Competition in Air Cargo*

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Abstract

In this paper I derive a heterogenous manufacturing model of international trade with endogenous air shipping costs. I introduce an air transport sector characterized by identical global air cargo carriers, competing à la Cournot, with fixed entry costs into air cargo shipping. My results suggest that the optimal pricing rule of an exported manufacturing product is given by a constant markup over a marginal cost structure determined by two components: 1) a manufacturer's specific marginal production cost; and 2) a route-specific cargo component that varies with the number of cargo carriers per route. The endogenous reaction of the route specific component of the marginal cost enables me to unveil comparative statics that, under the Melitz (2003) model of trade were equal to zero. Moreover, the endogenous reaction of the number of cargo carriers enables me to derive a model with welfare gains in trade that are larger in magnitude to those obtained with the standard Melitz (2003) model. Empirical results confirm the significant impact of competition in cargo shipping. Estimates suggest that a 10% increase in air cargo competition reduces cargo shipping prices by 1%.

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1 Introduction

Between 1980 and 2010, world economies became more integrated. World trade grew at an annual average rate of 8.45%, and trade measured as ratio to GDP increased by 76.5%.[1] However, the real costs of international trade deter countries from fully enjoying its benefits. Estimates in trade literature suggest that overall trade costs amount to an import tariff rate of 170%. As Anderson and van Wincoop (2004) suggest, 55% of this rate is associated with retail and wholesale distribution costs, 44% is associated with border-related trade barriers, and 21% is directly related to transport costs. Understanding the factors behind each trade cost component provides an opportunity to determine a country's ability to fully participate in the global economy.

In this paper, I depart from the usual assumption of exogenous iceberg transport costs and I develop a heterogenous model of trade with endogenous transport costs. I assume that the service of international cargo shipping is provided by identical global air cargo carriers competing in a oligopolistic market structure à la Cournot with fixed entry costs. As in Melitz (2003), a manufacturer's total cost structure is determined by a manufacturer-specific constant marginal production cost, an international shipping cost, and a fixed production cost. In this model, a manufacturer's productivity draw not only determines a manufacturer's marginal production costs, but it also determines the per unit shipping weight content of the exported cargo. This implies that, within a sector, highly productive manufacturers not only produce goods with lower marginal production costs, but they also export products with lower per unit shipping weight content.

Cournot competition enables me to obtain optimal shipping prices determined by a markup over constant handling cargo costs. The markup depends on the number of carriers per route, while handling cargo costs are determined by a carrier's productivity level, an airport's marginal handling cost, and the cost of jet fuel. Comparative statics on air shipping prices enable me to show that the net effect of a change of an exogenous parameter affects shipping prices directly, and indirectly through the adjustment of the number of carriers. By construction, the endogenous response of the number of cargo carriers not only impacts air shipping prices, but also affects a manufacturer's delivery price, total demand and export revenue. Thus, the endogenous adjustment in competition in air cargo enables me to derive a model with welfare adjustments higher than those achieved by Melitz (2003).

To test the importance of competition in air cargo shipping, I use the US Import of Merchandize data set joint with other sources to construct

[1] In comparison to the level achieved in 1980.

an unbalanced panel dataset containing $696,981$ observations, with information related to air shipping costs, cargo weight and a product's price for $13,401$ products defined at the 10 digit level of the harmonized system code for the period between 1990 and 2009. Additional data includes the number of carriers per cargo route and a country's airport cargo handling costs. Empirical results suggest that air shipping prices are higher when transportation is performed through airports characterized with higher marginal cargo fees. Similarly, shipping prices decrease as competition in air cargo shipping increases. In all specifications, results are significant at 1%, and the magnitude of the estimated coefficients do not seem to vary as I control for product characteristics affecting the marginal handling costs of cargo shipping, or as I control for the competition arising from other transport modes.

My findings contribute to and build upon a wealth of literature in this field. In particular, this paper is closely related to two strands of the trade literature. First, the paper is related to the literature of firm heterogeneity. Similar to Melitz (2003), I derived optimal manufacturing pricing rules that are firm specific. However, I decompose Melitz's (2003) manufacturing marginal export cost into two components: A manufacturer's specific marginal production cost, and a route specific shipping marginal cost that varies with the number of cargo carriers. Second, this paper is also related to the literature studying the determinants of international cargo shipping. Initial empirical findings by Limão and Venables (2001), Clark, Dollar, and Micco (2004) and Micco and Serebrisky (2006) provide evidence of the reducing effect of an improvement in a country's infrastructure on both ocean and air cargo shipping prices. But as explained in Hellermann (2006), the market structure in cargo shipping is an important factor that should not be disregarded when analyzing the determinants of prices in cargo industry. Moving in this direction, Hummels, Lugovskyy, and Skiba (2009) provide evidence of the importance of competition in determining ocean cargo transport prices. Inspired by their approach, I endogenize transport costs assuming that carriers compete in an oligopolistic market structure à la Cournot. However, my paper differs in two ways: First, I focus my attention on air cargo shipping. Second, I derive a general equilibrium model of trade with a transportation sector characterized by an oligopolistic market structure with the additional assumption that air carriers incur in fixed entry costs into air cargo shipping. This additional assumption enables me to identify the factors determining entry into air cargo shipping. Thus, the endogenous response of the number of cargo carriers proves to be the key element to understand why in the comparative statics of the model I find higher welfare effects than the ones obtained in the standard Melitz (2003) model of trade.

This paper is structured as follows: Section 2 derives the model; Section 3 formulates the empirical estimation strategy, describes the data and discusses the results; and finally, section 4 concludes.

2 The Model

2.1 Set-up

Consider an economy with two countries; home (denoted by sub-index 1) and foreign (denoted by sub-index 2). In both countries, labor is the only factor of production, and market size in each country is L_1 and L_2, respectively. Each country has three sectors: 1) A sector that produces a freely traded homogeneous good; 2) A sector producing a continuum of differentiated goods; and 3) An transportation sector composed by global air cargo carriers and airport entities.

In both countries, the homogeneous good is produced under a constant returns to scale production function $q_{oj} = \alpha_o \ell_{oj} \quad \forall \ j = 1, 2$. α_o is the labor productivity and ℓ_{oj} is the labor required to produce q_{oj} units. In both countries, wages are set by the productivity level of the homogenous good as $\frac{w_j}{p_o} = \alpha_o \quad \forall \ j = 1, 2$. I set this good as the numeraire ($p_o = 1$). Since the productivity level is the same across destinations, wages in both countries are the same $w_1 = w_2 = \alpha_o$. This implies that the homogenous good is locally produced in both markets, and that no trade should be expected as marginal productions costs are the same.

As in Melitz (2003), production of differentiated goods is performed by monopolistically competitive firms with heterogenous constant marginal costs of production and increasing returns to scale. When exporting, firms incur a transportation cost which is payed to a cargo carrier.

The transportation sector is composed by airport entities and N^c identical global air cargo carriers. Within each country, airports are identical agents with a cost structure characterized by constant marginal costs. Airports charge cargo carriers a handling fee for the cargo load transported when arriving and departing. For simplicity, I assume that the optimal price of cargo handling is set at the airport's marginal cost $\frac{w}{\varepsilon_j}$. ε_j is the infrastructure level which I assume to be country specific and I also take as given.

Global air cargo carriers are identical agents competing in an oligopolistic market structure à la Cournot. As in Mas-Collel, Whinston, and Green (1995), I introduce entry into an oligopolistic market structure by first allowing potential cargo carriers to simultaneously decide if they want to "enter" or "stay out" of the cargo route. Entrants pay a route specific set up cost of wF^a. In a second stage, once the setup costs are sunk, competing carriers compete à la Cournot.[2]

Every consumer is endowed with one unit of labor, $\theta_j \quad \forall \quad j=1,2$ ownership shares of local firms, and θ_w ownership shares of airports and air cargo carriers.[3] For every imported variety, consumers pay an ad-valorem import tariff $\tau_j \quad \forall \quad i=1,2$ that without loss of generality I assume to be equal across varieties.[4] Tax revenues are redistributed as a lump sum transfer within the country's population.

2.2 Demand

Consumers exhibit quasi-linear preferences defined over a homogeneous good q_{oj}, and a set Ω of differentiated products.[5] A representative consumer in market j has a utility function

$$U_j = q_{oj} + \int\limits_{\omega\in\Omega} \frac{\sigma}{\sigma-1} q_\omega^{\frac{\sigma-1}{\sigma}} \mathrm{d}\omega, \quad \sigma > 1, \quad \forall \quad j=1,2. \tag{1}$$

σ is the consumer price elasticity of demand of differentiated goods, assumed to be elastic. Imported varieties produced in foreign country i are sold to consumers in market j at a per unit price $p^c_{\omega j} = p_{\omega j}\tau_j$. $p_{\omega j}$ is the supplier price and τ_j is the generalized per unit ad-valorem import tariff. As expected, when the product is locally produced $\tau_j = 1$. Individual consumption of the homogeneous good and all varieties are:

$$q_{oj} = \frac{I_j}{p_o} - \left[\frac{\bar{P}_j}{p_o}\right]^{1-\sigma} \quad \text{and} \quad q_{\omega j} = \left[\frac{p_o}{p_{\omega i}\tau_j}\right]^{\sigma}; \tag{2a}$$

$$\text{where} \quad \bar{P}_j = \left[\int\limits_{\omega\in\Omega_j} p^{c\,1-\sigma}_\omega \mathrm{d}\omega\right]^{\frac{1}{1-\sigma}}. \tag{2b}$$

$\bar{P}_j$ and I_j are, respectively, the price index and the income level of the representative consumer in market j. As with the CES preference structure,

[2]For further details refer to Mas-Collel, Whinston, and Green (1995) section 12E.

[3]$\theta_j = \frac{1}{L_j} \quad \forall \quad j=1,2.$ $\theta_w = \frac{1}{L_1+L_2}$.

[4]Alternatively, I could also assume that the import tax could be payed by foreign manufacturing firms. In this case $p^c_{\omega j} = \frac{1}{1-\tilde{\tau}_j} p_{\omega i} \quad \forall \quad i,j=1,2.$ $\tilde{\tau}_j < 1$, and is the ad-valorem import tax. Regardless of who bears the import tax, $p^c_{\omega j}$ exhibits a functional form that is similar to the achieve when consumers pay for the import tax. Notice that $p^c_{\omega j}$ will be the same when $\tau_j = \frac{1}{1-\tilde{\tau}_j}$.

[5]$\Omega = \Omega_1 \cup \Omega_2$

quasi-linear preferences imply that the delivery price elasticity for any variety ω is constant and is equal to $-\sigma$. However, two considerations should be taken into account: First, under the traditional CES preference structure, demand functions for any differentiated varieties are determined by the variety's own delivery price, the price index and the income allocated to the consumption of all varieties.[6] With quasi-linear preferences the demand function of every differentiated variety is only determined by the price ratio between the numeraire and the variety's own delivery price (equation 2a). This implies that income and cross price elasticities of differentiated varieties are all equal to zero, and a change in a consumer's income level only has a direct effect on the consumption of the homogenous good. Second, quasi-linear preferences imply that the demand function of differentiated varieties do not depend on the price index. This does not represent an issue since endogenizing air shipping prices enables me to show that factors determining the price index also determine a variety's own delivery price. This result enables me to derive demand changes that before where only possible to be obtained when assuming CES preferences, as the effect on demand was driven by the adjustment of the price index. Now, I'm able to derive similar results with a simpler functional form.

