}^{K}} w_i F_{mik}^{K} - \sum_{m \in \left\{\tilde{\Omega}_{if}^{NX} \backslash \Omega_{if}^{NX}\right\}} w_i F_{mi}^{X} \geq 0.$$

From proposition 1, an increase in final goods firm productivity (φ_{if}) implies higher sales (E_{mik}^{K}) of each product and higher markups (μ_{mif}^{F}) within each market for given values of $\{w_m, \Omega_{f}^{NP}, \Omega_{if}^{NX}, \Omega_{if}^{NI}, \Omega_{mif}^{K}\}$. Therefore, this increase in productivity implies greater variable profits from expanding the set of export markets from Ω_{if}^{NX} to $\tilde{\Omega}_{if}^{NX}$ in (28).

PROPOSITION 3: *Given wages (w_m) and aggregate expenditure (E_m) in all countries m, the set of production countries in which plants are located for each final-goods firm*

f (Ω_f^{NP}), the set of source countries for intermediate inputs for each plant (Ω_{if}^{NI}), and the set of products exported from each plant to each export market (Ω_{mif}^{K}), an increase in final goods firm productivity (φ_{if}) increases the variable profits from an expansion in the set of export markets from Ω_{if}^{NX} to $\tilde{\Omega}_{if}^{NX}$ (where $\Omega_{if}^{NX} \subset \tilde{\Omega}_{if}^{NX}$).

PROOF:
See the appendix.

Finally, we consider the final-goods firm's decision of the set of source countries from which to obtain intermediate inputs (Ω_{if}^{NI}). As shown in Antràs, Fort, and Tintelnot (2017), even if firm supplier access (Φ_{ifk}) is increasing in firm productivity, the number of countries from which a firm sources need not be increasing in firm productivity. In the case in which source countries are substitutes $\left(\left(\sigma_g^K - 1\right)\left(1 - \alpha_g\right)/\theta_k^K < 1\right)$, a highly productive firm might pay a large fixed cost to source from one country with particularly low variable costs of producing intermediate inputs, after which the marginal incentive to add further source countries might be diminished. In contrast, in the case in which source countries are complements $\left(\left(\sigma_g^K - 1\right)\left(1 - \alpha_g\right)/\,\theta_k^K > 1\right)$, adding one source country increases the profitability of adding another source country, so that both firm supplier access (Φ_{ifk}) and the number of source countries are increasing in firm productivity.

Throughout the following, we focus on the complements case $\left(\left(\sigma_g^K - 1\right)\left(1 - \alpha_g\right)/\theta_k^K > 1\right)$ and examine the variable profits from adding an additional source country, holding constant wages in all countries m (w_m), the sets of production locations (Ω_f^{NP}), markets (Ω_{if}^{NX}), products supplied to each market (Ω_{mif}^{K}), and all model parameters besides productivity. A final-goods firm f from production location i will expand the set of source countries from Ω_{if}^{NI} to $\tilde{\Omega}_{if}^{NI}$ (where $\Omega_{if}^{NI} \subset \tilde{\Omega}_{if}^{NI}$) if the resulting increase in variable profits exceeds the additional fixed sourcing costs:

$$(29)\quad \left\{ \left[\sum_{m \in \Omega_{if}^{NX}} \sum_{k \in \Omega_{mif}^{K}} \left(\frac{\mu_{mif}^F\left(\tilde{\Omega}_{if}^{NI}\right) - 1}{\mu_{mif}^F\left(\tilde{\Omega}_{if}^{NI}\right)} \right) E_{mik}^K\left(\tilde{\Omega}_{if}^{NI}\right) \right] - \left[\sum_{m \in \Omega_{if}^{NX}} \sum_{k \in \Omega_{mif}^{K}} \left(\frac{\mu_{mif}^F\left(\Omega_{if}^{NI}\right) - 1}{\mu_{mif}^F\left(\Omega_{if}^{NI}\right)} \right) E_{mik}^K\left(\Omega_{if}^{NI}\right) \right] \right\} - \sum_{j \in \left\{\tilde{\Omega}_{if}^{NI} \setminus \Omega_{if}^{NI}\right\}} w_i F_{ij}^I \;\geq\; 0,$$

where we make explicit that both the markup (μ_{mif}^F) and sales of each product (E_{mik}^K) are functions of the set of source countries (Ω_{if}^{NI}).

An expansion in the set of source countries from Ω_{if}^{NI} to $\tilde{\Omega}_{if}^{NI}$ increases firm variable profits through two channels. First, the expansion in the set of source countries increases firm supplier access $(\Phi_{ifk}\left(\Omega_{if}^{NI}\right))$, which reduces variable unit costs (17) and prices (20), and in turn increases sales for each product (E_{mik}^K). Second, the expansion in sales for each product increases firm market share and markups (μ_{mif}^F). Together, these two effects ensure that the first term in curly braces for the increase in variable profits is positive.

From proposition 1, an increase in final goods firm productivity (φ_{if}) implies higher sales (E_{nik}^K) of each product and higher markups (μ_{nif}^F) within each market for any given values of $\{w_m, \Omega_f^{NP}, \Omega_{if}^{NX}, \Omega_{if}^{NI}, \Omega_{mif}^{K}\}$. Therefore, this increase in productivity implies greater variable profits from expanding the set of source countries from Ω_{if}^{NI} to $\tilde{\Omega}_{if}^{NI}$ in (29).

PROPOSITION 4: *Given wages (w_m) and aggregate expenditure (E_m) in all countries m, the set of production countries in which plants are located for each final goods firm f (Ω_f^{NP}), the set of export markets for each* *plant (Ω_{if}^{NI}), and the set of products exported from each plant to each export market (Ω_{mif}^{K}), an increase in final goods firm productivity (φ_{if}) increases the variable profits from an expansion in the set of source countries for intermediate inputs from Ω_{if}^{NX} to $\tilde{\Omega}_{if}^{NX}$ (where $\Omega_{if}^{NX} \subset \tilde{\Omega}_{if}^{NX}$).*

PROOF:
See the appendix.

Taking propositions 2–4 together, a key empirical prediction of the model is that higher final goods firm productivity leads to an expansion of the extensive margins of the number of products exported to each market, the number of export markets, and the number of source countries for intermediate inputs. Combining these results with those from proposition 1, the model implies that more productive firms participate more in the international economy along all margins simultaneously: higher exports of each product, higher imports of each intermediate input, more products exported to each market, more export markets, and more import sources. Therefore, we should expect to see that all these margins of international participation co-move together across firms: more exports and imports on the intensive margins should be systematically correlated with more export and import participation on the extensive margins.

This correlation implies that a given exogenous difference in productivity between final-goods firms has a magnified impact on endogenous differences in firm performance, such as sales and employment, because it induces firms to simultaneously expand along each of the margins of international participation. Therefore, our framework suggests that the skewed size distribution across firms studied in the industrial-organization literature (see for example Sutton 1997, Axtell 2001, and Rossi-Hansberg and Wright 2007) is, in part, driven by these magnification effects. Furthermore, the correlation between these margins of international participation has implications for measured firm productivity. As more productive firms import intermediate inputs from a wider range of source countries, this improves their supplier access and reduces their production costs, magnifying the endogenous difference in costs between firms relative to the exogenous difference in productivity.[18] Together, the expansion by more successful firms along multiple margins of international participation, and the magnification of primitive productivity differences by endogenous sourcing decisions, help to explain the extent to which international trade is concentrated across firms, with a relatively small number of firms accounting for a disproportionate share of trade.

3. *Data*

To provide empirical evidence on these predictions of the model, we use the Linked-Longitudinal Firm Trade Transactions Database (LFTTD), which combines information from three separate databases collected by the US Census Bureau and the US Customs Bureau. The first data set is the US Census of Manufactures (CM), which reports data on the operation of establishments in the US manufacturing sector, including information on output (shipments and value-added), inputs (capital, employment, and wagebills for production and non-production workers, and

[18] Although we focus on firms' *international* sourcing decisions, because we observe these decisions in our international trade data, similar forces are likely to be at work across regions and firms within countries, further reinforcing these magnification effects. For example, Bernard, Moxnes, and Saito (forthcoming) find that the number of domestically sourced products rises more than proportionately with firm productivity.

materials), and export participation (whether a firm exports and total export shipments).[19]

The second data set is the Longitudinal Business Database (LBD), which records employment and survival information for all US establishments outside of agriculture, forestry and fishing, railroads, the US Postal Service, education, public administration, and several other smaller sectors.[20] The third data set includes all US export and import transactions between 1992 and 2007. For each flow of goods across a US border, this data set records the product classification(s) of the shipment (ten-digit harmonized system (HS)), the value and quantity shipped, the date of the shipment, the destination or source country, the transport mode used to ship the goods, the identity of the US firm engaging in the trade, and whether the trade is with a related party or occurs at arm's length.[21]

In our main results, we aggregate the establishment-level data from the CM and LBD and the trade transactions data up to the level of the firm. We thus obtain a data set for each firm that contains information on firm characteristics (e.g., industry, employment, productivity, and total shipments) as well as on each of the margins of firm international participation considered above (exports of each product, the number of products exported to each market, the number of export markets, imports of each input, the number of imported inputs from each source country, and the number of source countries). We also report some additional results in which we use the information on exports and imports by firm, product, destination, and year in the trade transactions data.[22]

4. *Evidence on Global Firms*

We now provide empirical evidence on our model's predictions for the margins of firm international participation. Section 4.1 examines the frequency of firm exporting. Section 4.2 compares exporter and non-exporter characteristics. Section 4.3 considers the prevalence of firm importing. Section 4.4 contrasts the characteristics of importers, exporters, and other firms. Section 4.5 investigates the extensive margins of the number of exported products, the number of export markets, the number of imported products, and the number of import countries. Section 4.7 provides further evidence on the correlations between firm decisions to participate in international markets along each of the intensive and extensive margins.

4.1 *Firm Exporting*

As in the literature on heterogeneous firms following Melitz (2003), our model emphasizes the self-selection of firms into exporting, such that only some firms export within each industry. Table 1 examines these predictions for US manufacturing industries using data from the 2007 LFTTD. In column 1, we provide a sense of the relative size of each industry, by reporting the share of each three-digit North American Industrial Classification

[19] For further discussion of the CM see, for example, Bernard, Redding, and Schott (2010).

[20] See Jarmin and Miranda (2002) for further details on the LBD.

[21] See Bernard, Jensen, and Schott (2009) for a detailed description of the LFTTD and its construction. Related-party trade refers to trade between US companies and their foreign subsidiaries as well as trade between US subsidiaries of foreign companies and their foreign affiliates. For imports, firms are related if either owns, controls, or holds voting power equivalent to 6 percent of the outstanding voting stock or shares of the other organization (see Section 402(e) of the Tariff Act of 1930). For exports, firms are related if either party owns, directly or indirectly, 10 percent or more of the other party (see Section 30.7(v) of The Foreign Trade Statistics Regulations).

[22] Relatively little research has examined the properties of the trade transactions data at finer levels of disaggregation than firm, product, destination, and year, with some exceptions such as Hornok and Koren (2015a, 2015b).

TABLE 1
Firm Exporting

		Percent of firms (1)	Fraction of firms that export (2)	Mean exports as a share of total shipments (3)
311	Food manufacturing	6.8	0.23	0.21
312	Beverage and tobacco product	0.9	0.30	0.30
313	Textile mills	0.8	0.57	0.39
314	Textile product mills	2.7	0.19	0.12
315	Apparel manufacturing	3.6	0.22	0.16
316	Leather and allied product	0.3	0.56	0.19
321	Wood product manufacturing	4.8	0.21	0.09
322	Paper manufacturing	1.5	0.48	0.06
323	Printing and related support	11.1	0.15	0.10
324	Petroleum and coal products	0.5	0.34	0.13
325	Chemical manufacturing	3.3	0.65	0.23
326	Plastics and rubber products	3.9	0.59	0.11
327	Nonmetallic mineral product	4.3	0.19	0.09
331	Primary metal manufacturing	1.5	0.58	0.31
332	Fabricated metal product	20.6	0.30	0.09
333	Machinery manufacturing	8.7	0.61	0.15
334	Computer and electronic product	3.9	0.75	0.28
335	Electrical equipment, appliance	1.7	0.70	0.47
336	Transportation equipment	3.4	0.57	0.16
337	Furniture and related product	6.5	0.16	0.14
339	Miscellaneous manufacturing	9.3	0.32	0.16
Aggregate manufacturing		100.0	0.35	0.17

Notes: Data are for 2007 and are for firms that appear in both the US Census of Manufactures and the LFTTD. Column 1 summarizes the distribution of manufacturing firms across three-digit NAICS manufacturing industries. Column 2 reports the share of firms in each industry that export. Firm exports are measured using customs information from LFTTD. Column 3 reports mean exports as a percent of total shipments across all firms that export in the noted industry. Percentages in column 1 need not sum exactly to 100 due to rounding.