2.3 Production

A continuum of manufacturing firms each produce a variety ω. Labor is the only factor required for production, and a manufacturer's technology is provided by a cost function characterized by a constant marginal cost and a destination specific fixed overhead cost $wF_j \quad \forall \quad j = 1, 2$. A firm's marginal production cost is determined by its productivity level φ, drawn from the known distribution $g(\varphi)$, defined over the positive support $(0, \infty)$, and characterized by the continuous cumulative distribution function $G(\varphi)$. Manufacturers with a higher productivity draw exhibit lower marginal production costs. Fixed overhead costs are market specific and foreign manufacturers incur higher overhead costs (e.g. $F_1 > F_2$) for manufacturing firms exporting to foreign market 1).

Depending on the productivity draw, a manufacturing firm can produce for its own domestic market, or it can also produce for the foreign market. When exporting, manufacturers incur shipping costs determined by the total

[6] Under CES preferences, a consumer's utility function is $U_j = q_{oj}^{\alpha} \left[\int_{\omega \in \Omega_1} q_{\omega}^{\frac{\sigma-1}{\sigma}} \right]^{(1-\alpha)\frac{\sigma}{\sigma-1}}$. α is the income share allocated to consumption of all varieties. In this case, optimal demand of any variety ω is $(1-\alpha) I_j \frac{p_{\omega}^{-\sigma}}{P_j^{1-\sigma}}$.

weight of the exported cargo. The cost structure of a manufacturer exporting to market 1 is

$$TC_2 = \frac{w}{\varphi} q_{\varphi 2} + wF_2 \quad \text{and} \tag{3a}$$

$$TC_1 = \frac{w}{\varphi} q_{\varphi 1} + f_1 h(\varphi) q_{\varphi 1} + wF_1. \tag{3b}$$

Equation 3a corresponds to the total cost incurred when a firm produces for its own domestic market, while equation 3b is the total cost when a firm chooses to export. Exporting is a more expensive activity. On the one hand, exporters incur higher fixed overhead costs. On the other hand, exporters incur product-specific shipping costs determined by the per kilogram shipping price f_1 and by the total weight content of the exported cargo $h(\varphi)q_{\varphi 1}$. Under this setup, a firm's productivity draw not only determines the marginal production cost $\frac{w}{\varphi}$, but it also determines a product's per unit shipping weight content $h(\varphi)$. Highly productive manufacturers not only produce products with lower marginal production costs, but they are also the cleverest at exporting products with better shipping attributes; namely lower shipping weight. Then $h(\varphi)$ is a continuous differentiable function that is inversely related to a manufacturer's productivity draw; i.e., $\frac{\partial h}{\partial \varphi} < 0$. To keep the model as tractable as possible, I assume that a product's per unit shipping weight $h(\varphi)$ is equal to $\frac{\nu}{\varphi}$. ν is a weight parameter that is common to all the products classified within the sector. Manufacturers with a productivity draw higher than ν will produce goods with lower per unit shipping costs $(f_1 h(\varphi))$.

A product's optimal pricing rule when producing for the domestic and the foreign market is determined by a mark-up over the marginal costs:

$$p_{\varphi 2} = \frac{\sigma}{\sigma - 1} \frac{w}{\varphi} \quad , \tag{4a}$$

$$p_{\varphi 1} = \frac{\sigma}{\sigma - 1} \left[\frac{w}{\varphi} + \frac{\nu f_1}{\varphi} \right]. \tag{4b}$$

These pricing choices imply that a manufacturer located in country 2, having drawn a productivity level φ, could make a profit in the domestic market π_2 and a profit abroad π_1:

$$\pi_2 = \left[\frac{\varphi(\sigma-1)}{w}\right]^{\sigma-1}\left[\frac{p_o}{\sigma}\right]^{\sigma}\mathrm{L}_2 - wF_2 \quad , \tag{5a}$$

$$\pi_1 = \left[\frac{\varphi(\sigma-1)}{w+\nu f_1}\right]^{\sigma-1}\left[\frac{p_o}{\sigma\tau_1}\right]^{\sigma}\mathrm{L}_1 - wF_1 \quad . \tag{5b}$$

As in Melitz (2003), only manufacturers that are able to profit domestically will survive, and those who can profitably produce to foreign market destinations will be active in equilibrium. The endogenous productivity thresholds for entry into the domestic and foreign market are:[7]

$$\underline{\varphi}_2 = \left[\frac{w}{\sigma-1}\right]\left[\frac{wF_2}{\mathrm{L}_2}\right]^{\frac{1}{\sigma-1}}\left[\frac{\sigma}{p_o}\right]^{\frac{\sigma}{\sigma-1}} \quad \text{and} \tag{6a}$$

$$\underline{\varphi}_1 = \left[\frac{w+\nu f_1}{\sigma-1}\right]\left[\frac{wF_1}{\mathrm{L}_1}\right]^{\frac{1}{\sigma-1}}\left[\frac{\sigma\tau_1}{p_o}\right]^{\frac{\sigma}{\sigma-1}} . \tag{6b}$$

This implies that the total demand for air cargo transportation when shipping products to countries 1 and 2 are [8]

$$W_1 = \nu\mathrm{L}_1\left[\frac{p_o(\sigma-1)}{\sigma\tau_1(w+\nu f_1)}\right]^{\sigma}\int_{\underline{\varphi}_1}^{\infty}\varphi^{\sigma-1}\mathrm{d}G(\varphi) \quad \text{and} \tag{7a}$$

$$W_2 = \nu\mathrm{L}_2\left[\frac{p_o(\sigma-1)}{\sigma\tau_2(w+\nu f_2)}\right]^{\sigma}\int_{\tilde{\underline{\varphi}}_2}^{\infty}\varphi^{\sigma-1}\mathrm{d}G(\varphi) . \tag{7b}$$

I find that the price elasticity of cargo is equal to the sum of two effects working in the same direction: an intensive effect, reinforced by the extensive effect of cargo pricing.[9] As derived in equation (8) the intensive effect is equal to the price elasticity of demand weighted by the relative importance

[7] If both countries have the same market size, $\underline{\varphi}_1$ will be always be greater than $\underline{\varphi}_2$ since $F_1 > F_2$. But, under asymmetrical market sizes we need to assume that $\frac{\mathrm{L}_2}{\mathrm{L}_1} > \left[\frac{F_2}{F_1}\right]^{\sigma-1}\left[\frac{w}{w+\nu f_1}\right]^{\sigma-1}\left[\frac{1}{\tau_1}\right]^{\sigma}$ so that $\frac{\underline{\varphi}_1}{\underline{\varphi}_2} > 1$.

[8] Where $\tilde{\underline{\varphi}}_2$ is the export threshold for manufacturers exporting to country 2. Similar to equation 6b, $\tilde{\underline{\varphi}}_2 = \left[\frac{w+\nu f_2}{\sigma-1}\right]\left[\frac{w\tilde{F}_2}{\mathrm{L}_2}\right]^{\frac{1}{\sigma-1}}\left[\frac{\sigma\tau_2}{p_o}\right]^{\frac{\sigma}{\sigma-1}}$. $\tilde{F}_2$ is the fixed overhead cost incur by manufactures exporting to country 2.

[9] Appendix A provides a complete derivation of this expression.

of shipping costs in an exporter marginal cost. This is the result obtained by Hummels, Lugovskyy, and Skiba (2009). But in a model where firm heterogeneity determines the per unit shipping weight content of a good, the price elasticity of cargo has a second component derived from the effect of shipping prices on the extensive margin of trade because the export threshold condition (equation 6b) shifts with changes in shipping prices. Disregarding the product heterogeneity in the per unit weight content of goods implies that the model will underestimate the price elasticity of cargo, as the price elasticity of cargo will be equal to the intensive effect.

$$\xi_{f_1} = \underbrace{-\sigma \frac{\nu f_1}{w + \nu f_1}}_{\text{intensive}} \underbrace{- \frac{\underline{\varphi}_1^{\ \sigma}}{\int_{\underline{\varphi}_1}^{\infty} \varphi^{\sigma-1} \mathrm{d}G\left(\varphi\right)} \times g(\underline{\varphi}_1) \frac{\nu f_1}{w + \nu f_1}}_{\text{extensive}} \tag{8}$$

As in Melitz (2003), manufacturers draw their productivity level from a distribution function that is Pareto distributed with a cumulative distribution $G(\varphi)$ equal to $1 - \frac{1}{\kappa}\varphi^{-\kappa}$: $\varphi \in [\underline{b}, \infty)$, and shape parameter $\kappa > 2$. Three technicalities should be taken into account: First, $\underline{b} = \kappa^{-\kappa}$. Second, setting κ greater than 2 guarantees a well defined second moment of φ. Third, given the consumer preferences and the distribution function on φ, the price elasticity of demand should be defined as a value on the interval $(1, \kappa + 1)$, thus $\kappa + 1 > \sigma$. Under these assumptions, I find that the price elasticity of cargo shipping is

$$\xi_{f_1} = -\left(\kappa + 1\right) \frac{\nu f_1}{w + \nu f_1}. \tag{9}$$

The price elasticity of cargo demand depends on the shape parameter of the distribution function determining productivity, weighted by the relative importance of the per unit freight cost in an exporter's marginal total cost. As in Hummels, Lugovskyy, and Skiba (2009), this result relies on the concept that transportation is a service that arises from the demand of imported products. However, my result implies a higher response of cargo demand as $\kappa + 1 > \sigma$. I obtain this result based on two assumptions: First, a carrier sets shipping prices by the unit of weight of a product; i.e., dollars per kilogram, instead of setting cargo prices per unit of exported goods. Second, the weight component of a good is determined by a manufacturer's productivity draw. These two assumptions enable me to obtain that the price elasticity of cargo shipping depends on the dispersion of the productivity distribution function instead of the price elasticity of demand. When $\frac{\nu f_1}{w + \nu f_1}$ is small, cargo carriers may raise prices at the margin as the increase in shipping prices has a low effect on cargo demand. I use this elasticity to solve for the optimal pricing rule of air cargo carriers.

2.4 Air Cargo Carriers

Cournot competition in air cargo shipping implies that a carrier must decide on the optimal cargo weight W_j^n transported to markets 1 and 2, given the total weight choice of other competing carriers, and the cargo demand function derived in equations (7a) and (7b).

A carrier's total cost structure is determined by the workforce required to transport cargo, an airport specific cargo handling fee, the jet fuel[10] used to lift the cargo load throughout d_j miles of cargo haul, and the fixed overhead cost wF^a. A carrier's optimization problem is

$$\max_{W_1^n, W_2^n} \Pi^n = \max_{W_1^n, W_2^n} \sum_{j=1}^{2} \left[f_j - w \left(\frac{1}{\theta} + \frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} + \frac{d_j \alpha_g}{\theta_g} \right) \right] W_j^n - wF^a, \quad (10a)$$

$$\text{where:} \quad W_j^n = \frac{W_j}{\mathrm{N}^c} \quad \forall \quad j = 1, 2, \quad (10b)$$

$$W_1 = \nu \mathrm{L}_1 \left[\frac{p_o (\sigma - 1)}{\sigma \tau_1 (w + \nu f_1)} \right]^{\sigma} \int_{\underline{\varphi}_1}^{\infty} \varphi^{\sigma-1} \mathrm{d}G(\varphi) \quad \text{and} \quad (10c)$$

$$W_2 = \nu \mathrm{L}_2 \left[\frac{p_o (\sigma - 1)}{\sigma \tau_2 (w + \nu f_2)} \right]^{\sigma} \int_{\underline{\tilde{\varphi}}_2}^{\infty} \varphi^{\sigma-1} \mathrm{d}G(\varphi). \quad (10d)$$

$\frac{1}{\theta}$ is the labor content of a unit of transported cargo. $\frac{1}{\varepsilon_j}$ is the labor content of a unit of cargo weight handled by an airport in country j. The additive structure of the handling components implies that a carrier pays a handling fee of $\frac{w}{\varepsilon_j}$ for every unit of weight of cargo handled by airport entities at both the departing and arriving locations. $d_j \alpha_g W_j^n$ is the jet fuel required to lift W_j^n pounds of cargo through the effective air-born distance d_j,[11] where α_g is

[10] I assume that jet fuel is produced by competitive firms requiring $\frac{1}{\theta_g}$ workers to produce a gallon of jet fuel. Therefore, the optimal jet fuel price is $\frac{w}{\theta_g}$.