(NAIC) industry in the number of manufacturing firms, which ranges from 0.3 percent for leather and allied products (316) to 20.6 percent for fabricated metal products (332).

In column 2, we confirm the prediction that only some firms export within each industry. For the US manufacturing sector as a whole, around 35 percent of firms export. However, this fraction of exporters varies substantially from around 75 percent of firms in computer and electronic products (334) to around 15 percent of firms in printing and related support (323). This variation across sectors is roughly in line with the idea that the United States has a comparative advantage in high-skill and capital-intensive sectors such as electrical equipment, appliances (335), which have exporter shares more than twice as large as those of labor-intensive sectors such as apparel manufacturing (315). In our model in section 2, comparative advantage is driven by productivity differences and the geography of access to intermediate inputs. More broadly, Bernard, Redding, and Schott (2007) develop a model that combines firm heterogeneity with Heckscher–Ohlin comparative advantage, in which firm export decisions are influenced by the interaction of cross-industry differences in factor intensity and cross-country differences in factor abundance.

In column 3, we report the average share of exports in firm shipments for each sector. In a world of identical and homothetic preferences and no trade costs, this share of exports in firm shipments would equal the share of the rest of the world in world GDP (see also Brooks 2006). However, we find an average export share for manufacturing as a whole of 17 percent, which is substantially lower than this frictionless benchmark. A natural explanation is variable trade costs. In our theoretical framework, these trade frictions reduce the share of exports in firm shipments through both the extensive margins (the number of countries to which a firm exports and the number of products the firm exports to a given country) and the intensive margin (exports of a given product to a given country).

As apparent from column 3, this average share of exports in firm shipments also varies substantially across sectors, from a a high of 47 percent in electrical equipment (335) to a low of 6 percent in paper manufacturing (322). In the theory developed above, such variation in average export shares is driven by differences in trade costs across industries and the pattern of comparative advantage, as determined by productivity differences and the geography of access to intermediate inputs. In the model of Bernard, Redding, and Schott (2007), differences in average export shares across industries also reflect the interaction of cross-industry differences in factor intensity and cross-country differences in factor abundance.

Comparing the results for 2007 in table 1 with those for 2002 in Bernard et al. (2007), we find a larger fraction of exporters and a higher share of firm exports in total shipments in table 1. The main reason for this difference is that table 1 measures firm exporting using the customs records from LFTTD, whereas Bernard et al. (2007) measure firm exporting using the export question in the Census of Manufactures.[23] Following the 2001 recession and the granting of permanent normal trade relations (PNTR) to China, there was also a sharp decline in overall employment and high rates of exit in US manufacturing (as examined in Pierce and Schott 2016). To the extent that exporting and non-exporting firms were differentially affected by this decline, this could also affect the evolution of the fraction of exporters over time.

Following the early evidence on firm export participation for the United States in Bernard and Jensen (1995, 1999), similar results have been reported for many countries, including Brazil (Labanca, Molina, and Muendler 2014), France (Eaton, Kortum, and Kramarz 2004), Germany (Bernard and Wagner 1997), sub-Saharan Africa (Van Biesebroeck 2005), the United Kingdom (Girma, Greenaway, and Kneller 2004). As summarized in World Trade Organization (2008), the share of manufacturing firms that export is 20.9 percent for Chile, 18.2 percent for Columbia, 17.4 percent for France, 20 percent for Japan, and 39.2 percent for Norway. Therefore, the finding that a relatively small share of firms export is robust across this diverse range of countries.

4.2 *Exporter Characteristics*

The self-selection of firms into exporting in our theoretical model above implies systematic differences in performance between exporters and non-exporters. In table 2, we present evidence on these

[23] Using this alternative definition of firm exporting from the Census of Manufactures, we find a relatively similar pattern of results for 2007 as for 2002 in Bernard et al. (2007). Therefore the customs records from LFTTD imply that exporting is more prevalent than would be concluded based on the export question in the Census of Manufactures.

TABLE 2
Exporter Premia

	Exporter premia		
	(1)	(2)	(3)
log employment	1.28	1.11	—
log shipments	1.72	1.35	0.24
log value added per worker	0.33	0.19	0.21
log TFP	0.03	0.04	0.04
log wage	0.21	0.09	0.10
log capital per worker	0.28	0.16	0.20
log skill per worker	0.06	0.01	0.11
Additional covariates	None	Industry fixed effects	Industry fixed effects, log employment

Notes: Data are for 2007 and are for firms that appear in both the US Census of Manufactures and the LFTTD. All results are from bivariate ordinary least squares regressions of firm characteristic in first column on a dummy variable indicating firm's export status. Firm exports measured using customs information from LFTTD. Columns two and three include industry fixed effects and industry fixed effects plus log firm employment, respectively, as additional controls. Total factor productivity (TFP) is computed as in Caves et al. (1982). Capital and skill per worker are capital stock and non-production workers per total employment, respectively. All results are significant at the 1 percent level except the log Skill per Worker results in column 2 which are not significant at the 10 percent level.

performance differences for US manufacturing industries using data from the 2007 LFTTD. We regress the log of each measure of firm performance on a dummy variable for whether a firm exports. In the rows of the table, we report the results for different measures of firm performance. Column 1 includes no other controls; column 2 controls for industry fixed effects; and column 3 incorporates industry fixed effects and firm size as measured by log firm employment. Therefore, each cell of the table corresponds to a separate regression specification.

As shown in column 1, we find that exporting firms have 128 percent more employment, 172 percent higher shipments, 33 percent higher value added per worker, and 3 percent higher total factor productivity (TFP).[24] All of these differences are statistically significant at conventional critical values. When we include industry fixed effects in column 2 to focus on within-industry differences between exporters and non-exporters, these performance differences become slightly smaller, but remain statistically significant at the 1 percent level. We continue to find that exporters are larger than non-exporters, by 111 percent for employment and 135 percent for shipments. Exporters also remain more productive than non-exporters, by 19 percent for value added per worker and 4 percent for TFP. Column 3 shows that these performance differences are not driven simply by firm size. After including log firm employment as an additional control, we continue

[24] We measure TFP using the Törnqvist superlative index number of Caves, Christensen, and Diewert (1982). We use log differences to approximate the percentage differences between exporters and non-exporters, which understates the magnitude of the percentage differences. For example, from column 1 of table 2, exporters are 260 percent larger than non-exporters in terms of employment (since $100 \times (\exp(1.28) - 1) = 260$).

to find statistically significant differences between exporters and non-exporters within the same industry for all the other performance measures.

Comparing the results for 2007 in table 2 with those for 2002 in Bernard et al. (2007), we find stable performance differences between exporters and non-exporters, which become somewhat larger over time. Following the early evidence for the United States in Bernard and Jensen (1995, 1999), similar performance differences between exporters and non-exporters have been found for a range of developed and developing countries, including France (Eaton, Kortum, and Kramarz 2004), Germany (Bernard and Wagner 1997), Slovenia (De Loecker 2007), and sub–Saharan African countries (Van Biesebroeck 2005), among many others. Even within a given country, similar performance differences are observed between plants that ship long versus short distances, as shown for the United States by Holmes and Stevens (2012).

One notable feature of the results in table 2 is that the differences in firm productivity (both value added and TFP) are smaller than those in employment and shipments. This is consistent with our theoretical framework above, in which productivity differences between firms are amplified by elastic demand (an elasticity of substitution greater than one) and firm participation in the international economy along multiple margins. In the model, causality runs from high productivity to exporting, through firms' endogenous decisions to self-select into the export market. However, in principle, causality also could run from exporting to high productivity (e.g., through "learning by exporting"). As productivity differences between future exporters and other non-exporters are typically found to predate entry into exporting, most existing research interprets these productivity differences as largely the result of selection into exporting (see Bernard and Jensen 1999 for US evidence and Clerides, Lach, and Tybout 1998 for evidence from Mexico, Colombia, and Morocco). More recently, a number of empirical studies have provided evidence that firm entry into exporting can stimulate the adoption of new productivity-enhancing technologies including, in particular, Bustos (2011) and Lileeva and Trefler (2010).

One limitation of the model is that it focuses on differences in productivity and size between exporters and non-exporters. The results in table 2, however, suggest that exporters also differ along a range of other characteristics, including wages, capital per worker, and skill per worker. The literature on heterogeneous firms in international trade has explored a number of mechanisms that can account for these other dimensions of performance differences. Burstein and Vogel (2017) and Harrigan and Reshef (2015) consider technology–skill complementarities, in which higher firm productivity raises the marginal product of skilled workers relative to that of unskilled workers, which in turn induces more productive firms to choose more skill-intensive production techniques. Helpman, Itskhoki, and Redding (2010) and Helpman et al. (2017) develop a model of search and screening frictions, in which more productive firms screen their workers to a higher ability threshold, and hence employ workers of higher average ability and pay higher wages. This environment implies both an employer-size wage premium and higher wages for exporters than for non-exporters. Opening the closed economy to trade increases the dispersion of revenue across firms through the selection of more productive firms into export markets, which in turn increases the dispersion of wages across firms. This thereby provides a new mechanism for trade to affect wage inequality through export market selection.[25]

[25] For a review of the literature on heterogeneous workers and trade, see Grossman (2013).

An empirical literature using linked employer-employee data sets has sought to further decompose the observed wage differences between exporters and non-exporters into the contributions of unobserved differences in workforce composition and wage premia for workers with identical characteristics. Following Abowd, Kramarz, and Margolis (1999) and Abowd, Creecy, and Kramarz (2002), this literature typically assumes that the production function is log additively separable in worker ability and that the switching of workers between firms is random conditional on firm fixed effects, worker fixed effects, and time-varying worker observables. In general, this literature finds a role for both unobserved differences in workforce composition and wage premia, with their relative contributions varying across studies, as in Baumgarten (2013); Davidson et al. (2014); Frías, Kaplan, and Verhoogen (2015); Krishna, Poole, and Senses (2014); Munch and Skaksen (2008); and Schank, Schnabel, and Wagner (2007).

4.3 *Firm Importing*

Our theoretical framework above emphasizes that firms self-select into importing as well as exporting. In table 3, we compare firm importing and exporting using the 2007 LFTTD. Column 1 reproduces the share of each three-digit NAIC industry in the number of manufacturing firms from table 1; column 2 reproduces the share of firms within each industry that export from table 1; column 3 reports the share of firms within each industry that import; and column 4 summarizes the share of firms within each industry that both export and import.

We find a broadly similar pattern of results for firm importing in table 3 as for firm exporting in table 1. For the US manufacturing sector as a whole, around 20 percent of firms import. However, there is substantial variation across industries, with the share of importers ranging from a low of 5 percent in printing and related support (323) to a high of 50 percent in computer and electronic products (334). Our theoretical model from section 2 predicts a positive correlation between firm importing and exporting through two mechanisms. The first of these mechanisms is selection: more productive firms will find it profitable to incur the fixed costs for both importing and exporting. A second channel is through the interdependence and complementarities between the firm margins of international participation. On the one hand, when a firm incurs the fixed cost to export, the resulting increase in firm sales increases the profitability of incurring the fixed cost to import. On the other hand, when a firm incurs the fixed costs for importing, the resulting improvement in supplier access and reduction in marginal costs increases the profitability of incurring the fixed cost for exporting. Consistent with these predictions, we find a strong positive correlation across industries between the shares of firms that export and import in columns 2 and 3 of table 3. As a result, many of the firms that engage in one of these forms of international participation also engage in the other, as is evident from a comparison of columns 2–4 of table 3.