[11] Following Mattingly, Heiser, and Pratt (2005), I assume that air-born distance traveled by a carrier when incoming and outgoing from a destination is asymmetric. The argument relies on the evidence that air-born distance of a flight changes as the flight trajectory varies on: altitude, head wind or tail wind, the weather conditions and the air-traffic encountered during the flight, and within the lifting and landing phases of a flight. Provided that none of these factors are constant for both departing and returning flight legs, I assume that

the gallon per weight-distance lift factor of jet fuel. Altogether, I assumed that a carrier's marginal cost is constant, and is determined by the following three components: the price of labor, the fees payed to airport entities at both the departing and arriving locations, and the jet fuel costs. First order conditions imply that a carrier's marginal revenue is equal to it's marginal costs wB_j

$$f_j \left[1 + \frac{1}{\mathrm{N}^c \xi_{f_j}}\right] = w \underbrace{\left[\frac{1}{\theta} + \frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} + \frac{d_j \alpha_g}{\theta_g}\right]}_{B_j} \qquad \forall \quad j = 1,2 \quad , \quad \forall \quad \mathrm{N}^c. \tag{11}$$

The former determined by the price elasticity of cargo shipping, and the latter determined by the per unit of weight cost of handling cargo by the carrier, the per unit weight cost of handling cargo by airports and the per unit weight cost of fuel. Substituting equation (9) into equation (11) I find that the shipping price per unit of weight is a function of the labor productivity of cargo carriers (θ), the labor productivity of cargo handling at both the departing and arrival airports (ξ_2, ξ_1), the effective air-born distance traveled (d_j), the number of competing carriers per cargo route (N^c), and the shape parameter of the productivity distribution function (κ)

$$f_j = \frac{(\kappa + 1)\, wB_j + \frac{w}{\nu \mathrm{N}^c}}{\kappa + 1 - \frac{1}{\mathrm{N}^c}} \qquad \forall \quad j = 1,2 \quad , \quad \forall \quad \mathrm{N}^c. \tag{12}$$

Per unit of weight, shipping prices for all imported (exported) products are the same (equation 12). The difference in shipping prices between imported and exported products is determined by the difference in fuel expenditure $\alpha_g \frac{w}{\theta_g} [d_1 - d_2]$ amplified by term B_3 (equation (13)) which under Cournot competition is greater than 1

$$f_1 - f_2 = \alpha_g \frac{w}{\theta_g} [d_1 - d_2] \underbrace{\left[\frac{\kappa + 1}{\kappa + 1 - \frac{1}{\mathrm{N}^c}}\right]}_{B_3}. \tag{13}$$

Since the jet fuel price is the same across markets, the difference in air shipping prices is mainly due to the assumption that air-born distance is asymmetric. If $d_1 = d_2$, air shipping prices for imported and exporter cargo will

air-born distance is asymmetric.

be the same.

Competition in air cargo shipping plays a key role in determining air shipping prices. As implied by equation (12), carriers set shipping prices that exhibit a markup that varies with the number of competing carriers. A shock to any of the fundamentals determining competition in air cargo shipping affects the markup of shipping prices through its impact on N^c. By construction, the endogenous response of the number of competitors is expected not only to impact air shipping prices, but also manufacturing firms, as entry into exporting and optimal delivery prices depend on the number of competing carriers.

My result nests the competitive outcome; i.e., when $\text{N}^c \to \infty$ shipping prices decrease, converging to the marginal costs of air cargo shipping as $f_j = wB_j \quad \forall \quad j = 1, 2$. Furthermore, as $\text{N}^c \to \infty$ the price difference in air shipping derived in equation (13) will decrease, and in the limit the price difference in air cargo shipping is only determined by the difference in fuel expenditure (as B_3 is equal to one); i.e., given by the difference in the distance traveled

$$f_1 - f_2 = \alpha_g \frac{w}{\theta_g} \left[d_1 - d_2 \right]. \tag{14}$$

2.4.1 Number of Cargo Carriers

Cournot competition with fixed entry costs into air cargo shipping implies that the optimal number of cargo carriers per cargo route is an endogenous variable that I can pin down using a carrier's zero profit condition (setting equation (10a) equal to zero). Unfortunately, the nonlinear functional form implied by this problem does not allow me to find a closed form solution for N^c. Instead, I use a carrier's zero profit condition to define function NC, which I then use to determine the fundamentals affecting entry into air cargo shipping. NC is a continuously differentiable convex function in N^c with the following functional form:[12]

$$\text{NC} = \text{N}^{c\,\frac{\kappa+2}{\kappa}} \underbrace{\left[\frac{w^{\frac{\kappa+1-\sigma}{\kappa(\sigma-1)}}}{\kappa+1} \right] \left[\frac{F^a}{(\text{H}_1 + \text{H}_2)\,\text{H}_{\sigma\kappa}} \right]^{\frac{1}{\kappa}}}_{\text{H}_3} - \text{N}^c + \frac{1}{\kappa+1}. \tag{15}$$

[12] Appendix B provides a complete characterization of function NC.

H_3 is a positive constant determined by constants H_1, H_2 and $H_{\sigma\kappa}$.[13] Under the additional assumption that $NC(1) < 0$,[14] I find that solution for the optimal number of cargo carriers N^{c*} is unique. Figure 2(a) provides the graphical representation of this scenario as I set σ, κ and H_3 to take the values 1.52, 4 and .4358. Graphically, a solution for the optimal number of air carriers is provided when NC is equal to zero. In this particular case, the optimal number of cargo carriers is 4.84.[15]

As implied by H_1, H_2 and $H_{\sigma\kappa}$, the optimal number of cargo carriers N^c (equation (16)) is determined by the following four factors: *i)* Wages (w) and Jet fuel costs ($\frac{w}{\theta_g}$); *ii)*Product Specific Determinants: Price elasticity of demand (σ), average per unit weight content (ν) and product import tariffs (τ_j); *iii)* Route specific determinants: Market Size (L_j), Effective air-born distance (d_j), Infrastructure of Airports (ξ_j), Fixed overhead cost of exporting (F_j) and the fixed entry costs into air cargo (F^a) and; *iv)* The dispersion of the productivity distribution function (κ). Henceforth, I refer to these variables as the fundamentals.[16]

$$N^c = \mathfrak{F}\left(w, \sigma, \nu, \vec{\tau}, \vec{L}, \vec{d}, \theta, \theta_g, \vec{\xi}, \vec{F}, F^a, \kappa\right) \tag{16}$$

Column one in table 1 summarizes the sign of the effect of a shock to a fundamental on the number of competing carriers. Applying the implicit function theorem to function NC I obtain that $\frac{\partial N^c}{\partial x} = -\frac{\partial NC}{\partial x} / \frac{\partial NC}{\partial N^c}$. Since $NC(1) < 0$, $\frac{\partial NC}{\partial N^c}$ is always positive since we are always on the increasing part of function NC. Then, the overall effect on competition in due to the sign obtained for $\frac{\partial NC}{\partial x}$.

An increase in wages, fuel charges, import tariffs, effective air-born distance, fixed overhead costs of exporting or entry costs into cargo shipping decrease competition.[17] Graphically, this is consistent with an increase in the magnitude of H_3, which is associated with an increase in the convexity of NC. Figure 2(b) provides the graphical representation of the backward displace-

[13] $H_{\sigma\kappa} = \frac{(\sigma-1)^{\kappa+1}}{(\kappa+1-\sigma)(1+\kappa)^{\kappa+1}\sigma^{\frac{\sigma\kappa}{\sigma-1}}}$ and $H_j = \frac{1+\nu B_j}{(w+\nu B_j)^{\kappa+1}}\left[\frac{L_j^{\kappa} p_o^{\kappa\sigma}}{\tau_j^{\sigma\kappa} F_j^{\kappa+1-\sigma}}\right]^{\frac{1}{\sigma-1}} \quad \forall \quad j = 1, 2.$

[14] This condition enables me to rule out the cases where there is no equilibrium, or when the equilibria is characterized by two solutions.

[15] At 0.257 (the first case), a carrier's optimal profit function will be negative, implying that the first case is not a feasible equilibrium.

[16] Vector representation implies that the variable is associated to both exporting and importing countries.

[17] In these cases $\frac{\partial NC}{\partial x} > 0$.

ment of the NC function. In all cases, NC shifts from the initial position (blue line), to the new situation (red line), producing a decrease in the optimal number of cargo carriers.[18] Similarly, an increase in market size, airport infrastructure or an increase in a carrier's productivity level decreases the convexity of NC.[19] Graphically, the function shifts forward, producing an increase in the optimal number of cargo competitors. As shown, NC shifts from the initial position (blue line), to the new situation (black line).[20]

2.5 Equilibrium

Since the optimal number of carriers is given by equation (16), a manufacturer's optimal pricing rule, optimal total demand and optimal total revenue are

$$p_{\varphi j} = \left[\frac{\sigma}{\sigma - 1}\right] \underbrace{\left[\frac{(\kappa + 1)\left(1 + \nu \mathrm{B}_j\right)}{\kappa + 1 - \frac{1}{\mathrm{N}^c}}\right]}_{\mathrm{CA}_j} \left[\frac{w\tau_j}{\varphi}\right] \quad , \tag{17a}$$

$$q_{\varphi j} = \left[\frac{\sigma - 1}{\sigma}\right]^{\sigma} \left[\frac{\varphi}{w\tau_j}\right]^{\sigma} \mathrm{L}_j \left[\frac{1}{\mathrm{CA}_j}\right]^{\sigma} \quad \text{and} \tag{17b}$$

$$r_{\varphi j} = \left[\frac{\sigma - 1}{\sigma}\right]^{\sigma-1} \left[\frac{\varphi}{w}\right]^{\sigma-1} \mathrm{L}_j \left[\frac{1}{\mathrm{CA}_j}\right]^{\sigma-1} \left[\frac{1}{\tau_j}\right]^{\sigma} \qquad \forall \;\; j = 1, 2. \tag{17c}$$

The number of exporting manufacturing firms (M_j) and the total value of exports (IMP_j) realized by manufacturers exporting to countries 1 and 2 are

[18] I increase H_3 from 0.4358 (blue line) up to 0.4951 (red line).
[19] In these cases, $\frac{\partial \mathrm{NC}}{\partial x} < 0$.
[20] In this case, I decrease H_3 from 0.4358 (blue line) up to 0.3938 (black line).

$$\mathrm{M}_1 = \psi^2\left[1 - G(\underline{\varphi}_1)\right] = \frac{\psi^2}{\kappa}\underline{\varphi}_1^{-\kappa} \quad , \quad \mathrm{M}_2 = \psi^1\left[1 - G(\underline{\tilde{\varphi}}_2)\right] = \frac{\psi^1}{\kappa}\underline{\tilde{\varphi}}_2^{-\kappa},$$

(18a)

$$\mathrm{IMP}_1 = \underbrace{\left[\frac{\sigma - 1}{\sigma w}\right]^{\sigma-1}\left[\frac{\mathrm{L}_1}{\tau_1^{\sigma}}\right]\left[\frac{1}{\mathrm{CA}_1}\right]^{\sigma-1}}_{\mathrm{IM}_1}\underbrace{\left[\frac{1}{\kappa+1-\sigma}\right]\left[\frac{1}{\underline{\varphi}_1}\right]^{\kappa+1-\sigma}}_{\mathrm{EM}_1} \quad \text{and}$$