Although the literature on firm importing is less extensive than that on firm exporting, similar results again have been found for a number of other countries, including Belgium (Amiti, Itskhoki, and Konings 2014), Chile (Kasahara and Lapham 2013), France (Blaum, Lelarge, and Peters 2013, forthcoming), Hungary (Halpern, Koren, and Szeidl 2015) and Indonesia (Amiti and Davis 2012) among others. While table 3 reports results for firms in the US manufacturing sector, many firms in other sectors also import or export. A small body of research has sought to analyze the trade behavior of such intermediaries, wholesalers, and retailers, including Ahn, Khandelwal, and Wei (2011); Akerman (2018); Antràs

TABLE 3
Firm Importing and Exporting

NAICS Industry		Percent of all firms (1)	Fraction of firms that export (2)	Fraction of firms that import (3)	Fraction of firms that import and export (4)
311	Food manufacturing	6.8	0.23	0.15	0.10
312	Beverage and tobacco product	0.9	0.30	0.18	0.11
313	Textile mills	0.8	0.57	0.44	0.37
314	Textile product mills	2.7	0.19	0.14	0.09
315	Apparel manufacturing	3.6	0.22	0.23	0.15
316	Leather and allied product	0.3	0.56	0.53	0.40
321	Wood product manufacturing	4.8	0.21	0.09	0.06
322	Paper manufacturing	1.5	0.48	0.25	0.21
323	Printing and related support	11.1	0.15	0.05	0.03
324	Petroleum and coal products	0.5	0.34	0.18	0.14
325	Chemical manufacturing	3.3	0.65	0.40	0.36
326	Plastics and rubber products	3.9	0.59	0.34	0.29
327	Nonmetallic mineral product	4.3	0.19	0.15	0.09
331	Primary metal manufacturing	1.5	0.58	0.32	0.29
332	Fabricated metal product	20.6	0.30	0.12	0.10
333	Machinery manufacturing	8.7	0.61	0.30	0.28
334	Computer and electronic product	3.9	0.75	0.50	0.47
335	Electrical equipment, appliance	1.7	0.70	0.46	0.41
336	Transportation equipment	3.4	0.57	0.35	0.31
337	Furniture and related product	6.5	0.16	0.12	0.07
339	Miscellaneous manufacturing	9.3	0.32	0.20	0.17
Aggregate manufacturing		100.0	0.35	0.20	0.16

Notes: Data are for 2007 and are for firms that appear in both the US Census of Manufactures and the LFTTD. Firm exports and imports are measured using customs information from LFTTD. Column 1 summarizes the distribution of manufacturing firms across three-digit NAICS industries. Remaining columns report the percent of firms in each industry that export, import and do both. Percentages in column 1 need not sum exactly to 100 due to rounding.

and Costinot (2011); Bernard, Grazzi, and Tomasi (2015); Bernard et al. (2010b); and Blum, Claro, and Horstmann (2010). Some firms can also transition from manufacturing to nonmanufacturing, as they offshore the entirety of their production process, as examined in Bernard and Fort (2015) and Bernard, Smeets, and Warzynski (2017). More generally, Boehm, Flaaen, and Pandalai-Nayar (2015) examine the role of offshoring by US and foreign-owned multinationals in understanding the evolution of US manufacturing employment. Although imports of goods have received much more attention than imports of services, because of the scarcity of data on trade in services, notable exceptions are Liu and Trefler (2008) and Breinlich and Criscuolo (2011).[26] Finally, more recent research on networks has examined patterns of exporting and importing between individual buyers and sellers, including Bernard, Moxnes, and Saito (forthcoming); Bernard,

[26] Gervais and Jensen (2013) develop a methodology to produce estimates of trade costs for detailed service industries.

TABLE 4
EXPORTER AND IMPORTER PREMIA

	Exporter premia (1)	Importer premia (2)	Exporter and importer premia (3)
log employment	1.11	1.20	1.39
log shipments	0.24	0.32	0.36
log value added per worker	0.21	0.25	0.28
log TFP	0.04	0.03	0.03
log wage	0.10	0.09	0.11
log capital per worker	0.20	0.28	0.34
log skill per worker	0.11	0.16	0.18

Notes: Data are for 2007 and are for firms that appear in both the US Census of Manufactures and the LFTTD. All results are from bivariate OLS regressions of a given firm characteristic on the dummy variable noted at the top of each column as well as industry fixed effects. All specifications except for employment also include firm employment as an additional control. Firm exports and imports are measured using customs information from LFTTD. Total factor productivity (TFP) is computed as in Caves et al. (1982). Capital and skill per worker are capital stock and non-production workers per total employment, respectively. All results are significant at the 1 percent level.

Moxnes, and Ulltveit-Moe (forthcoming); Chaney (2014, 2018); Eaton et al. (2014); Eaton et al. (2016); and Lim (2016).

4.4 *Importer Characteristics*

The self-selection of firms into importing in our theoretical model above also implies systematic differences in performance between importers and non-exporters. In table 4, we provide evidence on these performance differences for US manufacturing industries using an analogous specification to that for firm exporting in table 2. All specifications in table 4 control for industry fixed effects and all specifications except for employment control for firm size as measured by log employment.

Consistent with the selection forces emphasized in our model, we find a similar pattern of results for importing as for exporting. After controlling for firm size, we find import premia within industries of around 120 percent for employment, 32 percent for shipments, 25 percent for value added per worker, 3 percent for TFP, 9 percent for wages, 28 percent for capital intensity, and 16 percent for skill intensity.[27] Consistent with both the selection and magnification effects emphasized by our model, we find the largest performance differences for firms that simultaneously export and import. In the model, participation in the international economy along multiple margins amplifies the effect of true differences in firm primitives on endogenous measures of firm performance.[28]

To examine the implications of firm selection into importing for firm and aggregate productivity, Blaum, Lelarge, and Peters (forthcoming) develop a framework in which firm-level data on value-added and domestic

[27] Again we use the log approximation, which can can substantially understate the size of these performance differences. Taking exponents of the employment coefficient in column 2 of table 4, importing firms have 232 percent more employment (since $100 \times (\exp(1.20) - 1) = 232$).

[28] While we focus on firm exporting and importing, similar performance differences are observed between multinationals and other firms. See, for example, Doms and Jensen (1998); Helpman, Melitz, and Yeaple (2004); and Yeaple (2009).

expenditure shares provide sufficient statistics for the impact of trade in intermediate inputs on consumer prices. Within this framework, a reduction in a firm's domestic expenditure share implies a reduction in its unit costs. Using the observed joint distribution of firm value-added and domestic expenditure shares in the data, this framework implies substantial heterogeneity across firms in the effects of input trade on consumer prices, which are 11 percent at the median, but over 80 percent for 10 percent of firms.

4.5 *Extensive Margins of Firm Exporting and Importing*

One of the central features of our theoretical framework above is that firms decide to participate in the international economy along multiple extensive margins: the number of products to export to each market, the number of export markets, the number of intermediate inputs to import from each source country, and the number of countries from which to source intermediate inputs. We now use US export and import transactions data to provide evidence on these multiple extensive margins.

In table 5, we report joint distributions for exporting firms across the number of products exported (rows) and the number of markets served (columns). The top panel reports the percentage of exporting firms; the middle panel reports the percentage of export value; and the bottom panel reports the percentage of exporter employment. The cells in each panel sum to 100. Comparing results across the three panels, we find that around 35 percent of exporters ship one product to one market (top panel, top left cell), but they account for only 11 percent of employment (bottom panel, top left cell) and a mere 1 percent of export value (middle panel, top left cell). In contrast, the 5 percent of exporters that ship 11 or more products to 11 or more markets (top panel, bottom right cell) account for around 46 percent of employment (bottom panel, bottom right cell) and nearly 80 percent of export value (middle panel, bottom right cell). Across all three panels, the diagonal terms in each panel tend to be large relative to the off-diagonal terms, so that firms that export to many markets also, on average, export many products. This pattern of results is consistent with the positive correlation between the different margins of firm international participation in our theoretical framework, above. More successful firms export more of each product to each market, as well as exporting more products to each market and exporting to more markets, thereby ensuring that relatively few firms account for most of aggregate export value.[29]

In table 6, we report analogous joint distributions of importing firms across the number of products imported (rows) and the number of foreign countries from which products are imported (columns). The cells in each panel again sum to one hundred. Looking across the three panels, we find a similar pattern of results for imports as for exports. Around 30 percent of importers source one product from one foreign country (top panel, top left cell), but they account for around 15 percent of employment (bottom panel, top-left cell) and less than 1 percent of import value (middle panel, top-left cell). By comparison, the 3 percent of importers that source 11 or more products from 11 or more countries (top panel, bottom right cell) account for around 48 percent of employment (bottom panel, bottom-right cell) and approximately 76 percent of import value (middle panel, bottom-right cell). We again find that the diagonal terms in each panel tend to be large relative to the off-diagonal terms, implying that firms that import from many

[29] Another feature of international trade besides its concentration across firms is its "sparsity"—the prevalence of zeros with many firms exporting few products to few destinations, as examined in Armenter and Koren (2014).

TABLE 5
EXPORT DISTRIBUTION BY PRODUCT AND COUNTRY

Number of products	Number of countries							
	1	2	3	4	5	6–10	11+	**All**
Percentage of exporting firms								
1	34.9	8.6	3.5	1.8	1.1	1.8	1.0	**52.8**
2	2.1	5.7	2.8	1.5	0.9	1.4	0.6	**14.9**
3	0.6	1.3	1.9	1.2	0.8	1.4	0.6	**7.7**
4	0.3	0.5	0.7	0.8	0.7	1.3	0.6	**4.8**
5	0.2	0.3	0.4	0.4	0.4	1.1	0.5	**3.3**
6–10	0.3	0.5	0.6	0.7	0.7	2.9	2.4	**8.1**
11+	0.1	0.2	0.2	0.3	0.3	1.8	5.5	**8.4**
All	**38.4**	**17.0**	**10.1**	**6.7**	**4.9**	**11.7**	**11.2**	**100.0**
Percentage of export value								
1	0.8	0.5	0.3	0.2	0.2	0.5	1.0	**3.6**
2	0.2	0.3	0.3	0.2	0.1	0.5	0.7	**2.4**
3	0.1	0.1	0.2	0.1	0.2	0.5	0.6	**1.9**
4	0.1	0.1	0.1	0.2	0.1	0.4	0.4	**1.4**
5	0.0	0.1	0.1	0.1	0.1	0.3	0.6	**1.2**
6–10	0.3	0.2	0.3	0.3	0.3	1.2	2.9	**5.6**
11+	0.2	0.4	0.3	0.4	0.3	2.6	79.7	**83.9**
All	**1.7**	**1.9**	**1.6**	**1.4**	**1.3**	**6.1**	**86.0**	**100.0**
Percentage of employment								
1	11.3	3.0	1.4	0.7	0.4	1.3	0.6	**18.7**
2	0.5	3.0	1.3	0.8	0.4	1.0	1.1	**8.1**
3	0.2	0.7	1.5	0.6	0.7	1.3	0.7	**5.7**
4	0.0	0.3	0.3	0.8	0.4	1.6	2.5	**6.0**
5	0.0	0.2	0.1	0.1	0.4	1.3	2.1	**4.2**
6–10	0.1	0.2	0.2	0.3	0.2	2.5	5.5	**9.0**
11+	0.0	0.0	0.1	0.1	0.3	1.5	46.4	**48.3**
All	**12.1**	**7.4**	**4.9**	**3.4**	**2.7**	**10.5**	**59.0**	**100.0**

Notes: Data are from the 2007 LFTTD. Table displays the joint distribution of US manufacturing firms that export (top panel), their export value (middle panel), and their employment (bottom panel) according to the number of products firms export (rows) and their number of export destinations (columns). Products are defined as ten-digit HS categories. Percentages in each panel of the table need not sum exactly to 100 due to rounding.

countries also, on average, import many products. These results again confirm the positive correlation between the different margins of international participation in our model. More successful firms import more of each product from each country, as well as importing more products from each country and importing from more countries, thereby again enabling a relatively small number of firms to be responsible for most of aggregate import value.

More broadly, these findings provide additional support for a growing body of research that emphasizes the importance of the firm extensive margin of trade participation. Comparing the Krugman (1980) model to the Melitz (2003) model with an untruncated Pareto productivity distribution, Chaney

TABLE 6
Import Distribution by Product and Country

Number of products	Number of countries							
	1	2	3	4	5	6–10	11+	**All**
Share of importing firms								
1	29.7	8.5	4.1	2.5	1.6	3.6	2.1	**52.1**
2	2.4	5.3	3.1	1.8	1.3	3.2	2.3	**19.3**
3	0.6	1.2	1.5	1.2	0.8	2.3	2.1	**9.6**
4	0.2	0.4	0.5	0.6	0.5	1.6	1.6	**5.5**
5	0.1	0.2	0.2	0.3	0.3	1.1	1.4	**3.5**
6–10	0.1	0.2	0.2	0.3	0.3	1.6	3.9	**6.6**
11+	0.0	0.0	0.0	0.0	0.0	0.2	3.0	**3.4**
All	**33.0**	**15.7**	**9.7**	**6.6**	**4.9**	**13.5**	**16.5**	**100.0**
Share of import value								
1	0.6	0.5	0.3	0.2	0.2	0.6	0.5	**3.0**
2	0.2	0.3	0.2	0.3	0.2	0.8	1.0	**3.0**
3	0.1	0.2	0.2	0.2	0.2	0.8	1.2	**2.8**
4	0.1	0.1	0.1	0.2	0.1	0.4	1.2	**2.3**
5	0.0	0.0	0.1	0.1	0.1	0.4	1.3	**2.0**
6–10	0.0	0.0	0.1	0.2	0.2	1.3	7.1	**8.9**
11+	0.0	0.2	0.0	0.1	0.1	1.1	76.4	**78.0**
All	**1.0**	**1.4**	**1.1**	**1.2**	**1.1**	**5.5**	**88.7**	**100.0**
Share of employment								
1	14.8	1.8	0.6	0.6	0.2	0.8	0.2	**19.0**
2	0.4	2.8	1.3	0.6	0.5	0.6	0.4	**6.6**
3	0.1	0.5	1.0	0.8	1.0	1.7	0.8	**5.9**
4	0.0	0.1	0.2	0.4	0.9	1.7	1.2	**4.6**
5	0.0	0.0	0.1	0.3	0.6	0.8	1.1	**3.0**
6–10	0.0	0.0	0.1	0.2	0.3	2.6	8.6	**11.9**
11+	0.0	0.0	0.0	0.0	0.0	0.7	48.1	**48.9**
All	**15.4**	**5.3**	**3.4**	**3.0**	**3.4**	**9.0**	**60.5**	**100.0**

Notes: Data are from the 2007 LFTTD. Table displays the joint distribution of US manufacturing firms that import (top panel), their import value (middle panel), and their employment (bottom panel), according to the number of products firms import (rows) and their number of import sources (columns). Products are defined as ten-digit HS categories. Percentages in each panel of the table need not sum exactly to 100 due to rounding.

(2008) shows that the presence of the extensive margin in the heterogeneous firm model reverses the relationship between the elasticity of substitution and the sensitivity of trade flows to trade costs.[30] Using firm export data from France, Eaton, Kortum, and Kramarz (2004) decompose the variation in aggregate exports across destination markets and show that the extensive margin of the number of exporting firms accounts for over

[30] An untruncated Pareto distribution of productivity (φ) is characterized by a probability density function of $g(\varphi) = k\varphi_{\min}^{k}\varphi^{-(k+1)}$ with a corresponding cumulative distribution function of $G(\varphi) = 1 - (\varphi_{\min}/\varphi)^{k}$, where $\varphi_{\min} > 0$ is the minimum value for productivity and $k > 1$.

60 percent of this variation.[31] Using the same French data, Eaton, Kortum, and Kramarz (2011) structurally estimate an extension of the Melitz (2003) heterogeneous firm model and show that the extensive margin of firm export participation plays a central role in shaping the effects of a counterfactual 10 percent reduction in bilateral trade barriers for all French firms.[32] Most of the overall increase in French exports of around \$16 million is accounted for by a rise in the sales of the top decile of firms of around \$23 million. In contrast, every other decile of firms experiences a decline in sales, with around half the firms in the bottom decile exiting. Using a gravity equation specification, Helpman, Melitz, and Rubinstein (2008) show that incorporating the extensive margin of firm selection into export markets is consequential for estimates of the impact of standard trade frictions (such as distance and whether countries share a common border) on trade flows.[33]

Other research has established the importance of the product extensive margin within firms. Bernard, Redding, and Schott (2011) develop a general equilibrium model of multiple-product, multiple-destination firms, which features heterogeneity and selection across products within firms as well as across firms.[34] Firms choose whether to export to each market and the range of products to export to each market. Under the assumption of untruncated Pareto distributions for firm productivity and product attributes, the model implies log linear relationships for aggregate trade, the intensive margin of average exports per firm-product conditional on positive trade, and the extensive margin of the number of firm-product observations with positive trade. Estimating these gravity equation relationships using US trade transactions data, the negative effect of distance on aggregate bilateral trade is largely explained by the extensive margin of the number of firm-product observations with positive trade. Although distance reduces the intensive margin of exports of a given product by a given firm, average firm-product exports conditional on positive trade are largely uncorrelated with distance, because of endogenous changes in export composition.[35]

More recent research has begun to provide evidence on the extensive margins of firm importing. As discussed above, Antràs, Fort, and Tintelnot (2017) develop a quantitative multicountry sourcing model in which heterogeneous firms self-select into importing based on their productivity and country-specific variables (wages, trade costs, and technology). For parameter values

31 Following trade liberalization reforms, Kehoe and Ruhl (2013) find that much of the growth in overall trade occurs in goods that were not previously exported or were only previously exported in small amounts.

32 Other quantitative analyses of models of heterogeneous firms and trade include the study of trade integration in Corcos et al. (2012), the analysis of the impact of China's productivity growth on world welfare in Hsieh and Ossa (2016), the investigation of patterns of trade in Bangladesh's apparel sector in Cherkashin et al. (2015), and the exploration of foreign direct investment (FDI) activity in Irarrazabal, Moxnes, and Opromolla (2013).

33 The importance of the extensive margins of firm trade participation for aggregate trade flows does not necessarily imply that they are relevant for measuring the aggregate welfare gains from trade. For the circumstances under which the aggregate gains from trade can be summarized by a constant trade elasticity and an aggregate domestic trade share in the Melitz (2003) model, see Arkolakis, Costinot, and Rodriguez-Clare (2012) and Melitz and Redding (2015).

34 Other recent research on multiproduct firms in international trade includes Arkolakis, Muendler, and Ganapati (2016); Eckel and Neary (2010); Feenstra and Ma (2008); Mayer, Melitz, and Ottaviano (2014); and Nocke and Yeaple (2014).

35 As shown in Bernard et al. (2009), the extensive margins of the number of exported products and export markets account for much of the cross-section variation in aggregate US exports and imports. Over short time horizons, the intensive margin of average trade conditional on trade being positive is relatively more important, and the extensive and intensive margins behave differently for arms-length versus related-party trade in response to macroeconomic shocks such as the 1997 Asian financial crisis.

for which firm importing decisions are complementary across source countries, firm import participation exhibits a strict hierarchy, according to which the number of countries from which a firm sources is (weakly) increasing in its productivity. The presence of endogenous import sourcing decisions plays a central role in shaping the effects of a counterfactual shock of increased import competition from China. While this common import competition shock decreases overall domestic sourcing and employment, some firms can be induced to select into sourcing from China as a result of the shock. For parameter values for which importing decisions are complementary across source countries, these firms, on average, increase their input purchases not only from China, but also from the United States and other countries.

4.6 *Concentration*

Another central implication of our model is that the correlation among the margins of international participation magnifies differences in firm performance, thereby helping to explain the observed skewed distribution of firm size. In this section, we present further evidence on the degree to which trade is concentrated across firms. Table 7 shows that trade of all types is extremely concentrated in the largest firms. The largest decile of firms accounts for over 95 percent of total trade, exports and imports, and over 99 percent of related-party trade in 2007. Even among the largest firms, the top 1 percent stand out. They control more than 80 percent of total US trade and more than 92 percent of related-party trade. These "largest of the large" firms are fifteen times more important in exports and imports than are firms in the second-largest percentile.

Following the early US evidence in Bernard, Jensen, and Schott (2009), this finding that trade is disproportionately concentrated in the largest firms has been confirmed across a range of different countries. For example, using data for manufacturing exports, Mayer and Ottaviano (2007) report that the share of exports accounted for by the top 1 percent of firms is 48 percent for Belgium, 44 percent for France, 59 percent for Germany, 77 percent for Hungary, 32 percent for Italy, 53 percent for Norway, and 42 percent for the United Kingdom. Therefore, the extreme concentration of trade across firms is also a robust empirical finding across this diverse range of countries.

4.7 *Co-movement in the Margins of International Participation*

We now turn to examine in more detail our model's central prediction of co-movement in the margins of firm participation in international markets. In table 8, we calculate the correlations of log value (total trade, imports, exports, and related-party trade) and log counts (import and export counts of country-products, products, and countries) for firms with positive values in the category. In every case, we find positive and significant correlations across the different dimensions of international activity of the firm. Perhaps unsurprisingly, total firm trade is strongly positively correlated with firm exports and imports as well as related-party trade. In addition, however, we see that export value and counts of export products and countries are positively related to similar measures on the import side. Therefore, as predicted by our model, firms that source from more countries, or import more products, also export more products to more countries and the total value of their exports is higher.

In figure 1, we begin by examining the relationship between a firm's decision to import and its decision to export. For each decile or percentile bin of the distribution of total firm trade, we compute the fraction of all trading firms within the bin that both export

TABLE 7
Export Shares

Decile	Trade Total (1)	Trade RP (2)	Exports Total (3)	Exports RP (4)	Imports Total (5)	Imports RP (6)
1	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.001	0.000	0.000	0.000
5	0.001	0.000	0.001	0.000	0.001	0.000
6	0.002	0.000	0.003	0.000	0.001	0.000
7	0.004	0.000	0.005	0.001	0.003	0.000
8	0.008	0.001	0.011	0.001	0.006	0.001
9	0.023	0.005	0.028	0.005	0.020	0.004
10	0.963	0.994	0.951	0.993	0.970	0.994
Percentile						
91	0.004	0.001	0.005	0.001	0.004	0.001
92	0.005	0.001	0.006	0.001	0.005	0.001
93	0.006	0.002	0.007	0.002	0.006	0.002
94	0.008	0.002	0.009	0.002	0.007	0.002
95	0.010	0.003	0.010	0.003	0.009	0.003
96	0.013	0.005	0.014	0.004	0.012	0.005
97	0.017	0.007	0.020	0.006	0.016	0.007
98	0.027	0.013	0.030	0.012	0.026	0.013
99	0.054	0.031	0.060	0.030	0.051	0.032
100	0.818	0.929	0.789	0.933	0.835	0.927

Note: Data are from the 2007 LFTTD. The table reports shares accounted for by firms in each decile/percentile of the total trade distribution (total exports plus total imports). Trade corresponds to exports plus imports. Total corresponds to related-party plus arm's length. RP corresponds to related-party. Columns 1–2 report shares for total trade (total exports plus total imports) and related-party trade (related-party exports plus related-party imports); columns 3–4 present shares for total exports and related-party exports; and columns 5–6 list shares for total imports and related-party imports.

and import. As shown in the main panel of the figure, the extent of two-way trade increases nonlinearly across the distribution of total firm trade, whether we look across decile bins of the distribution as a whole or across percentile bins of the top decile of the distribution. Therefore, the most successful trading firms are disproportionately likely to both export and import, consistent with the presence of fixed costs of both exporting and importing in the theoretical framework above.

Our framework also predicts that the various margins of international participation will interact with each other. Increases in firm productivity result in more than proportional increases in international trade because of the reinforcing connections between exporting and importing. In figures 2–6 and table 9, we examine how the different margins of firm international participation vary across deciles and percentiles of the value of total firm trade (exports plus imports). The horizontal axis of the graph in the lower left

TABLE 8
Correlations Across Firms in 2007

	Value				Counts					
					Import			Export		
	Trade	Exports	Imports	RP trade	Product-Countries	Products	Countries	Product-Countries	Products	Countries
Value										
Trade	1.00									
	270.0									
Exports	0.85	1.00								
	210.0	*210.0*								
Imports	0.88	0.34	1.00							
	140.0	*77.1*	*140.0*							
RP trade	0.70	0.52	0.65	1.00						
	44.7	*38.7*	*35.4*	*44.7*						
Counts										
Import										
Product-Countries	0.66	0.30	0.74	0.47	1.00					
	140.0	*77.1*	*140.0*	*35.4*	*140.0*					
Products	0.62	0.27	0.70	0.45	0.98	1.00				
	140.0	*77.1*	*140.0*	*35.4*	*140.0*	*140.0*				
Countries	0.62	0.42	0.64	0.40	0.79	0.69	1.00			
	140.0	*77.1*	*140.0*	*35.4*	*140.0*	*140.0*	*140.0*			
Export										
Product-Countries	0.71	0.79	0.31	0.39	0.37	0.34	0.47	1.00		
	210.0	*210.0*	*77.1*	*38.7*	*77.1*	*77.1*	*77.1*	*210.0*		
Products	0.68	0.75	0.33	0.41	0.39	0.38	0.46	0.95	1.00	
	210.0	*210.0*	*77.1*	*38.7*	*77.1*	*77.1*	*77.1*	*210.0*	*210.0*	
Countries	0.62	0.68	0.25	0.28	0.31	0.28	0.44	0.87	0.74	1.00
	210.0	*210.0*	*77.1*	*38.7*	*77.1*	*77.1*	*77.1*	*210.0*	*210.0*	*210.0*

Note: Data are from the 2007 LFTTD. This table reports correlations across firms of the log of the variables (value or counts) for firms that have positive values of both variables. All correlations are for the year 2007. Trade refers to the sum of exports and imports; RP Trade reports to related-party trade (sum of related-party exports and related-party imports). Products correspond to HS ten-digit products. The numbers in italics are the counts of firms in thousands for each cell. All correlations are significant at the 1 percent level.

of each figure represents the ten deciles of firms sorted by their total trade and is held constant across each of the figures. The horizontal axis of the graph in the upper-right-hand corner of each figure covers firms in the ninetieth to one hundredth percentiles of the firm total trade distribution and is held constant across the figures. The vertical axes in the five figures use a log scale. In the main panel of each figure, we report means across decile bins of total firm trade. In the callout panel of each figure, we show means across percentile bins of the top decile of total firm trade.