(18b)

$$\mathrm{IMP}_2 = \underbrace{\left[\frac{\sigma - 1}{\sigma w}\right]^{\sigma-1}\left[\frac{\mathrm{L}_2}{\tau_2^{\sigma}}\right]\left[\frac{1}{\mathrm{CA}_2}\right]^{\sigma-1}}_{\mathrm{IM}_2}\underbrace{\left[\frac{1}{\kappa+1-\sigma}\right]\left[\frac{1}{\underline{\tilde{\varphi}}_2}\right]^{\kappa+1-\sigma}}_{\mathrm{EM}_2}. \qquad (18c)$$

ψ^j is the mass of domestic firms in country $j \quad \forall \quad j = 1, 2$. IM_j and $\mathrm{EM}_j \quad \forall \quad j = 1, 2$ are the intensive and extensive margins of trade. $\underline{\varphi}_1$ and $\underline{\tilde{\varphi}}_2$ are the optimal export thresholds when exporting to markets one and two.[21]

$$\underline{\varphi}_1 = \left[\frac{\sigma^{\frac{\sigma}{\sigma-1}}}{\sigma - 1}\right]\left[\frac{F_1\left(w\tau_1\right)^{\sigma}}{\mathrm{L}_1}\right]^{\frac{1}{\sigma-1}}\mathrm{CA}_1 \quad \text{and} \qquad (19a)$$

$$\underline{\tilde{\varphi}}_2 = \left[\frac{\sigma^{\frac{\sigma}{\sigma-1}}}{\sigma - 1}\right]\left[\frac{F_2\left(w\tau_2\right)^{\sigma}}{\mathrm{L}_2}\right]^{\frac{1}{\sigma-1}}\mathrm{CA}_2. \qquad (19b)$$

Four considerations should be taken into account: First, equations (17a) through (19b) nest the results on pricing, total demand, entry into exporting and total volume of exports as originally derived by the Melitz (2003) model of trade. The difference between the two models is only due to the competitive adjustment factor CA_j. Setting $\mathrm{B}_j = 0$ and assuming that the market structure in air cargo shipping is competitive ($\mathrm{N}^c \to \infty$), CA_j will be equal to unity and equations (17a) through (19b) will simplify back to the standard Melitz (2003) results.

Second, highly productive manufacturers set lower optimal import prices. The latter is not only provided because highly productive manufacturers exhibit lower marginal production costs, but also because highly productive manufacturers are able to produce goods with lower per unit weight content

[21] $\underline{\tilde{\varphi}}_2$ was previously derived in footnote 8.

implying lower per unit transportation charges.[22]

Third, I derived an alternative setup in which a manufacturer's optimal product price exhibits a marginal costs that varies with entry into air cargo shipping. The endogenous change in marginal costs arise when I endogenize air shipping costs by introducing a sector characterized by carriers competing in an oligopolistic market structure à la Cournot with fixed entry costs.

As derived in equation (17a), a manufacturer's marginal cost is determined by the product of two terms: the firm specific marginal production cost derived in Melitz (2003) $\frac{w}{\varphi}$, and term $\tau_j \mathrm{CA}_j$. The latter being the parameter through which endogeneity arises, as CA_j also depends on the optimal number of cargo carriers. Thus, a manufacturer's marginal cost is endogenous to the fundamentals determining entry into air cargo shipping and entry into exporting. Interestingly, the marginal cost not only varies with the fixed entry costs in the exporting destination, but it also varies with fixed entry costs into air cargo shipping and with factors associated to the market where the exporting manufacturer is located (e.g. local market size (see equation (16))). I reconcile this result with the more general claim that a manufacturer's optimal price exhibits an endogenous marginal cost that varies with the fundamentals, determining entry to both export markets, and entry into air cargo shipping.

Fourth, this model provides optimal per unit product prices and optimal export entry conditions higher by a magnitude CA_j than the value obtained in the standard Melitz (2003) model. Thus, a country's total volume of exports is lower because both the intensive and extensive margins of trade are lower than the levels achieved in the standard set up. The intensive margin is lower because manufacturers are setting optimal pricing rules at higher levels, causing demand and revenue to fall. The extensive margin is lower because the entry condition into exporting is set at a higher level, making entry into exporting a more difficult situation as manufacturers now require a higher productivity draw to be able to enter into foreign markets.

2.6 Comparative Statics

In this sub-section I provide a detailed derivation of the effect of a shock to a fundamental on prices, total demand, a manufacturer's revenue, the export threshold condition, and the total volume of trade.[23] First, I derive the effect

[22] A product's per unit shipping cost is given by the product of the optimal shipping price (equation 12) and a product's weight content $\frac{\nu}{\varphi}$.

[23] Appendix C provides a complete derivation of these results.

of a shock to a fundamental on the air shipping price per unit of weight and on a manufacturer's product price. This not only enables me to relate my findings to the results implied by the standard Melitz (2003) model, but it also enables me to show the additional effects that arise when I let transport prices be set by carriers competing à la Cournot with fixed entry costs into air cargo. Second, I use the change in prices to derive the comparative statics on demand, a firm's optimal revenue, and on a country's volume of exports. Tables 1 and 2 provide the complete summary of the comparative statics derived on prices, demand, revenue and total volume of trade. − and + corresponds to the sign of the effect, while 0 means no effect.

Without loss of generality, the optimal shipping price (equation (12)) and a manufacturer's product price (equation 4b) can be re-expressed as

$$f_j(\vec{x}, \mathrm{N}^c(\vec{x})) \quad \text{and} \quad p_{\varphi j}(\vec{x}, f_j(\vec{x}, \mathrm{N}^c(\vec{x}))). \tag{20}$$

$\vec{x}$ is the vector representation of the exogenous factors of the model;i.e. the fundamentals. Let x be an exogenous factor in $\vec{x}$. A shock to an exogenous variable x may have a direct impact on prices, but it also has an indirect effect canalized through the endogenous reaction of the number of cargo carriers. The latter reaction is what I refer to as the competitive channel. In this model, the net effect of a shock to any fundamental on prices, demand, a manufacturer's revenue and a country's volume of exports is equal to the effect of the shock transmitted through the direct and the competitive channels. As reported in table 1, the net effect might be equal to −, +, −− or ++. − and + implies that the net effect is derived by the transmission of the shock through the competitive channel. −− and ++ imply that the net effect of the shock on air shipping prices is the result of adding the effect canalized through the the direct and the competitive channels; both working in the same direction. Then, the effect of a shock to x on air shipping prices is

$$\frac{\mathrm{d}f_j}{\mathrm{d}x} = \left[\frac{f_j}{x}\right]\left[\tilde{\delta}_{f_j,x} + \delta_{f_j,\mathrm{N}^c}\delta_{\mathrm{N}^c,x}\right]. \tag{21}$$

$\tilde{\delta}_{f_j,x} = \frac{\partial f_j}{\partial x}\frac{x}{f_j}$ is the direct effect of the change in x on air shipping prices, while the competitive effect of a change in x is determined by the product of the following two components: the effect of a change in the number of cargo carriers on shipping prices $\delta_{f_j,\mathrm{N}^c} = \frac{\partial f_j}{\partial \mathrm{N}^c}\frac{\mathrm{N}^c}{f_j}$, and the effect of a change in x on the optimal number of cargo carriers $\delta_{\mathrm{N}^c,x} = \frac{\partial \mathrm{N}^c}{\partial x}\frac{x}{\mathrm{N}^c}$. As implied by equation (12) $\delta_{f_j,\mathrm{N}^c} = -\left[\frac{1}{\mathrm{N}^c} + \frac{w}{\nu f_j \mathrm{N}^c}\right]$, while $\delta_{\mathrm{N}^c,x}$ is derived by using the implicit function theorem on equation (15). The negative sign on $\delta_{f_j,\mathrm{N}^c}$ guarantees that a shock deterring competition will always imply a net positive effect on air shipping prices. Furthermore, this is the reason why when $\tilde{\delta}_{f_j,x} \neq 0$, both the direct and the competitive channels reinforce each other.

Results in table 1 show that $\frac{\mathrm{d}f_j}{\mathrm{d}x}$ is never equal to zero. Even when $\tilde{\delta}_{f_j,x} = 0$, the shock has an still effect on air shipping prices through the adjustment in the number of competitor cargo carriers. I find that a shock to the fixed entry costs into exporting, the fixed entry cost into air cargo shipping, import tariffs in the origin market or a shock to market size impacts air shipping prices only through the competitive channel. In all the others cases, the shock affects air shipping prices through both the direct and competitive channels.

Understanding the adjustment of air shipping prices enables me to infer that the effect of the shock on a manufacturer's product price is

$$\frac{\mathrm{d}p_{\varphi j}}{\mathrm{d}x} = \left[\frac{p_{\varphi j}}{x}\right] \left[\tilde{\delta}_{p_{\varphi j},x} + \mathrm{S}_{f_j} \left(\frac{\mathrm{d}f_j}{\mathrm{d}x}\frac{x}{f_j}\right)\right]. \quad \text{Implying} \tag{22}$$

$$\frac{\mathrm{d}p_{\varphi j}}{\mathrm{d}x} = \left[\frac{\sigma}{\sigma-1}\right] \left[\frac{w+\nu f_j}{\varphi x}\right] \left[\underbrace{\tilde{\delta}_{p_{\varphi j},x}}_{1} + \underbrace{\mathrm{S}_{f_j}\tilde{\delta}_{f_j,x}}_{2} + \underbrace{\mathrm{S}_{f_j}\delta_{f_j,\mathrm{N}^c}\delta_{\mathrm{N}^c,x}}_{3}\right]. \tag{23}$$

$\tilde{\delta}_{p_{\varphi j},x} = \frac{\partial p_{\varphi j}}{\partial x}\frac{x}{p_{\varphi j}}$ is the direct effect of the change in x on a manufacturer's marginal cost. S_{f_j} is the relative importance of the per unit freight cost in a manufacturer's optimal price; i.e. $\frac{vf_j}{w+vf_j}$. In equation (23) terms 2 and 3 correspond to the endogenous response of air shipping prices weighted by the relative importance of freight charges on a manufacturer's marginal cost. In comparison to the standard Melitz model, the comparative statics that I derive are higher in magnitude because of two reasons: First, as implied by equation 4a, a shock to a fundamental has three effects; a direct effect on a manufacturer's optimal price, a direct effect on the optimal per unit of weight cargo price f_j and an a third effect arising from the endogenous reaction of competition in air cargo (term 3). It is the competition adjustment in air cargo shipping that explains why manufacturing companies adjust their optimal pricing rule even when the shock is only related to the entry conditions in the air cargo industry; e.g., a shock to the fixed entry cost into cargo (F^a). In this case, terms 1 and 2 would be zero, and all of the price adjustment is given by the endogenous response to the number of cargo carriers (term 3). Second, in the cases where the shock implies that terms 1, 2 and 3 are all different from zero (e.g. a shock to wages), a manufacturer's price adjustment is greater than the adjustment suggested by the models assuming iceberg transport costs. As derived, terms 1 and 2 always have the same sign, while the interaction between $\delta_{f_j,\mathrm{N}^c}$ and $\delta_{\mathrm{N}^c,x}$ guarantees that term 3 always has the same sign too.