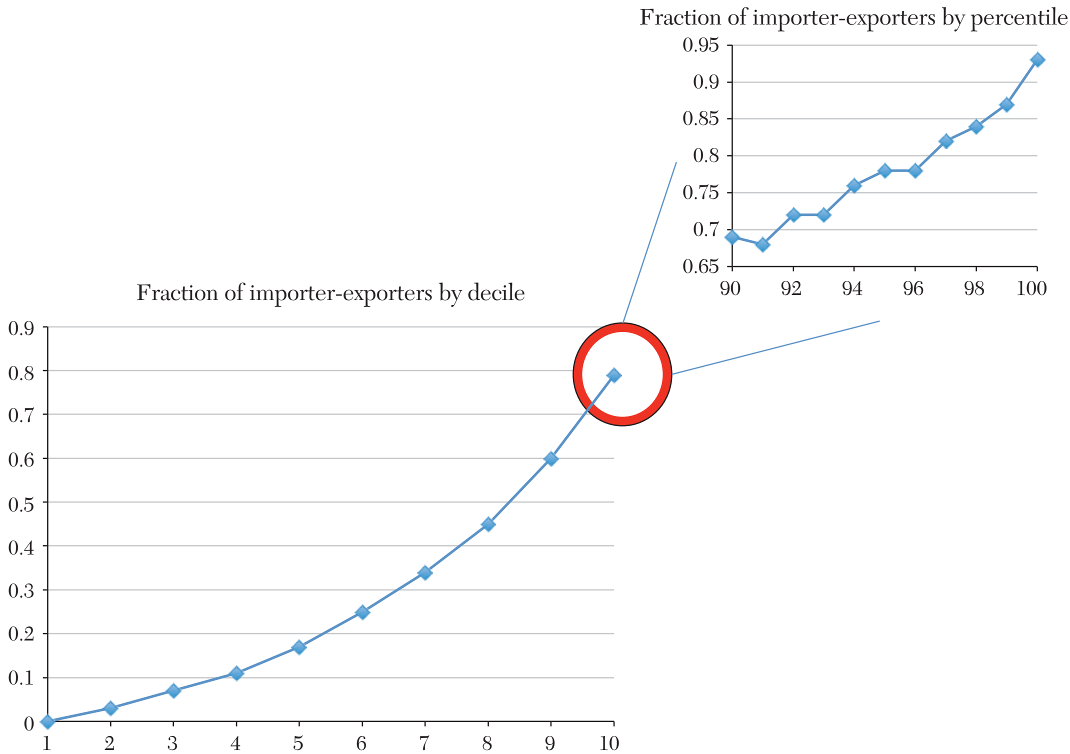

Figure 1. Fraction of Importer-Exporters by Decile/Percentile of Firm Total Trade

Notes: Data are from the 2007 LFTTD. Total trade is related-party and arm's length trade (exports plus imports). Horizontal axis of the bottom-left figure is the decile of total trade. Horizontal axis of the upper-right figure is the percentile of total trade. Vertical axes of both figures are fractions of firms within each decile/percentile that import and export.

As shown in the main panel of figure 2, the logs of the average values of firm exports and imports increase monotonically across the first nine deciles of the firm total trade distribution. Total trade for the average firm increases roughly 225 percent from one decile to the next.[36] The picture changes drastically for the top decile. Average total trade for the largest ten percent of firms is 42 times greater than that of the previous decile. The biggest traders are far larger than the rest of the trading firms and this pattern holds for both their imports as well as their exports. Comparing the main and callout panels of figure 2, we find that the distribution of trade across firms has a fractal property, where we find the same pattern across percentiles of the top decile as across the deciles of the distribution as a whole. Average total trade, exports, and imports increase relatively steadily until the very top percentile, when it jumps again. The top one

[36] The growth of exports is slightly lower, 210 percent, while the growth of imports is slightly higher, 244 percent. See table 9.

TABLE 9
MEAN VALUES AND COUNTS BY DECILE/PERCENTILE OF THE VALUE OF TOTAL TRADE IN 2007

	Trade		Exports					Imports				
Decile	All	Related-Party	All	Related-Party	Product-Countries	Products	Countries	All	Related-Party	Product-Countries	Products	Countries
1	3,636	83	2,710		1.0	1.0	1.0	926		1.2	1.2	1.0
2	9,089	221	6,667		1.3	1.3	1.1	2,422		1.5	1.5	1.1
3	19,602	488	13,731		1.8	1.7	1.3	5,871		1.9	1.8	1.2
4	39,083	1,057	26,162	671	2.4	2.1	1.6	12,921	386	2.4	2.2	1.3
5	76,677	2,254	47,753	1,263	3.2	2.7	2.0	28,924	991	3.0	2.8	1.4
6	154,424	5,331	90,274	2,453	4.5	3.5	2.6	64,149	2,879	4.0	3.6	1.6
7	324,256	14,500	175,594	5,695	6.3	4.5	3.4	148,661	8,805	5.5	4.7	1.9
8	733,326	42,046	367,218	13,358	9.0	5.9	4.4	366,109	28,688	7.3	6.0	2.3
9	2,065,189	182,897	936,988	49,775	13.7	8.3	6.0	1,128,201	133,122	11.1	8.6	3.0
10	88,061,648	39,984,764	32,075,318	10,515,436	56.2	23.4	12.8	55,986,328	29,469,326	42.0	23.0	6.6
Percentile												
90	3,435,321	357,656	1,490,421	100,988	16.8	9.8	7.1	1,944,900	256,668	14.7	11.0	3.5
91	4,023,476	443,004	1,745,703	105,011	18.3	10.4	7.5	2,277,773	337,993	14.3	10.5	3.7
92	4,745,500	540,808	2,051,352	122,827	20.2	11.2	8.0	2,694,148	417,981	15.9	11.7	3.9
93	5,699,326	749,423	2,360,996	178,258	22.0	12.2	8.4	3,338,330	571,165	16.6	12.3	4.0
94	6,976,046	942,954	2,916,673	231,552	24.1	13.0	9.1	4,059,373	711,402	17.9	13.0	4.3
95	8,759,872	1,198,860	3,537,986	267,746	25.4	13.6	9.2	5,221,886	931,115	20.2	14.4	4.7
96	11,483,836	1,845,385	4,772,462	438,196	28.7	14.8	9.9	6,711,374	1,407,188	22.3	16.0	5.0
97	15,995,423	2,856,674	6,607,454	675,232	34.1	16.6	11.4	9,387,969	2,181,443	26.1	18.3	5.6
98	24,941,730	5,088,683	10,179,695	1,244,585	42.8	20.9	13.3	14,762,034	3,844,098	32.7	21.3	6.5
99	49,822,084	12,626,625	20,263,520	3,136,505	63.2	28.4	17.1	29,558,564	9,490,120	44.8	28.4	8.6
100	748,328,256	373,635,840	266,373,648	98,775,784	261.7	86.0	31.4	481,954,592	274,860,064	193.4	78.2	18.0

Note: Data are from the 2007 LFTTD. This table reports mean values and counts by decile or percentile of the value of total trade. Total trade is related-party and arm's length trade (exports plus imports). Related-party refers to trade between related parties. Products correspond to HS ten-digit products.

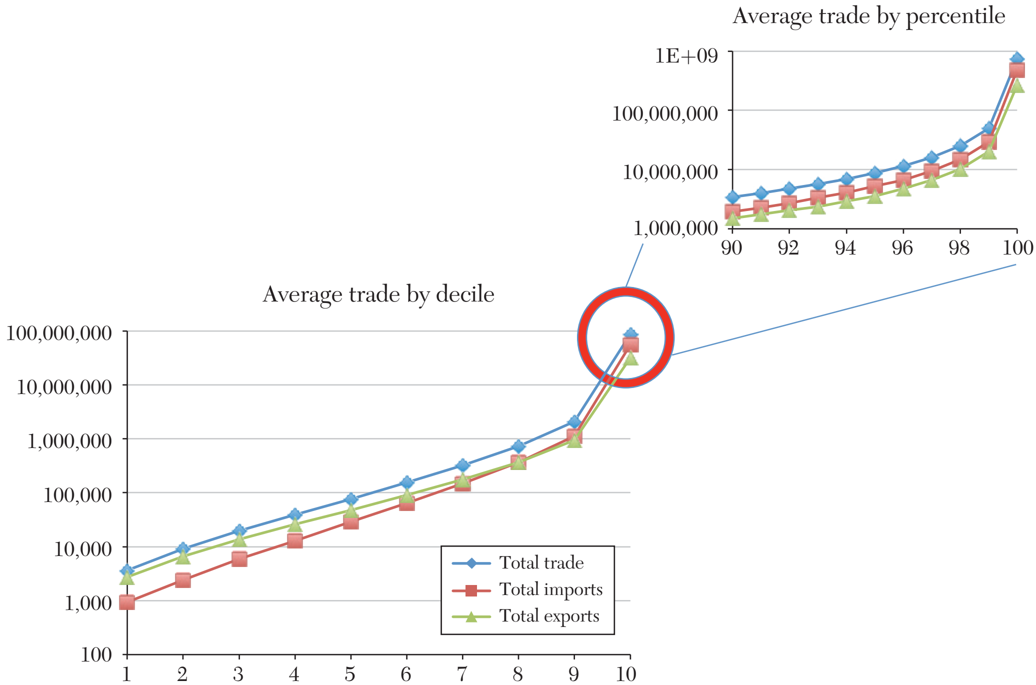

Figure 2. Value of Firm Exports, Imports, and Total Trade by Decile/Percentile of Firm Total Trade

Notes: Data are from the 2007 LFTTD. The figures display average exports, imports, and total trade for firms within each quantile of the total trade distribution. Total trade is related-party and arms length trade (exports plus imports). Horizontal axis of the bottom-left figure is the decile of total trade. Horizontal axis of the upper-right figure is the percentile of total trade. Vertical axes of both figures use log scales.

percent of trades are fifteen times larger than the second-largest percentile of firms.

In figure 3, we calculate the average value of related-party trade (exports plus imports), exports, and imports.[37] As is apparent from the main panel, average related-party trade is sharply increasing across the deciles.[38] Again we find a positive correlation between the margins of international participation: firms that trade more not only import and export more overall, but also import and export more with related parties. We find that related-party exports and imports increase more rapidly across deciles of the total trade distribution than overall exports and imports, so that related-party trade accounts for a bigger share of overall trade for the larger trading firms. Comparing the main and callout panels of the figure, we again observe that the results exhibit a fractal property, with the same pattern across percentiles of the top decile as across the deciles of the distribution as a whole. The average firm in the top percentile of trading

[37] To conform with census disclosure requirements we only report results for related-party exports and imports from the fourth decile upwards.

[38] For evidence on firm productivity as a determinant of related-party trade, see Nunn and Trefler (2008, 2013) and Bernard et al. (2010a).

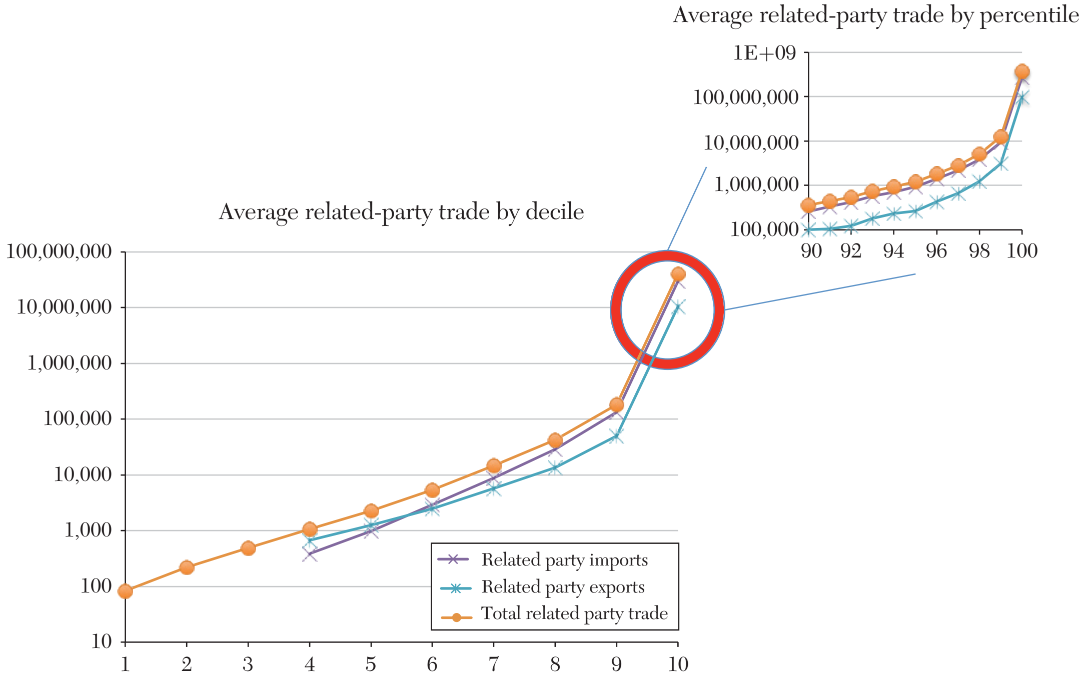

Figure 3. Value of Firm Related-Party Trade by Decile/Percentile of Firm Total Trade

Notes: Data are from the 2007 LFTTD. The figures display average related-party exports, related-party imports, and related-party trade (exports plus imports) for firms within each quantile of the total trade distribution. Total trade is related-party and arm's length trade (exports plus imports). Horizontal axis of the bottom-left figure is the decile of total trade. Horizontal axis of the upper-right figure is the percentile of total trade. Vertical axes of both figures use log scales.

firms conducts twenty-nine times as much related-party trade as the average firm in the next percentile.[39]

While the first two figures focus on trade values, the next several figures examine the extensive margins of firm participation in international markets. In figure 4, we display the number of product-country observations with positive exports or imports across percentiles of the value of total firm trade. As evident from the main panel, the product-country extensive margin increases monotonically across deciles of the total firm trade distribution, with the level of activity in terms of country-products jumping in the highest decile. Consistent with the predictions of the model, more successful firms trade more than less successful firms, not only because they export or import more of a given number of products

[39] The sharp increase in the share of related-party trade with the size of firm total trade explains why related-party trade accounts for around half of aggregate US imports (see Antràs 2003 and Bernard, Jensen, and Schott 2009), even though intrafirm shipments are relatively unimportant for the average plant or firm (see Atalay, Hortaçsu, and Syverson 2014 and Ramondo, Rappoport, and Ruhl 2016). The key to reconciling these features of the data is that related-party trade is disproportionately important for the very largest firms that account for a disproportionate share of aggregate trade value.

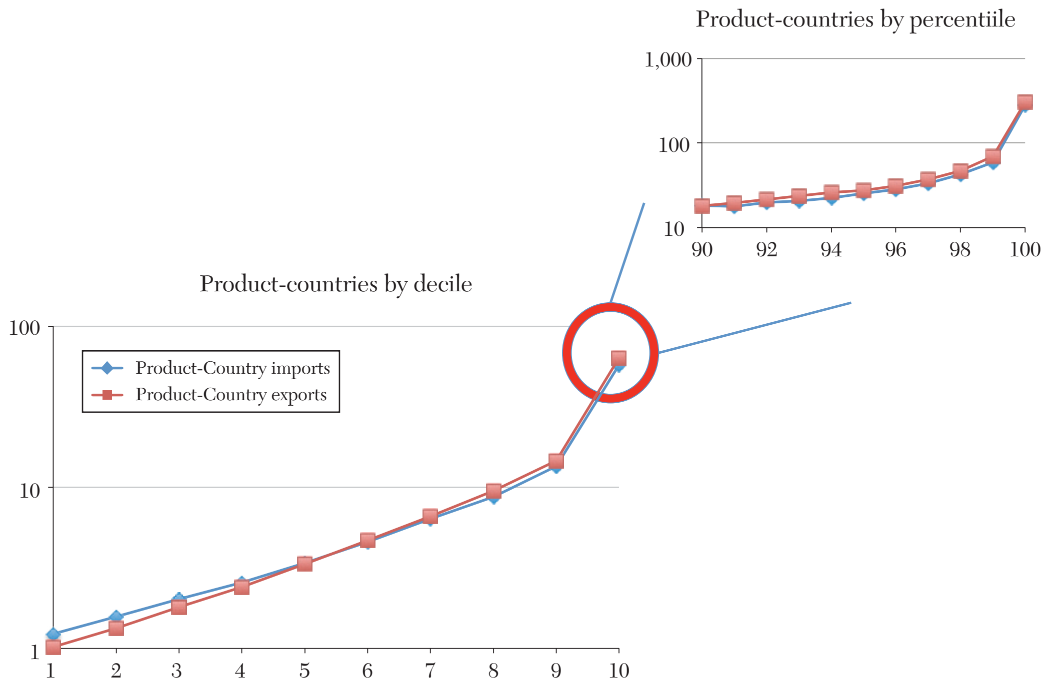

Figure 4. Product-Country Extensive Margin by Decile/Percentile of Firm Total Trade

Notes: Data are from the 2007 LFTTD. Figure displays average number of exported product destinations and imported product sources for firms within each quantile of the total trade distribution. Products are defined as HS10 categories. Total trade is related-party and arm's length trade (exports plus imports). Horizontal axis of the bottom-left figure is the decile of total trade. Horizontal axis of the upper-right figure is the percentile of total trade. Vertical axes of both figures use log scales.

with a given number of countries, but also because they export and import with more product-country pairs. Again, we find the same properties across the percentiles of the top decile (in the callout panel) as across the deciles of the distribution as a whole (in the main panel).

In figures 4 and 5, we break out the product-country extensive margin into the contributions of the product and country extensive margins separately. As shown in the main panel, the increase in the number of product-country observations with positive trade across the deciles of the total firm trade distribution is achieved partly through an increase in the number of products with positive trade and partly through an increase in the number of countries with positive trade. While the extensive margins for export and import products rise at approximately the same rate across the deciles of total firm trade, the extensive margin for export destinations rises more rapidly than that for import source countries, suggesting that fixed sourcing costs are large relative to fixed exporting costs. For all these extensive margins, the level

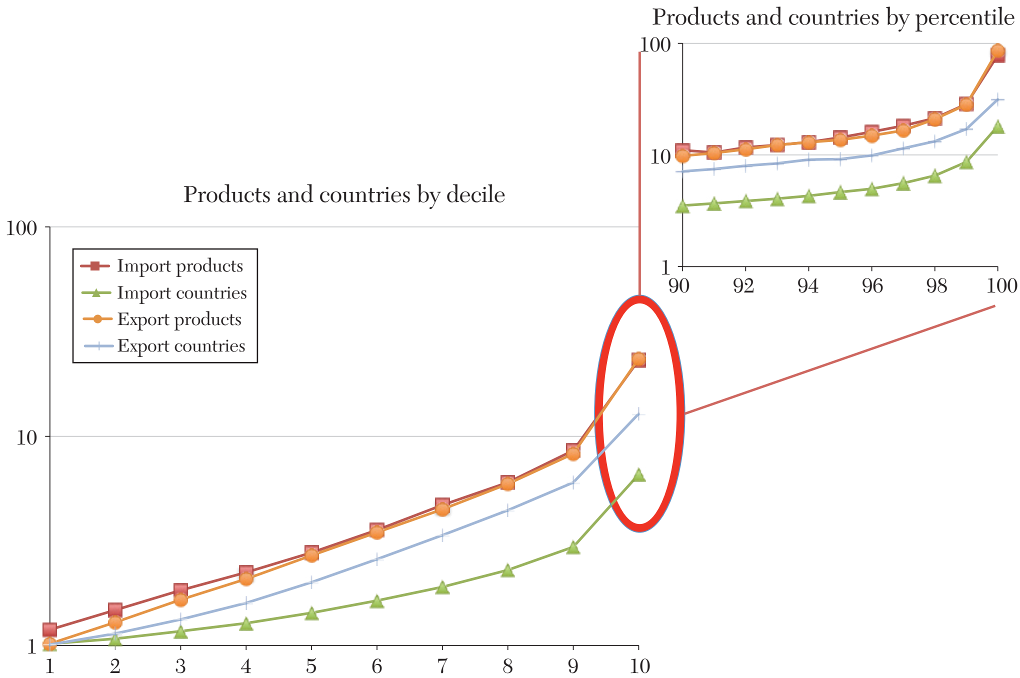

Figure 5. Product and Country Extensive Margins by Decile/Percentile of Firm Total Trade

Notes: Data are from the 2007 LFTTD. Figure displays average number of exported products, export destinations, imported products, and import sources for firms in each quantile of the total trade distribution. Products are defined as HS10 categories. Total trade is related-party and arm's length trade (exports plus imports). Horizontal axis of the bottom-left figure is the decile of total trade. Horizontal axis of the upper-right figure is the percentile of total trade. Vertical axes of both figures use log scales.

of activity jumps for the top decile, and the distributions are fractal, in the sense that we observe a similar pattern across percentiles of the top decile as across the deciles of the distribution as a whole.

Figure 6 shows the distribution of the extensive margins for related-party trade. The pattern is a familiar one with a roughly log-linear increase across the deciles until the largest decile, where there is a substantial jump in activity. Again, we see the pattern repeated within the top decile, as the largest trading firms have many more related-party connections for both imports and exports. This extensive margin of related-party activity suggests a useful extension of our framework to incorporate the decision whether to organize overseas production within the boundaries of the firm FDI or through arm's length transactions (outsourcing). Work on firm-level FDI has consistently found that more productive firms are more likely to be multinationals, i.e., have at least one foreign affiliate, and that the numbers of host countries and affiliates are increasing in measures of firm performance.[40]

[40] The large literature on FDI includes Antràs (2003); Antràs and Helpman (2004); Arkolakis et al.

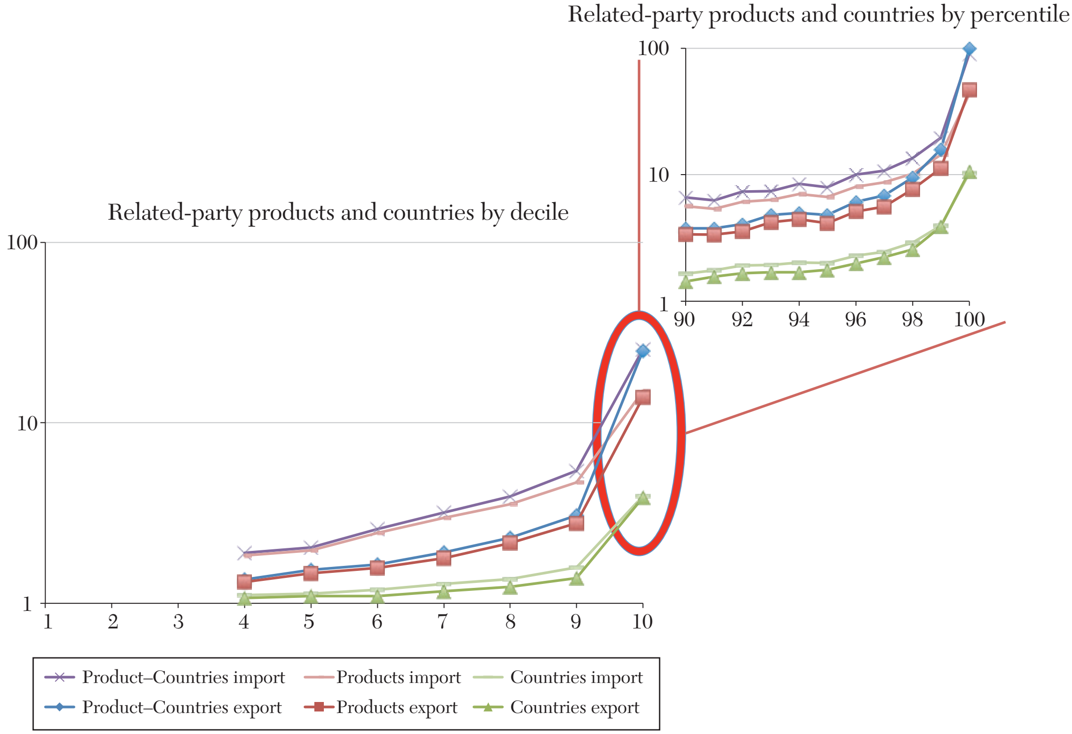

Figure 6. Related-Party Product and Country Extensive Margins by Decile/Percentile of Firm Total Trade

Notes: Data are from the 2007 LFTTD. Figure displays the average number of related-party export products, destinations, and product-destinations, as well as the average number of related-party import products, sources, and product-sources, for firms in each quantile of the total trade distribution. Products are defined as HS10 categories. Total trade is related-party and arm's length trade (exports plus imports). Horizontal axis of the bottom-left figure is the decile of total trade. Horizontal axis of the upper-right figure is the percentile of total trade. Vertical axes of both figures use log scales.

Figure 7 shows that the largest trading firms account for larger shares of exports for individual product markets. The average export market share of a firm's top product in each market rises systematically across deciles and percentiles of total trade. The largest firms in terms of total trade have average shares of US exports for their top product within each market of 25 percent, while firms in the fifth decile average under 7 percent of US exports of their top product within each market. In our model, such variation in market shares gives rise to strategic market power, and generates variation in markups across firms.

Taken together, the results of this section provide further evidence in support of

(forthcoming); Muendler and Becker (2010); Brainard (1997); Cravino and Levchenko (2017); Doms and Jensen (1998); Hanson, Mataloni, and Slaughter (2005); Helpman (1984); Helpman, Melitz, and Yeaple (2004); Markusen and Venables (1998, 2000); Ramondo and Rodriguez-Clare (2013); and Yeaple (2009), as reviewed in Antràs and Yeaple (2009).