Similarly, comparative statics on total demand and on a manufacturer's revenue are:

$$\frac{\mathrm{d}q_{\varphi j}}{\mathrm{d}x} = \left[\frac{q_{\varphi j}}{x}\right]\left[\tilde{\delta}_{q_{\varphi j},x} - \sigma\left[\tilde{\delta}_{p_{\varphi j},x} + \mathrm{S}_{f_j}\left(\frac{\mathrm{d}f_j}{\mathrm{d}x}\frac{x}{f_j}\right)\right]\right] \quad \text{and} \tag{24}$$

$$\frac{\mathrm{d}r_{\varphi j}}{\mathrm{d}x} = \left[\frac{r_{\varphi j}}{x}\right]\left[\tilde{\delta}_{q_{\varphi j},x} - (\sigma-1)\left[\tilde{\delta}_{p_{\varphi j},x} + \mathrm{S}_{f_j}\left(\frac{\mathrm{d}f_j}{\mathrm{d}x}\frac{x}{f_j}\right)\right]\right]. \quad \text{Substituting,} \tag{25}$$

equation (21) into equations (24) and (25) I obtain that the comparative statics for demand and revenue are also higher in magnitude than the effect obtained when shipping costs are exogenous (terms 2 and 3 are equal to zero):

$$\frac{\mathrm{d}q_{\varphi j}}{\mathrm{d}x} = \left[\frac{\tau_j^{\sigma}}{x}\right]\left[\frac{(\sigma-1)\,\varphi}{\sigma\left(w+\nu f_j\right)}\right]^{\sigma}\left[\underbrace{\tilde{\delta}_{q_{\varphi j},x}}_{4} - \sigma\left(\underbrace{\tilde{\delta}_{p_{\varphi j},x}}_{1} - \underbrace{\mathrm{S}_{f_j}\tilde{\delta}_{f_j,x}}_{2} - \underbrace{\mathrm{S}_{f_j}\delta_{f_j,\mathrm{N}^c}\delta_{\mathrm{N}^c,x}}_{3}\right)\right] \tag{26}$$

$$\frac{\mathrm{d}r_{\varphi j}}{\mathrm{d}x} = \left[\frac{\tau_j^{-\sigma}}{x}\right]\left[\frac{(\sigma-1)\,\varphi}{\sigma\left(w+\nu f_j\right)}\right]^{\sigma-1} \times \left[\underbrace{\tilde{\delta}_{q_{\varphi j},x}}_{4} - (\sigma-1)\left(\underbrace{\tilde{\delta}_{p_{\varphi j},x}}_{1} + \underbrace{\mathrm{S}_{f_j}\tilde{\delta}_{f_j,x}}_{2} + \underbrace{\mathrm{S}_{f_j}\delta_{f_j,\mathrm{N}^c}\delta_{\mathrm{N}^c,x}}_{3}\right)\right]. \tag{27}$$

Interestingly, a shock affects manufacturers differently as most productive exporters are the ones who experience the higher adjustment in demand, implying a higher response in revenue too.

Table 2 summarizes the results derived on the export entry threshold, the extensive and intensive margins of trade. Without loss of generality I only derive the comparative statics for foreign country 2 (IMP_1). The endogenous response implied by the competitive effect in air cargo captured by the interaction of terms $\delta_{\underline{\varphi}_1, N^c}$ and $\delta_{N^c,x}$ implies that the export entry condition has a higher response to shocks as

$$\frac{d\underline{\varphi}_1}{dx} = \frac{\underline{\varphi}_1}{x}\left[\tilde{\delta}_{\underline{\varphi}_1,x} + \delta_{\underline{\varphi}_1,N^c}\delta_{N^c,x}\right]. \tag{28}$$

Since $\delta_{\underline{\varphi}_1,N^c} = -\frac{1}{(\kappa+1)N^c-1}$, the threshold change depends on the effect of the shock on the number of cargo carriers.

$$\frac{d\underline{\varphi}_1}{dx} = \frac{\underline{\varphi}_1}{x}\left[\tilde{\delta}_{\underline{\varphi}_1,x} - \frac{\delta_{N^c,x}}{(\kappa+1)\,N^c - 1}\right]. \tag{29}$$

I find that factors deterring competition in air cargo are also linked, causing a decrease in the number of exporting manufacturers because a decrease of competition in air cargo causes the export entry threshold to increase.

I use equation 18a to derive the net effect on the total volume of exports of country 2. The first two terms in the bracket derived in equation 30 correspond to the effect of a shock on the intensive margin, while the third term corresponds to the net effect of the shock on the extensive margin.

$$\frac{dIMP_1}{dx} = \frac{IM_1EM_1}{x}\left[\tilde{\delta}_{IM_1,x} + \delta_{IM_1,N^c}\delta_{N^c,x} + \delta_{EM_1,\underline{\varphi}_1}\left(\frac{d\underline{\varphi}_1}{dx}\frac{x}{\underline{\varphi}_1}\right)\right] \tag{30}$$

Since $\delta_{IM_1,N^c} = \frac{\sigma-1}{N^c(\kappa+1)-1}$ and $\delta_{EM_1,\underline{\varphi}_1} = -(\kappa+1-\sigma)$ I substitute these two expressions and equation (29) into equation (30) and I obtain that the effect on the total volume of exports depends on the direct effect over the intensive margin, the export entry condition, and the direct effect of shock on the optimal number of cargo carriers

$$\frac{dIMP_1}{dx} = \frac{IM_1EM_1}{x}\left[\tilde{\delta}_{IM_1,x} - (\kappa+1-\sigma)\,\tilde{\delta}_{\underline{\varphi}_1,x} + \left[\frac{\kappa}{N^c\,(\kappa+1)-1}\right]\delta_{N^c,x}\right]. \tag{31}$$

I find that an increase in the export threshold is accompanied by a decrease in the intensive and the extensive margins of trade. In all cases the channels reinforce each other, and the net effect on the total value of exports is the expected one.

Endogenizing air shipping costs assuming that cargo carriers compete à la Cournot with fixed entry costs into air cargo shipping enables me to derive a new set of results that the benchmark Melitz model of trade cannot capture, as it assumes that transport costs are exogenously given. The novelty of these results reside on the following three extensions: First, I showed that the comparative statics on a manufacturer's optimal price, demand, revenue and the total volume of exports are all higher in magnitude than the values obtained in the standard Melitz (2003) model. Second, I find that fixed entry costs into exporting and fixed entry costs into air cargo shipping not only determine entry into exporting, but they also determine a manufacturer's pricing rule. As derived, fixed entry costs (export or cargo related) determine the optimal number of cargo carriers per route. Hence, fixed entry costs (export or cargo related) determine a manufacturer's marginal costs. An increase in fixed entry costs (export or cargo related) reduces a manufacturer's total volume of exports, and reduces entry into exporting. A manufacturer's total volume of exports decreases because an increase in entry costs (export or cargo related) decreases the optimal number of cargo carriers, producing a subsequent increase in a manufacturer's marginal costs, which implies an increase in a manufacturer's product price. Less manufacturers will export since the increase fixed entry costs (export or cargo related) causes the export entry condition to increase. Third, I show that omitting the adjustment canalized through the competition channel produces comparative statics that are lower in magnitude, underestimating the net effect of changes in the exogenous parameters of the model.

3 Empirics

In equation 12, I find that a carrier's air shipping price is given by a markup over marginal air shipping costs. A carrier's markup is determined by the number of carriers servicing a cargo route, and by a constant parameter that measures the dispersion of the distribution function determining productivity. A carrier's marginal shipping costs is determined by a carrier's productivity level, an airport's marginal handling cost, and the per kilogram cost of jet fuel. Estimating the precise functional form for air shipping prices is difficult since the solution requires nonlinear interactions between the levels of these variables, which in some cases I'm unable to measure exactly (i.e, an airline productivity level). Since I'm mainly interested in testing the effect of competition on cargo prices, I estimate several specifications all relying on the following reduced log-linear specification

$$\ln f_{\varphi jt} = \gamma + \beta_1 \ln n_{jt} + \beta_2 \ln \tilde{mc}_{jt} + \Lambda_J \mathrm{D}_J + \Lambda_T \mathrm{D}_T + \Lambda_\Omega \mathrm{D}_\Omega + \mu_{\varphi jt}. \quad (32)$$

$f_{\varphi jt}$ is the per kilogram air shipping price of a product exported from foreign country j at time t. n_{jt} is the number of competing carriers and $\tilde{mc}_{jt}$ is an airport's handling cargo cost given by the ratio between a country's wage w_{jt} and a country's airport productivity level ε_{jt}. A carrier's productivity level and the jet fuel consumption are route-specific characteristics that I choose to control with route (D_J) and year-specific fixed effects (D_T). The inclusion of route and year fixed effects enables me to control for non-observables correlated with the marginal costs of air cargo shipping. The route-specific component controls for economies of scale that are route-specific, while the time component controls for the economies of scale of cargo shipping that affect all carriers in the same way; e.g., an improvement in fuel consumption of airplanes. But, air shipping prices may also vary per product, as product characteristics may imply that special handling needs are required for international transportation. Therefore, all specifications include a set of product fixed effect (D_φ) which I use to control for non-observable product characteristics that affect the marginal cost structure of cargo carriers. In the model the dispersion of the distribution function (κ) is a constant parameter that I captured in all my specifications with the intercept. $\mu_{\varphi jt}$ is the orthogonal error component of per kilogram air cargo shipping prices.

In section 2, I assumed that there is only one type of air cargo shipping service, air shipping prices are not affected by the pricing performed by other modes of transportation,[24] and marginal costs of cargo shipping are constant. For robustness purposes I expand my basic specification and I test wheter the results on competition hold as I control for the competition arising from other transport modes, and as I control for shipping requirements not captured by the set of product fixed effects

$$\begin{aligned}\ln f_{\varphi jt} =& \gamma + \beta_1 \ln n_{jt} + \beta_2 \ln \tilde{mc}_{jt} + \beta_3 \ln vess_{\varphi jt} + \beta_4 \ln p_{\varphi it} + \\ & \Lambda_J \mathrm{D}_J + \Lambda_T \mathrm{D}_T + \Lambda_\Omega \mathrm{D}_\Omega + \mu_{\varphi jt}. \end{aligned} \quad (33)$$

$vess_{\varphi j}$ is the per kilogram shipping cost when a product is transported by

[24]Hummels (2007a) and Hummels (2007b) provide a first characterization relating the choice of transportation mode with the type of goods shipped across international destinations. Alternatively Hummels and Schaur (2010) find that a firm's choice of international shipping mode can be use as a mean of responding to favorable demand realizations. Thus, the choice of a particular transport mode enables a manufacturer to limit the risk of producing unprofitably large quantities in periods of low demand.

ocean mode, while $p_{\varphi i}$ corresponds to a product's price at factory gate[25] used to proxy for product specific handling costs not captured by the set of product fixed effects. The inclusion of a product's factory gate price is explained by the following two reasons: First, empirically transport costs are usually reported including the insurance component. Second, air shipping services are usually offered with a variety of additional service options offered at additional marginal costs; i.e., time to delivery and special cargo handling requirements. Thus, manufacturers exporting more valuable products pay a higher insurance (as insurance is calculated as a function of the product price), and valuable products are also expected to require more careful handling, increasing the marginal cost of cargo shipping.[26] Estimates on β_3 and β_4 are both expected to be positive.

In the model, route-specific economies of scale are all canalized through the competitive channel, as the optimal number of cargo carriers increases with the total scale of cargo. But it might be the case that shipment scales may affect a carrier's marginal cost as this may vary with the scale of operations. Empirically, this could lead to pricing rules depending on the size of the shipment, charging a higher rate for shipments below a certain weight threshold.[27] Similar to Hummels, Lugovskyy, and Skiba (2009), I compare the estimates obtained in equation (33) as I sort cargo by it's total weight content into 10 equally sized bins. Lack of variation on the reported coefficients will reflect the idea that economies of scale of the route do not represent a source of potential bias for my estimates.