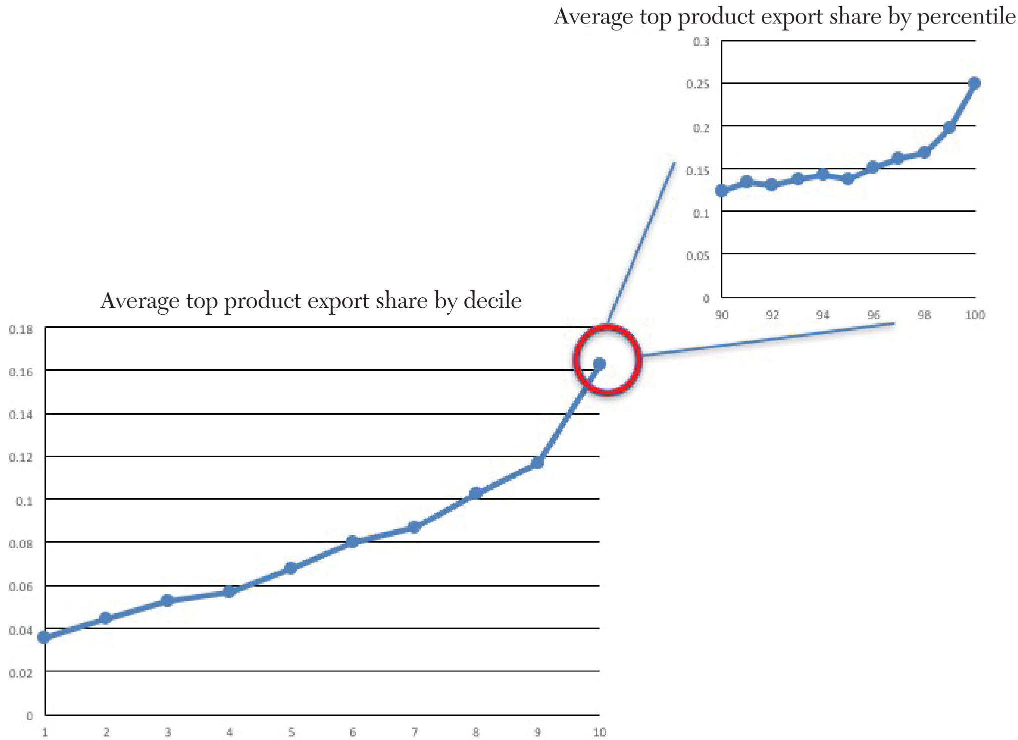

Figure 7. Average Shares of a Firm's Top Product in US Exports of That Product across Markets by Decile/Percentile of Firm Total Trade

Notes: Data are from the 2007 LFTTD. Figure displays the average across markets of the share of a firm's top product in US exports of that product to that market. We allow the definition of top product to vary across markets. We display this average for firms in each quantile of the total trade distribution. Total trade is related-party and arm's length trade (exports plus imports). Horizontal axis of the bottom-left figure is the decile of total trade. Horizontal axis of the upper-right figure is the percentile of total trade. Vertical axes of both figures are fractions.

the predictions of our theoretical model. All the margins of firm international participation strongly co-move, with greater participation along one margin correlated with more active engagement along another. In the model, these correlations are driven by two mechanisms. On the one hand, higher firm productivity propels greater international participation along all margins simultaneously because of the nonrandom selection of firms into these different activities. On the other hand, the decisions to participate in international markets along each margin are complementary with one another. As more productive firms incur the fixed exporting costs of serving additional markets, this increases their production scale, and raises the profitability of incurring the fixed importing costs for additional countries. Incurring these additional fixed importing costs in turn reduces production costs, which raises the profitability of incurring the fixed exporting costs for additional markets. Through these forces of selection and complementarity, exogenous differences across firms are magnified, such that a relatively small number of firms account for a disproportionately large share of aggregate trade.

5. *Conclusions*

Over the last two decades, a growing body of theoretical and empirical research has demonstrated the role of heterogeneous firm decisions in mediating the economy's response to international trade. The now-standard model of heterogeneous firms and trade envisions a continuum of measure-zero firms that compete under conditions of monopolistic competition and self-select into export markets. In this paper, we review this research and argue that this standard paradigm does not go far enough in recognizing the role of "global firms," defined as firms that participate in the international economy along multiple margins and account for substantial shares of aggregate trade.

We outline a theoretical framework that recognizes the role played by such global firms. We allow large firms to internalize the effects of their choices on market aggregates, which results in variable markups, pricing to market, and incomplete pass-through. We include a much richer range of margins along which firms can participate in international markets than the standard paradigm. Each firm can choose the set of production locations in which to operate plants, the set of export markets for each plant, the set of products to export from each plant to each market, the exports of each product from each plant to each market, the set of countries from which to source intermediate inputs for each plant, and imports of each intermediate input from each source country by each plant.

We use US firm and trade transactions data to provide empirical evidence on the predictions of this framework. Consistent with the selection forces in our model, we show that only a subset of firms participate in international markets (through either exporting or importing) and that these trading firms have superior performance characteristics: they are larger and more productive than purely domestic firms. We find strong support for our model's prediction of a correlation between the different margins of firm participation in the global economy. A substantial fraction of firms that export or import do both. More successful firms export more of each product to each market, export more products to each market, export to more markets, import more of each product from each source country, import more products from each source country, and import from more source countries. These empirical findings also provide support for the magnification effects emphasized in our model. Small differences in exogenous firm characteristics have amplified effects on endogenous firm performance (such as sales) because they are magnified by these endogenous market participation decisions, thereby helping to explain how a relatively small number of firms dominate aggregate international trade.

While much has already been achieved within the literature on heterogeneous firms and trade, there remains much to be done. Recognizing the importance of global firms opens up a number of avenues for further research, including their implications for the transmission of international shocks, the elasticity of trade with respect to trade costs, and the aggregate welfare gains from trade. Although we consider many margins of firm participation in the international economy, we abstract from the decision whether to organize global production chains within or beyond the boundaries of the firm, which itself has been the subject of much recent research. Therefore another interesting area for further inquiry is exploring the implications of this internalization decision for firm performance and country comparative advantage in a world of such global firms.

Appendix

Derivation of Equilibrium Pricing Rule

The first-order condition for the price of product k for firm f from production country i in market m within sector g is:

$$(30)\qquad Q_{mik}^{K} + \sum_{h \in \Omega_{mif}^{K}} \left(P_{mih}^{K} \frac{\partial Q_{mih}^{K}}{\partial P_{mik}^{K}} - \frac{d_{mi}^{X} w_{i}^{\alpha_g} \left(\gamma_{k}^{K}\right)^{1-\alpha_g} \left[\Phi_{ifh}\left(\Omega_{if}^{NI}\right)\right]^{-\frac{1-\alpha_g}{\theta_{k}^{K}}}}{\varphi_{if}} \frac{\partial Q_{mih}^{K}}{\partial P_{mik}^{K}} \right) = 0.$$

From equation (9), we have:

$$\frac{\partial Q_{mih}^{K}}{\partial P_{mik}^{K}} = \left(\sigma_{g}^{F} - 1\right) \frac{Q_{mih}^{K}}{P_{mg}^{G}} \frac{\partial P_{mg}^{G}}{\partial P_{mik}^{K}} + \left(\sigma_{g}^{K} - \sigma_{g}^{F}\right) \frac{Q_{mih}^{K}}{P_{mif}^{F}} \frac{\partial P_{mif}^{F}}{\partial P_{mik}^{K}} - \sigma_{g}^{K} \frac{Q_{mih}^{K}}{P_{mik}^{K}} \frac{\partial P_{mih}^{K}}{\partial P_{mik}^{K}}.$$

We now can use the expenditure shares (7) and (8) to solve for the elasticities and rewrite $\partial Q_{mih}^{K} / \partial P_{mik}^{K}$ as

$$(31)\qquad \frac{\partial Q_{mih}^{K}}{\partial P_{mik}^{K}} = \left(\sigma_{g}^{F} - 1\right) \left(\frac{\partial P_{mg}^{G}}{\partial P_{mif}^{F}} \frac{P_{mif}^{F}}{P_{mg}^{G}} \right) \left(\frac{\partial P_{mif}^{F}}{\partial P_{mik}^{K}} \frac{P_{mik}^{K}}{P_{mif}^{F}} \right) \frac{Q_{mih}^{K}}{P_{mik}^{K}} + \left(\sigma_{g}^{K} - \sigma_{g}^{F}\right) \left(\frac{\partial P_{mif}^{F}}{\partial P_{mik}^{K}} \frac{P_{mik}^{K}}{P_{mif}^{F}} \right) \frac{Q_{mih}^{K}}{P_{mik}^{K}}$$

$$- \sigma_{g}^{K} \frac{Q_{mih}^{K}}{P_{mik}^{K}} 1_{\{k=h\}}$$

$$= \left(\sigma_{g}^{F} - 1\right) S_{mif}^{F} S_{mik}^{K} \frac{Q_{mih}^{K}}{P_{mik}^{K}} + \left(\sigma_{g}^{K} - \sigma_{g}^{F}\right) S_{mik}^{K} \frac{Q_{mih}^{K}}{P_{mik}^{K}} - \sigma_{g}^{K} \frac{Q_{mih}^{K}}{P_{mik}^{K}} 1_{\{k=h\}}.$$

If we now substitute equation (31) into equation (30) and divide both sides by Q_{mik}^{K}, we get:

$$(32)\quad 1 + \sum_{h\in\Omega_{mif}^{K}} \left(\sigma_g^F - 1\right) S_{mif}^F S_{mik}^K \frac{P_{mih}^K Q_{mih}^K}{P_{mik}^K Q_{mik}^K} + \sum_{h\in\Omega_{mif}^{K}} \left(\sigma_g^K - \sigma_g^F\right) S_{mik}^K \frac{P_{mih}^K Q_{mih}^K}{P_{mik}^K Q_{mik}^K} - \sigma_g^K$$

$$- \sum_{h\in\Omega_{mif}^{K}} \left(\sigma_g^F - 1\right) S_{mif}^F S_{mik}^K \frac{\frac{d_{mi}^X w_i^{\alpha_g} \left(\gamma_k^K\right)^{1-\alpha_g} \left[\Phi_{ifh}\left(\Omega_{if}^{NI}\right)\right]^{-\frac{1-\alpha_g}{\theta_k^K}}}{\varphi_{if}} Q_{mih}^K}{P_{mik}^K Q_{mik}^K}$$

$$- \sum_{h\in\Omega_{mif}^{K}} \left(\sigma_g^K - \sigma_g^F\right) S_{mik}^K \frac{\frac{d_{mi}^X w_i^{\alpha_g} \left(\gamma_k^K\right)^{1-\alpha_g} \left[\Phi_{ifh}\left(\Omega_{if}^{NI}\right)\right]^{-\frac{1-\alpha_g}{\theta_k^K}}}{\varphi_{if}} Q_{mih}^K}{P_{mik}^K Q_{mik}^K}$$

$$+ \sigma_g^K \frac{\frac{d_{mi}^X w_i^{\alpha_g} \left(\gamma_k^K\right)^{1-\alpha_g} \left[\Phi_{ifk}\left(\Omega_{if}^{NI}\right)\right]^{-\frac{1-\alpha_g}{\theta_k^K}}}{\varphi_{if}}}{P_{mik}^K} = 0.$$

We define the markup as $\mu_{mih}^K \equiv P_{mih}^K \Big/ \left(d_{mi}^X w_i^{\alpha_g} \left(\gamma_k^K\right)^{1-\alpha_g} \left[\Phi_{ifh}\left(\Omega_{if}^{NI}\right)\right]^{-\frac{1-\alpha_g}{\theta_k^K}} / \varphi_{if} \right)$. Since $S_{mik}^K \frac{1}{P_{mik}^K Y_{mik}^K} = \frac{1}{\sum_{h\in\Omega_{mif}^K} P_{mih}^K Y_{mih}^K}$ and therefore $\sum_{h\in\Omega_{mif}^K} S_{mik}^K \frac{P_{mih}^K Y_{mih}^K}{P_{mik}^K Y_{mik}^K} = 1$, we can rewrite equation (32) as:

$$\left[1 + \left(\sigma_g^F - 1\right) S_{mif}^F + \left(\sigma_g^K - \sigma_g^F\right) - \sigma_g^K\right] - \left(\sigma_g^F - 1\right) S_{mif}^F \frac{\sum_{h\in\Omega_{mif}^K} \frac{d_{mi}^X w_i^{\alpha_g} \left(\gamma_k^K\right)^{1-\alpha_g} \left[\Phi_{ifh}\left(\Omega_{if}^{NI}\right)\right]^{-\frac{1-\alpha_g}{\theta_k^K}}}{\varphi_{if}} Q_{mih}^K}{\sum_{h\in\Omega_{mif}^K} P_{mih}^K Q_{mih}^K}$$

$$-\left(\sigma_g^K - \sigma_g^F\right) \frac{\sum_{h\in\Omega_{mif}^K} \frac{d_{mi}^X w_i^{\alpha_g} \left(\gamma_k^K\right)^{1-\alpha_g} \left[\Phi_{ifh}\left(\Omega_{if}^{NI}\right)\right]^{-\frac{1-\alpha_g}{\theta_k^K}}}{\varphi_{if}} Q_{mih}^K}{\sum_{h\in\Omega_{mif}^K} P_{mih}^K Q_{mih}^K} + \sigma_g^K \frac{1}{\mu_{mik}^K} = 0.$$