The data used to estimate these specifications come from different sources. I used the U.S. Imports of Merchandize dataset to build an unbalanced panel with product level information (10 digit harmonized system code) on shipping costs, cargo weight, f.o.b. value of exports and factory gate prices of the products exported to the U.S market by transportation mode (ocean or air mode) for the period between 1990 and 2009.[28] Ideally, a cargo route should be defined by the airports where the cargo service is provided. But given that the transport costs data is only available at the country level, I define a cargo route by the origin country from which the product is exported from. I use the T-100 Data Bank, also known as the Air Carrier Statistics database, to obtain information of competition per cargo route. Competition is first

[25]refer to equation (4a)

[26]In Hummels, Lugovskyy, and Skiba (2009) optimal air cargo shipping prices are a function of a product's gate price. But this result is derived under the exogenous assumption that a carriers marginal cost is given by the following functional form $\exp^{\gamma_o} p_{\varphi}^{\gamma_1} dist^{\gamma_3}$.

[27]For example, Delta Cargo set's a per kilogram price threshold at 100 kgs.

[28]See Feenstra, Romalis, and Schott (2002) for a detail description of the information available in this data-set.

measured as the count of cargo carriers that provide transportation of goods in fully cargo loaded flights departing from any country in the world to the US market. Second, I use the flight level information available in the data to construct a Herfindahl index per cargo route that I use as a robustness check on the validity of the sign of the effect of competition on air shipping prices.

A country's airport marginal cargo handling cost is a variable defined by the ratio between a country's wage and a country's airport productivity level. A country's wage is proxy by the GDP per capita extracted from the World Bank's World Development Indicators (WDI), while a country's airport productivity level is proxied with a country's average airport productivity level. Airport productivity estimates were obtained from the Global Airport Benchmarking Report produced by the Airport Transport Research Society (ATRS).[29] Unfortunately, the country coverage of the estimates of airport productivity constrained me to only using information from 31 countries.[30]Altogether, I'm able to build a dataset of transport costs for $18,756$ products exported from 31 countries to the U.S. market, for the period between 1990 and 2009. Figure 1 plots the number of cargo carriers operating between a given exporter and the US market. Consistent with the model, the number of carriers increases with the size of trade. Following the US Federal Trade Commission guidelines on market concentration,[31] summary statistics on the number of cargo carriers and the Herfindahl index in this data provides a first evidence that the assumption of oligopolistic competition in air cargo routes is valid, in the data the average cargo route is classified as a highly concentrade market (table 4).

3.1 Results

Table 5 reports the results of the effect of airport cargo handling fees and air cargo competition on air shipping prices. As expected air shipping prices are higher when transportation is performed through airports characterized by higher marginal cargo fees. Similarly, shipping prices decrease as competition in air cargo shipping increases. In all specifications, results are significant at 1%, and the magnitude of the estimated coefficients do not seem to vary as I control for product characteristics affecting the marginal handling costs of

[29]I thank Tomás Serebrisky for sharing this data with me.

[30]Table 3 provides a complete list of the countries included in the sample.

[31]According to the FTC, a Herfindhal Index (HHI) below 100 indicates that the market is highly competitive. When HHI is between 100 and $1,500$, the FTC classifies the market as unconcentrated. When HHI is between $1,500$ and $2,500$ the FTC classifies the market as moderate concentrated, and when HHI is above $2,500$ the FTC determines that the market is highly concentrated.

cargo shipping (column (2)), or as I also control for the competition arising from ocean transportation (column (3)). Results are also robust to the inclusion of the Herfindahl index, used as an alternative measure of competition in an air cargo route(column (4)).

The interaction between an airport's cargo handling cost and the degree of competition derived in equation 12 suggests that the effect on prices of an improvement in cargo handling costs or an increase in competition depends on the interaction term omitted in specifications 1 through 4. In column (5) I estimate equation 33, including the interaction term, and I find that the reduction in air shipping prices achieved by the reduction in an airport's handling charges is higher than the reduction achieved by air shipping prices due to a change in competition. Evaluated at sample means, a 10% decrease in a country's airport handling costs reduces air shipping prices by 3.58%, while a 10% increase in the degree of competition produces a 1% reduction in air shipping prices.

Although route and year fixed effects are expected to control for the economies of scale of cargo shipping, shipment scales might be at work as carriers are well known to charge prices depending on the overall shipping weight of a product. In table 6 I sorted the sample by a shipment's total cargo weight, and I organized cargo shipments into 10 equally sized bins. With this organization, I proceeded to test whether the coefficients derived from airport handling costs and competition in columns 3 and 4 in table 5 are similar in magnitude and significant across bins. Panel A reports the results obtained when competition is measured by the number of carriers, while panel B includes the estimates when the Herfindahl index is included as my measure of competition. As reported, the correlation of air shipping prices, airport handling charges and competition are not due to a scale effect. In both panels, the coefficients associated to airport handling charges and competition are robust in magnitude and they are all significant at 1%. Interestingly, in both panels the coefficient on ocean shipping costs increases as the weight of cargo increases. The monotonic relationship across cargo bins is explained because the competition for cargo between the two transport modes increases as shipments are characterized by higher weight content.

4 Conclusions

Recent literature on international trade has provided empirical evidence of the increasing role of transport costs as a component of trade deterrence. Understanding the underlying determinants of trade will help policy makers to implement policies to reduce transport costs, and help manufacturing firms become more integrated into the world market.

In this paper, I developed a firm heterogenous model of trade with endogenous air shipping costs. I introduced a transport sector characterized by carriers competing à la Cournot with fixed entry costs into air cargo shipping. As a result, I derived an optimal air shipping pricing rule determined by a varying markup and a constant cargo handling cost. The former determined by the number of cargo carriers, and the later determined by an airline's productivity level, airports cargo handling costs and fuel consumption. The endogenous response of the number of carriers enabled me to derived a general equilibrium model of trade that exhibits higher welfare effects due to the endogenous adjustment of competition in air cargo. I call this effect the competitive channel. To test the importance of the competitive channel, I take the model to the data and I use product level data of exports to the US market to test the relevance of competition in cargo shipping. I find that an increase in competition in air cargo is correlated with a significant reduction in air shipping prices. Results are robust to alternative measurements of competition, and they are also robust to the economies of scale present in air cargo shipping.

References

ANDERSON, J. E., AND E. VAN WINCOOP (2004): "Trade Costs," *Journal of Economic Literature*, 42(3), 691–751.

CLARK, X., D. DOLLAR, AND A. MICCO (2004): "Port efficiency , maritime transport costs , and bilateral trade," *Journal of Development Economics*, 75(2), 417 – 450.

FEENSTRA, R., J. ROMALIS, AND P. SCHOTT (2002): "U.S. Imports, Exports and Tariff Data, 1989-2001," *NBER Working Paper Series.*, WP 9387, 1989–2001.

HELLERMANN, R. (2006): *Capacity Options for Revenue Management. Theory and Applications in the Air Cargo Industry.* Springer., Heidelberg, Germany., 1 edn.

HUMMELS, D. (2007a): "Transportation Costs and International Trade in the Second Era of Globalization," *Journal of Economic Perspectives*, 21(3), 131–154.

——— (2007b): "Transportation Costs and International Trade over Time," *Journal of Economic Perspectives*, 21(3), 131–154.

HUMMELS, D., V. LUGOVSKYY, AND A. SKIBA (2009): "The trade reducing effects of market power in international shipping," *Journal of Development Economics*, 89(1), 84–97.

HUMMELS, D., AND G. SCHAUR (2010): "Hedging price volatility using fast transport," *Journal of International Economics*, 82(1), 15–25.

LIMÃO, N., AND A. J. VENABLES (2001): "Infrastructure , Geographical Disadvantage , Transport Costs , and Trade," *The World Bank Economic Review*, 15(3), 451–479.

MAS-COLLEL, A., M. WHINSTON, AND J. GREEN (1995): *Microeconomic Theory.* Oxford University Press.

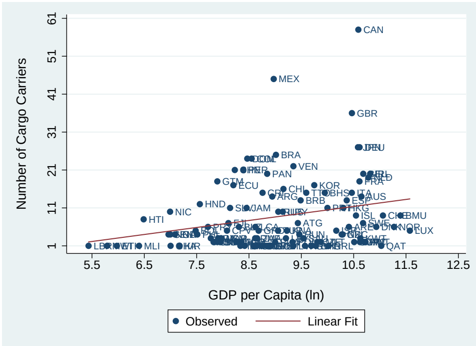
MATTINGLY, J., W. HEISER, AND D. PRATT (2005): *Aircraft Engine Design.*, vol. 1. AIAAEducationn Series., 2 edn.

MELITZ, M. (2003): "The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity," *Econometrica*, 71(6), 1695–1725.

Micco, A., and T. Serebrisky (2006): "Competition regimes and air transport costs : The effects of open skies agreements," *Journal of International Economics*, 70(1), 25 – 51.

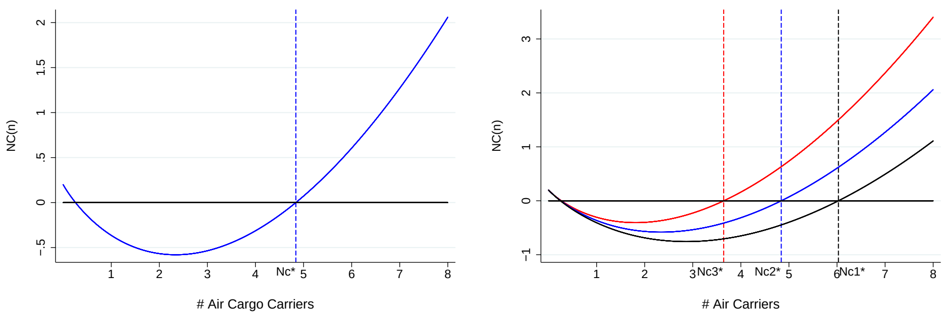
Figures

Figure 1: GDP per Capita (ln) vs. Number of Air Carriers, year 2009.



Note: GDP per capita was obtained from the World Bank WDI(2009). The number of air carriers per route was obtained from the BTS T-100 Database(2009).

Figure 2: Optimal Number of Air Cargo Carriers.



(a) Optimal N_c^* (b) ΔF_{12}^c

Note: See Appendix B for a detailed derivation of function NC. In both figures I assume $\kappa = 4$ and $\sigma = 1.5$. Figure 2(a) provides a complete characterization of function NC as defined in equation 16. N^c corresponds to the optimal number of air carriers when $H_3 = 0.4358$. n^c equal 0.257 is not a solution because at this value a carrier's optimal profit function will be negative. In the second case N^{c*} is 4.84. Figure 2(b) characterizes the solutions as H_3 varies in magnitude. Nc1 Nc2 and Nc3 are the solutions obtained when H_3 is either 0.4951, 0.4358 or 0.3938.

Tables

Table 1: **Comparative Statistics on the Number of Carriers, Per kg. Shipping Price, Product Import Price, Total Product Demand, and a Manufacturer's Total Revenue.**

Fundamentals	**Number of Carriers**	**Per kg. Shipping Price**			**Product Delivery Price**			**Product Demand**			**Total Revenue**
	$\mathrm{d}_{\mathrm{N}^{c*}}/\mathrm{d}x$	$\mathrm{d}f_1/\mathrm{d}x$			$\mathrm{d}p^c_{\varphi 1}/\mathrm{d}x$			$\mathrm{d}q_{\varphi 1}/\mathrm{d}x$			$\mathrm{d}r_{\varphi 1}/\mathrm{d}x$
	Net	**Direct**	**Comp.**	**Net**	**Direct**	**Comp.**	**Net**	**Direct**	**Comp.**	**Net**	**Net**
	(1)	(2)	(3)	(2)+(3)	(4)	(5)	(4)+(5)	(6)	(7)	(6)+(7)	(4)+(5)+(6)+(7)
Factor Related											
Wage (w)	-	+	+	++	+	+	++	-	-	- -	- -
Jet Fuel Cost ($w^{\frac{d_j \alpha_g}{\theta_g}}$)	-	+	+	++	+	+	++	-	-	- -	- -
Air Carrier Productivity (θ)	+	-	-	- -	-	-	- -	+	+	++	++
Product Specific											
Import Tariff in Country 1 (τ_1)	-	0	+	+	+	+	++	-	-	- -	- -
Import Tariff in Country 2 (τ_2)	-	0	+	+	0	+	+	0	-	-	-
Price Elasticity of Demand (σ)	+	0	-	- -	-	-	- -	+	+	+ +	+ +
Route Specific											
Market Size in Country 1 (L_1)	+	0	-	-	0	-	-	+	+	+	+
Market Size in Country 2 (L_2)	+	0	-	-	0	-	-	0	+	+	+
Airport Productivity in Country 1 (ξ_1)	+	-	-	- -	-	-	- -	+	+	+ +	+ +
Airport Productivity in Country 2 (ξ_1)	+	-	-	- -	-	-	- -	+	+	+ +	+ +
Fixed Costs of Exporting to Country 1 (F_1)	-	0	+	+	0	+	+	0	-	-	-
Fixed Costs of Exporting to Country 2 (F_2)	-	0	+	+	0	+	+	0	-	-	-
Fixed Entry Costs into Air Cargo Shipping (F^a)	-	0	+	+	0	+	+	0	-	-	-
Manufacturer Specific											
Manufacturer Productivity Level (φ)	0	0	0	0	-	0	-	+	0	+	+

Column (1) is derived using the implicit function theorem on equation (15). Columns (2) and (3) correspond to terms $\tilde{\delta}_{f_j,x}$ and $\delta_{f_j,\mathrm{N}^c}\delta_{\mathrm{N}^c,x}$ derived in equation (21). Columns (3) and (4) correspond to terms $\tilde{\delta}_{p_{\varphi j},x} + \mathrm{S}_{f_j}\tilde{\delta}_{f_j,x}$ and $\mathrm{S}_{f_j}\delta_{f_j,\mathrm{N}^c}\delta_{\mathrm{N}^c,x}$ derived in equation (23). Columns (5) and (6) correspond to $\tilde{\delta}_{q_{\varphi j},x} - \sigma\left(\tilde{\delta}_{p_{varphij},x} - \mathrm{S}_{f_j}\tilde{\delta}_{f_j,x}\right)$ and $\sigma \mathrm{S}_{f_j}\delta_{f_j,\mathrm{N}^c\delta_{\mathrm{N}^c},x}$ derived in equation (26). The net effect on a manufacturer's revenue corresponds to equation (27).

Table 2: **Comparative Statics on the Endogenous Export Entry Threshold, Extensive and Intensive Margins of Trade, and Total Value of Exports.**

Fundamentals	Export Threshold			Extensive Margin			Intensive Margin			Total Exports
	$d\underline{\varphi}_1$/x			dEM_1/dx			dIM_1/dx			$dIMP_1/dx$
	Direct	Comp.	Net	Direct	Comp.	Net	Direct	Comp.	Net	Net
	(1)	(2)	(2)+(3)	(4)	(5)	(4)+(5)	(6)	(7)	(6)+(7)	(4)+(5)+(6)+(7)
Factor Related										
Wage (w)	+	+	++	-	-	- -	-	-	- -	- -
Jet Fuel Cost ($w\frac{d_j\alpha_g}{\theta_g}$)	+	+	++	-	-	- -	-	-	- -	- -
Air Carrier Productivity (θ)	-	-	- -	+	+	++	+	+	++	++
Product Specific										
Import Tariff in Country 1 (τ_1)	+	+	++	-	-	- -	-	-	- -	- -
Import Tariff in Country 2 (τ_2)	0	+	+	0	-	-	0	-	-	-
Price Elasticity of Demand (σ)	-	-	- -	+	+	++	+	+	++	++
Route Specific										
Market Size in Country 1 (L_1)	-	-	- -	+	+	++	+	+	++	++
Market Size in Country 2 (L_2)	0	-	-	0	+	+	0	+	+	+
Airport Productivity in Country 1 (ξ_1)	-	-	- -	+	+	++	+	+	++	++
Airport Productivity in Country 2 (ξ_1)	-	-	- -	+	+	++	+	+	++	++
Fixed Costs of Exporting to Country 1 (F_1)	+	+	++	-	-	- -	-	-	- -	- -
Fixed Costs of Exporting to Country 2 (F_2)	0	+	+	0	-	-	0	-	-	-
Fixed Entry Costs into Air Cargo Shipping (F^a)	0	+	+	0	-	-	0	-	-	-

Columns (1) and (2) correspond to $\tilde{\delta}_{\underline{\varphi}_1,x}$ and $-\frac{\delta_{N^c,x}}{(\kappa+1)N^c-1}$ derived in equation (29). Columns (3) and (4) are derived as implied by $\delta_{EM_1,\underline{\varphi}_1}\left(\frac{d\underline{\varphi}_1}{dx}\frac{x}{\underline{\varphi}_1}\right)$ in equation (30). Columns (6) and (7) correspond to $\tilde{\delta}_{IM_1,x}-(\kappa+1-\sigma)\,\tilde{\delta}_{\underline{\varphi}_1,x}$ and $\left[\frac{\kappa}{N^c(\kappa+1)-1}\right]\delta_{N^c,x}$ derived in equation (31). The net effect on a country's volume of exports corresponds to equation (31).

Table 3: **Countries in Sample.**

Countries Included in the Sample.		
Australia	Finland	Netherlands
Austria	Greece	New Zealand
Belgium	Hong Kong	Norway
Bulgaria	Hungary	Poland
Canada	Japan	Singapore
China	Republic of South Korea	Slovakia
Czech Republic	Latvia	Slovenia
Denmark	Macao	Spain
Estonia	Malaysia	Sweden
Federal Republic Of Germany	Malta And Gozo	Switzerland
		United Kingdom

Sample: $1990 - 2009$. Source: US-Import of Merchandize, BTS- T-100 Database, ATRS Dataset and World Bank WDI.

Table 4: **Summary Statistics.**

Variables	**Mean**	**Stdev.**	**Min.**	**Max.**	**Percentile**	
					P50	**P**75
Endogenous Variables						
Air Cargo Shipping per kilogram (ln)	0.992	1.128	-9.868	9.873	1.064	1.526
Competition in Air Cargo						
Number of Cargo Carriers	20.620	13.237	1.000	83.000	20.000	31.000
Herfindahl Index	3,469	2,496	811	10000	2,691	4,586
Herfindahl Index (ln)	-1.296	0.686	-2.512	0.000	-1.313	-0.780
Country Specific						
Foreign Airport Cargo Handling Cost (ln)	3.861	1.520	0.870	7.794	3.701	5.328
Product Specific						
Product price at factory gate (ln)	3.252	2.621	-10.473	15.948	2.841	4.591
Ocean Cargo Shipping per kilogram (ln)	-0.984	1.120	-16.319	9.319	-0.995	-0.400
Interactions						
Number of Cargo Carriers (ln) × Foreign Airport Cargo Handling Costs (ln)	10.482	5.662	0.000	21.761	9.174	15.250

Sample: $1990 - 2009$. Statistics obtained using $696,981$ observations corresponding to exports of $18,756$ products from 31 countries to the US market.

Table 5: **Air Shipping Prices and Infrastructure.**

Dependant Variable: Air Cargo Shipping per kilogram ln $f_{\varphi j}$	**Number of Cargo Carriers** (1)	(2)	(3)	**Herfindahl** (4)	**Inter.** (5)
Foreign Airport Cargo Handling Cost (ln)	.249 (.008)***	.244 (.008)***	.247 (.008)***	.257 (.008)***	.183 (.009)***
Competition in Air Cargo	-.111 (.005)***	-.107 (.005)***	-.107 (.005)***	.117 (.006)***	-.319 (.010)***
Per Unit Price at Factory Gate (ln)		.053 (.002)***	.042 (.002)***	.042 (.002)***	.042 (.002)***
Shipping Price of Ocean Mode (ln)			.067 (.002)***	.067 (.002)***	.067 (.002)***
Competition in Air Cargo × Airpot Handling Costs (ln)					.058 (.002)***
Obs.	696981	696981	696981	696981	696981
R^2 overall	.037	.037	.059	.059	.06
Product Fixed Effects	Yes	Yes	Yes	Yes	Yes
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes

Sample: 1990 − 2009. In columns 1 − 3 competition in Air Cargo is measured by the number of cargo carriers in a cargo route. In column 4 competition in air cargo is measured by the logarithm of the Herfindahl Index of a cargo route. In Column 5, I interact the logarithm of the number of cargo carries with the logarithm of a foreign's airport cargo handling cost. In all specifications I include product, country and year fixed effects. Robust Standard Errors reported in parenthesis. ***, ** and * are significant at 1%, 5% and 10% respectively.

Table 6: **Air Shipping Prices across Cargo Routes.**

Panel A: Number of Cargo Carriers per Route.

Dependant Variable:	Cargo by weight bin									
Air Cargo Shipping per kilogram $\ln f_{\varphi j}$	1	2	3	4	5	6	7	8	9	10
Foreign Airport Cargo Handling Cost (ln)	.265	.267	.259	.285	.271	.310	.278	.258	.238	.235
	(.031)***	(.026)***	(.025)***	(.024)***	(.023)***	(.022)***	(.022)***	(.020)***	(.019)***	(.017)***
Competition in Air Cargo	-.125	-.110	-.096	-.105	-.074	-.101	-.087	-.067	-.030	-.074
	(.020)***	(.017)***	(.016)***	(.016)***	(.015)***	(.015)***	(.014)***	(.013)***	(.013)**	(.010)***
Per Unit Price at Factory Gate (ln)	.018	.024	.031	.030	.032	.027	.035	.032	.039	.023
	(.004)***	(.004)***	(.004)***	(.004)***	(.004)***	(.004)***	(.004)***	(.005)***	(.005)***	(.006)***
Shipping Price of Ocean Mode (ln)	.024	.042	.044	.053	.053	.069	.072	.072	.069	.087
	(.005)***	(.004)***	(.005)***	(.005)***	(.005)***	(.006)***	(.006)***	(.006)***	(.007)***	(.007)***
Obs.	70229	69528	69670	69626	69599	69754	69716	69670	69722	69467
R^2 overall	.059	.063	.059	.062	.062	.072	.075	.091	.122	.182

Panel B: Herfindahl Index per Cargo Route.

Dependant Variable:	Cargo by weight bin									
Air Cargo Shipping per kilogram $\ln f_{\varphi j}$	1	2	3	4	5	6	7	8	9	10
Foreign Airport Cargo Handling Cost (ln)	.284	.291	.261	.281	.294	.324	.272	.249	.236	.220
	(.032)***	(.026)***	(.025)***	(.025)***	(.023)***	(.023)***	(.022)***	(.021)***	(.020)***	(.018)***
Competition in Air Cargo	.145	.138	.095	.096	.102	.116	.075	.051	.027	.050
	(.022)***	(.018)***	(.017)***	(.017)***	(.017)***	(.016)***	(.015)***	(.014)***	(.014)*	(.012)***
Per Unit Price at Factory Gate (ln)	.018	.024	.031	.030	.031	.027	.035	.032	.039	.023
	(.004)***	(.004)***	(.004)***	(.004)***	(.004)***	(.004)***	(.004)***	(.005)***	(.005)***	(.006)***
Shipping Price of Ocean Mode (ln)	.025	.042	.044	.053	.053	.069	.072	.073	.069	.087
	(.005)***	(.004)***	(.005)***	(.005)***	(.005)***	(.006)***	(.006)***	(.006)***	(.007)***	(.007)***
Obs.	70229	69528	69670	69626	69599	69754	69716	69670	69722	69467
R^2 overall	.06	.064	.06	.062	.063	.072	.075	.091	.122	.182
Product Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Sample: 1990 – 2009. Weight bins are constructed sorting the cargo load in a cargo route by a shipment total weight content. Then I classify shipments in 10 equally sized bins. Panel A provides the results obtained when I measured competition in a cargo route with the count of carriers. Panel B reports the results obtained when competition is measured with a Herfindahl Index. Robust Standard Errors reported in parenthesis. ***, ** and * are significant at $1\%, 5\%$ and 10% respectively.