Note that μ_{mik}^K is the only k-specific term in this expression. Hence, μ_{mik}^K must take the same value for all products k supplied by firm f from production country i to market m within sector g: $\mu^K_{mik} = \mu^F_{mif}$ for all $k \in \Omega^K_{mif}$. In other words, *markups are the same across products within a given firm, market, and sector*. We can now solve for μ^F_{mif} using:

$$\left[1 + \left(\sigma^F_g - 1\right) S^F_{mif} + \left(\sigma^K_g - \sigma^F_g\right) - \sigma^K_g\right] - \left(\sigma^F_g - 1\right) S^F_{mif} \frac{1}{\mu^F_{mif}} - \left(\sigma^K_g - \sigma^F_g\right) \frac{1}{\mu^F_{mif}} + \sigma^K_g \frac{1}{\mu^F_{mif}} = 0$$

$$\Rightarrow \mu^F_{mif} = \frac{\sigma^F_g - \left(\sigma^F_g - 1\right) S^F_{mif}}{\sigma^F_g - \left(\sigma^F_g - 1\right) S^F_{mif} - 1}.$$

PROOF OF PROPOSITION 1:

(i) From the firm price index (6) and firm pricing rule (20), we have:

$$P^F_{mif} = \left(\frac{\mu^F_{mif}}{\varphi_{if}}\right) \Gamma^F_{mif}, \tag{33}$$

where

$$\Gamma^F_{mif} = d^X_{mi} w_i^{\alpha_g} \left[\sum_{k \in \Omega^K_{mif}} \left(\frac{\left(\gamma^K_k\right)^{1-\alpha_g} \left[\Phi_{ifk}\left(\Omega^{NI}_{if}\right)\right]^{-\frac{1-\alpha_g}{\theta^K_k}}}{\lambda^K_{mik}}\right)^{1-\sigma^K_g}\right]^{\frac{1}{1-\sigma^K_g}},$$

$$\Phi_{ifk}\left(\Omega^{NI}_{if}\right) \equiv \sum_{j \in \Omega^{NI}_{if}} T^K_{jk} \left(w_j d^I_{ij}\right)^{-\theta^K_k}.$$

Using the firm expenditure share (7) and (33), we obtain:

$$S^F_{mif} = \frac{\left(\mu^F_{mif}/\varphi_{if}\right)^{1-\sigma^F_g} \left(\Gamma^F_{mif}/\lambda^F_{mif}\right)^{1-\sigma^F_g}}{\sum_{i \in \Omega^N} \sum_{o \in \Omega^F_{mig}} \left(\mu^F_{mio}/\varphi_{io}\right)^{1-\sigma^F_g} \left(\Gamma^F_{mio}/\lambda^F_{mio}\right)^{1-\sigma^F_g}}. \tag{34}$$

Using the markup (21) and perceived elasticity (22), we define the following implicit function:

$$\Xi = S^F_{mif} - \frac{\left(\frac{\sigma^F_g - \left(\sigma^F_g - 1\right) S^F_{mif}}{\left(\sigma^F_g - 1\right) - \left(\sigma^F_g - 1\right) S^F_{mif}}\right)^{1-\sigma^F_g} \varphi_{if}^{\sigma^F_g - 1} \left(\Gamma^F_{mif} / \lambda^F_{mif}\right)^{1-\sigma^F_g}}{\sum_{i \in \Omega^N} \sum_{o \in \Omega^F_{mig}} \left(\frac{\sigma^F_g - \left(\sigma^F_g - 1\right) S^F_{mio}}{\left(\sigma^F_g - 1\right) - \left(\sigma^F_g - 1\right) S^F_{mio}}\right)^{1-\sigma^F_g} \varphi_{io}^{\sigma^F_g - 1} \left(\Gamma^F_{mio} / \lambda^F_{mio}\right)^{1-\sigma^F_g}} = 0. \tag{35}$$

From the implicit function theorem:

$$\frac{\partial S_{mif}^{F}}{\partial \varphi_{if}} = -\frac{\partial \Xi / \partial \varphi_{if}}{\partial \Xi / \partial S_{mif}^{F}}, \tag{36}$$

where we hold constant $\{w_m, \Omega_f^{NP}, \Omega_{if}^{NX}, \Omega_{if}^{NI}, \Omega_{mif}^{K}\}$ and all other model parameters except productivity. From (35), we have:

$$\frac{\partial \Xi}{\partial \varphi_{if}} = -\frac{\sigma_g^F - 1}{\varphi_{if}} S_{mif}^{F}\left(1 - S_{mif}^{F}\right) < 0, \tag{37}$$

$$\frac{\partial \Xi}{\partial S_{mif}^{F}} = 1 + \left(\sigma_g^F - 1\right)\left(\frac{\partial \mu_{mif}^{F}}{\partial S_{mif}^{F}} \frac{S_{mif}^{F}}{\mu_{mif}^{F}}\right)\left(1 - S_{mif}^{F}\right) > 0, \tag{38}$$

since

$$\frac{\partial \mu_{mif}^{F}}{\partial S_{mif}^{F}} \frac{S_{mif}^{F}}{\mu_{mif}^{F}} = \frac{\sigma_g^F - 1}{\varepsilon_{mif}^{F} - 1} S_{mif}^{F}\left(1 - \frac{1}{\mu_{mif}^{F}}\right) > 0. \tag{39}$$

From (36)–(39), an increase in firm productivity raises expenditure shares within each market:

$$\frac{\partial S_{mif}^{F}}{\partial \varphi_{if}} > 0. \tag{40}$$

(ii) Together (39) and (40) imply that an increase in firm productivity raises markups:

$$\frac{\partial \mu_{mif}^{F}}{\partial \varphi_{if}} > 0. \tag{41}$$

From (34), the firm expenditure share is decreasing in the ratio of the markup to firm productivity $(\mu_{mif}^{F}/\varphi_{if})$:

$$\frac{\partial S_{mif}^{F}}{\partial\left(\mu_{mif}^{F}/\varphi_{if}\right)} = -\frac{\sigma_g^F - 1}{\left(\mu_{mif}^{F}/\varphi_{if}\right)} S_{mif}^{F}\left(1 - S_{mif}^{F}\right) < 0. \tag{42}$$

Now we combine (40)–(42). The firm expenditure share increases in productivity in (40), even though the firm markup increases in productivity in (41). Therefore, from (42), the firm markup must rise less than proportionately with productivity (to ensure that the firm expenditure share increases in productivity), which implies that the price of each product must decrease in productivity:

$$\frac{\partial P_{mik}^{K}}{\partial \varphi_{if}} = \frac{\partial\left(\frac{\mu_{mif}^{F}}{\varphi_{if}} d_{mi}^{X} w_{i}^{\alpha_g} \left(\gamma_{k}^{K}\right)^{1-\alpha_g} \left[\Phi_{ifk}\left(\Omega_{if}^{NI}\right)\right]^{-\frac{1-\alpha_g}{\theta_k^K}}\right)}{\partial \varphi_{if}} < 0. \tag{43}$$

(iii) Sales of each product in each sector in each market can be written as:

$$E_{mik}^{K} = S_{mik}^{K} S_{mif}^{K} \left(\lambda_{mg}^{G} w_{m} L_{m}\right), \tag{44}$$

where the share of each product k in firm expenditure (S_{mik}^{K}) is independent of firm productivity and the markup because both are common across products within a given firm in a given market:

$$S_{mik}^{K} = \frac{\left(\left(\gamma_{k}^{K}\right)^{1-\alpha_g} \left[\Phi_{ifk}\left(\Omega_{if}^{NI}\right)\right]^{-\frac{1-\alpha_g}{\theta_k^K}} / \lambda_{mik}^{K}\right)^{1-\sigma_g^K}}{\sum_{n \in \Omega_{mif}^{K}} \left(\left(\gamma_{k}^{K}\right)^{1-\alpha_g} \left[\Phi_{ifn}\left(\Omega_{if}^{NI}\right)\right]^{-\frac{1-\alpha_g}{\theta_k^K}} / \lambda_{min}^{K}\right)^{1-\sigma_g^K}}. \tag{45}$$

From (40), (44), and (45), the firm expenditure share (S_{mif}^{K}) increases in firm productivity, while the product expenditure share (S_{mik}^{K}) is unaffected by firm productivity. Therefore an increase in firm productivity raises sales of each product in a given market:

$$\frac{\partial E_{mik}^{K}}{\partial \varphi_{if}} > 0. \tag{46}$$

Output of each product in a given sector and market can be written as:

$$Q_{mik}^{K} = \frac{E_{mik}^{K}}{P_{mik}^{K}}. \tag{47}$$

From (43) and (46), an increase in firm productivity raises sales (E_{mik}^{K}) and reduces (P_{mik}^{K}) of each product in each market, which implies that it raises output (Q_{mik}^{K}) of each product in each market:

$$\frac{\partial Q_{mik}^{K}}{\partial \varphi_{if}} > 0. \tag{48}$$

Since an increase in firm productivity raises sales and output of each product in each market, it also raises overall sales (E_{ik}^{K}) and output (Q_{ik}^{K}) of each product across all markets:

$$\frac{\partial E_{ik}^{K}}{\partial \varphi_{if}} > 0, \quad \frac{\partial Q_{ik}^{K}}{\partial \varphi_{if}} > 0, \tag{49}$$

where $E_{ik}^{K} = \sum_{m \in \Omega_{if}^{NX}} E_{mik}^{K}$ and $Q_{ik}^{K} = \sum_{m \in \Omega_{if}^{NX}} Q_{mik}^{K}$. ∎

PROOF OF PROPOSITION 2:

From proposition 1, we have:

$$\frac{\partial E_{mik}^{K}}{\partial \varphi_{if}} > 0, \quad \frac{\partial \mu_{mif}^{F}}{\partial \varphi_{if}} > 0,$$

where we hold constant $\{w_m, \Omega_f^{NP}, \Omega_{if}^{NX}, \Omega_{if}^{NI}, \Omega_{mif}^{K}, \tilde{\Omega}_{mif}^{K}\}$ and all model parameters except productivity. Therefore we have:

$$\frac{\partial\left(\left(\dfrac{\mu_{mif}^{F}-1}{\mu_{mif}^{F}}\right) E_{mik}^{K}\right)}{\partial \varphi_{if}} > 0, \quad \text{for all } k \in \left\{\tilde{\Omega}_{mif}^{K} \backslash \Omega_{mif}^{K}\right\},$$

which together with (27) establishes the proposition. ∎

PROOF OF PROPOSITION 3:

From proposition 1, we have:

$$\frac{\partial E_{mik}^{K}}{\partial \varphi_{if}} > 0, \quad \frac{\partial \mu_{mif}^{F}}{\partial \varphi_{if}} > 0,$$

where we hold constant $\{w_m, \Omega_f^{NP}, \Omega_{if}^{NX}, \Omega_{if}^{NI}, \Omega_{mif}^{K}, \tilde{\Omega}_{mif}^{K}\}$ and all model parameters except productivity. Therefore we have:

$$\frac{\partial\left(\left(\dfrac{\mu_{mif}^{F}-1}{\mu_{mif}^{F}}\right) E_{mik}^{K}\right)}{\partial \varphi_{if}} > 0, \quad \text{for all } k \in \Omega_{mif}^{K},$$

which together with (28) establishes the proposition. ∎

PROOF OF PROPOSITION 4:

From proposition 1, we have:

$$\frac{\partial E_{mik}^{K}\left(\Omega_{if}^{NI}\right)}{\partial \varphi_{if}} > 0, \quad \frac{\partial \mu_{mif}^{F}\left(\Omega_{if}^{NI}\right)}{\partial \varphi_{if}} > 0,$$

where we make explicit that both the markup (μ_{mif}^{F}) and sales of each product (E_{mik}^{K}) are functions of the set of source countries (Ω_{if}^{NI}); we also hold constant $\{w_m, \Omega_f^{NP}, \Omega_{if}^{NX}, \Omega_{if}^{NI}, \Omega_{mif}^{K}, \tilde{\Omega}_{mif}^{K}\}$ and all model parameters except productivity. Therefore we have:

$$\frac{\partial\left(\left(\frac{\mu_{mif}^{F}\left(\Omega_{if}^{NI}\right)-1}{\mu_{mif}^{F}\left(\Omega_{if}^{NI}\right)}\right)E_{mik}^{K}\left(\Omega_{if}^{NI}\right)\right)}{\partial \varphi_{if}} > 0, \quad \text{for all } k \in \Omega_{mif}^{K},$$

which together with (29) establishes the proposition. ■

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