Appendix A

From equation 7a I take the partial respect to f_1 obtaining:

$$\frac{\partial W_1}{\partial f_1} = -\sigma \frac{\nu W_1}{w + \nu f_1} + \frac{W_1}{\int\limits_{\underline{\varphi}_1}^{\infty} \varphi^{\sigma-1} \mathrm{d}G(\varphi)} \times \frac{\partial \int\limits_{\underline{\varphi}_1}^{\infty} \varphi^{\sigma-1} \mathrm{d}G(\varphi)}{\partial f_1} \tag{34}$$

Multiplying by $\frac{f_1}{W_1}$ I obtain that the price elasticity of cargo can be decomposed in an intensive and extensive margin as follows:

$$\xi_{f_1} = \underbrace{-\sigma \frac{\nu f_1}{w + \nu f_1}}_{\text{intensive margin}} + \underbrace{\frac{f_1}{\int\limits_{\underline{\varphi}_1}^{\infty} \varphi^{\sigma-1} \mathrm{d}G(\varphi)} \times \frac{\partial \int\limits_{\underline{\varphi}_1}^{\infty} \varphi^{\sigma-1} \mathrm{d}G(\varphi)}{\partial f_1}}_{\text{extensive margin}} \tag{35}$$

$$\xi_{f_1} = \underbrace{-\sigma \frac{\nu f_1}{w + \nu f_1}}_{\text{intensive margin}} - \underbrace{\frac{f_1}{\int\limits_{\underline{\varphi}_1}^{\infty} \varphi^{\sigma-1} \mathrm{d}G(\varphi)} \times \underline{\varphi}_1^{\sigma-1} g(\underline{\varphi}_1) \frac{\partial \underline{\varphi}_1}{\partial f_1}}_{\text{extensive margin}} \tag{36}$$

$$\xi_{f_1} = \underbrace{-\sigma \frac{\nu f_1}{w + \nu f_1}}_{\text{intensive margin}} - \underbrace{\frac{\underline{\varphi}_1^{\sigma}}{\int\limits_{\underline{\varphi}_1}^{\infty} \varphi^{\sigma-1} \mathrm{d}G(\varphi)} \times g(\underline{\varphi}_1) \frac{\partial \underline{\varphi}_1 f_1}{\partial f_1 \underline{\varphi}_1}}_{\text{extensive margin}} \tag{37}$$

From equation 6b I obtain:

$$\frac{\partial \underline{\varphi}_1}{\partial f_1} \frac{f_1}{\underline{\varphi}_1} = \frac{\nu f_1}{w + \nu f_1} \tag{38}$$

Substituting 38 in 37 I obtain:

$$\xi_{f_1} = \underbrace{-\sigma \frac{\nu f_1}{w + \nu f_1}}_{\text{intensive margin}} \underbrace{- \frac{\underline{\varphi}_1^{\ \sigma}}{\int_{\underline{\varphi}_1}^{\infty} \varphi^{\sigma-1} \mathrm{d}G(\varphi)} \times g(\underline{\varphi}_1) \frac{\nu f_1}{w + \nu f_1}}_{\text{extensive margin}} \tag{39}$$

$$\xi_{f_1} = -\left[\frac{\nu f_1}{w + \nu f_1}\right] \left[\sigma + \frac{\underline{\varphi}_1^{\ \sigma}}{\int_{\underline{\varphi}_1}^{\infty} \varphi^{\sigma-1} \mathrm{d}G(\varphi)} \times g(\underline{\varphi}_1)\right] \tag{40}$$

Under the assumption that φ is Pareto with $G(\varphi) = 1 - \frac{1}{\kappa}\varphi^{-\kappa}$: $\varphi \in [\underline{b}, \infty)$ and shape parameter $\kappa > 2$. Implying that the pdf is $g(\varphi) = \varphi^{-\kappa-1}$. Therefore:

$$g\left(\underline{\varphi}_1\right) = \underline{\varphi}_1^{\ -\kappa-1} \tag{41a}$$

$$\int_{\underline{\varphi}_1}^{\infty} \varphi^{\sigma-1} \mathrm{d}G(\varphi) = \left[\frac{1}{\sigma - \kappa - 1}\right] \left[\left(\frac{1}{\infty}\right)^{\kappa+1-\sigma} - \left(\frac{1}{\underline{\varphi}_1}\right)^{\kappa+1-\sigma}\right] \tag{41b}$$

$$\int_{\underline{\varphi}_1}^{\infty} \varphi^{\sigma-1} \mathrm{d}G(\varphi) = \left[\frac{1}{\kappa + 1 - \sigma}\right] \left[- \underbrace{\left(\frac{1}{\infty}\right)^{\kappa+1-\sigma}}_{0} + \left(\frac{1}{\underline{\varphi}_1}\right)^{\kappa+1-\sigma}\right] \tag{41c}$$

$$\int_{\underline{\varphi}_1}^{\infty} \varphi^{\sigma-1} \mathrm{d}G(\varphi) = \left[\frac{1}{\kappa + 1 - \sigma}\right] \underline{\varphi}_1^{\ \sigma-\kappa-1} \tag{41d}$$

Substituting equations 41a and 41d in 40 I obtain:

$$\xi_{f_1} = -(\kappa + 1) \frac{\nu f_1}{w + \nu f_1} \tag{42}$$

Appendix B

Setting the optimal profit function of a representative air carrier to zero I obtain:

$$w^{\frac{\kappa+1-\sigma}{\sigma-1}} F^a = \frac{\left[\text{N}^c (\kappa+1) - 1\right]^\kappa}{\left[\text{N}^c\right]^{\kappa+2}} \underbrace{\left[\frac{(\sigma-1)^{\kappa+1}}{(\kappa+1-\sigma)(1+\kappa)^{\kappa+1} \sigma^{\frac{\sigma\kappa}{\sigma-1}}}\right]}_{\text{H}_{\sigma\kappa}} \times \tag{43a}$$

$$\left[\underbrace{\left[\frac{\text{L}_1^\kappa p_o^{\kappa\sigma}}{\tau_1^{\sigma\kappa} F_1^{\kappa+1-\sigma}}\right]^{\frac{1}{\sigma-1}} \left[\frac{1+\nu \text{B}_1}{(w+\nu\text{B}_1)^{\kappa+1}}\right]}_{\text{H}_1} + \underbrace{\left[\frac{\text{L}_2^\kappa p_o^{\kappa\sigma}}{\tau_2^{\sigma\kappa} F_2^{\kappa+1-\sigma}}\right]^{\frac{1}{\sigma-1}} \left[\frac{1+\nu \text{B}_2}{(w+\nu\text{B}_2)^{\kappa+1}}\right]}_{\text{H}_2}\right]$$

$$\text{NC} = \text{N}^{c\,\frac{\kappa+2}{\kappa}} \underbrace{\left[\frac{w^{\frac{\kappa+1-\sigma}{\kappa(\sigma-1)}}}{\kappa+1}\right] \left[\frac{F^a}{(\text{H}_1+\text{H}_2)\,\text{H}_{\sigma\kappa}}\right]^{\frac{1}{\kappa}}}_{\text{H}_3} - \text{N}^c + \frac{1}{\kappa+1} \tag{43b}$$

As implied by equations 44a and 44b, NC is a continuous convex differentiable function on N^c.

$$\text{NC}' = \left[\frac{\kappa+2}{\kappa}\right] \text{H}_3 \text{N}^{c\,\frac{2}{\kappa}} - 1 \tag{44a}$$

$$\text{NC}'' = \left[\frac{2(\kappa+2)}{\kappa^2}\right] \text{H}_3 \text{N}^{c\,-\frac{\kappa-2}{\kappa}} > 0 \tag{44b}$$

Conditional of the value of H_3, NC will achieves a minimum in $\underline{\text{N}}^c = \left[\frac{\kappa}{\text{H}_3(\kappa+2)}\right]^{\frac{\kappa}{2}}$. It will exhibit a decreasing pattern $\forall \quad \text{N}^c \in (0, \underline{\text{N}}^c]$, and exhibit an increasing pattern $\forall \quad \text{N}^c \in (\underline{\text{N}}^c, \infty)$.

Appendix C

From equation (20) I obtain:

$$\frac{\mathrm{d} f_j}{\mathrm{d} x} = \frac{\partial f_j}{\partial x} + \frac{\partial f_j}{\partial \text{N}^c} \frac{\partial \text{N}^c}{\partial x} \tag{45a}$$

Factorizing by $\frac{f_j}{x}$ and multiplying and dividing the second term in equation (45a) by N^c I get:

$$\frac{\mathrm{d}f_j}{\mathrm{d}x} = \left[\frac{f_j}{x}\right]\left[\frac{\partial f_j}{\partial x}\frac{x}{f_j} + \left(\frac{\partial f_j}{\partial \mathrm{N}^c}\frac{\mathrm{N}^c}{f_j}\right)\left(\frac{\partial \mathrm{N}^c}{\partial x}\frac{x}{\mathrm{N}^c}\right)\right] \tag{45b}$$

$$\frac{\mathrm{d}f_j}{\mathrm{d}x} = \left[\frac{f_j}{x}\right]\left[\tilde{\delta}_{f_j,x} + \delta_{\mathrm{N}^c f_j}\delta_{\mathrm{N}^c,x}\right] \tag{45c}$$

$$\frac{\mathrm{d}f_j}{\mathrm{d}x}\frac{x}{f_j} = \tilde{\delta}_{f_j,x} + \delta_{f_j,\mathrm{N}^c}\delta_{\mathrm{N}^c,x} \tag{45d}$$

$$\delta_{f_j,x} = \tilde{\delta}_{f_j,x} + \delta_{f_j,\mathrm{N}^c}\delta_{\mathrm{N}^c,x} \tag{45e}$$

From equation (20) I obtain:

$$\frac{\mathrm{d}p_{\varphi j}}{\mathrm{d}x} = \frac{\partial p_{\varphi j}}{\partial x} + \frac{\partial p_{\varphi j}}{\partial f_j}\frac{\mathrm{d}f_j}{\mathrm{d}x} \tag{46a}$$

Factorizing by $\frac{p_{\varphi j}}{x}$ and multiplying and dividing by f_j in the second term of equation (46a) I obtain:

$$\frac{\mathrm{d}p_{\varphi j}}{\mathrm{d}x} = \left[\frac{p_{\varphi j}}{x}\right]\left[\frac{\partial p_{\varphi j}}{\partial x}\frac{x}{p_{\varphi j}} + \left(\frac{\partial p_{\varphi j}}{\partial f_j}\frac{f_j}{p_{\varphi j}}\right)\left(\frac{\mathrm{d}f_j}{\mathrm{d}x}\frac{x}{f_j}\right)\right] \tag{46b}$$

From equation (4b) I get that $\frac{\partial p_{\varphi j}}{\partial x}\frac{x}{p_{\varphi j}} = \frac{\frac{\nu}{\varphi}f_j}{p_{\varphi j}} = \frac{\nu f_j}{w+\nu f_j} = \mathrm{S}_{f_j}$.

$$\frac{\mathrm{d}p_{\varphi j}}{\mathrm{d}x} = \left[\frac{p_{\varphi j}}{x}\right]\left[\frac{\partial p_{\varphi j}}{\partial x}\frac{x}{p_{\varphi j}} + \mathrm{S}_{f_j}\left(\frac{\mathrm{d}f_j}{\mathrm{d}x}\frac{x}{f_j}\right)\right] \tag{46c}$$

Substituting equation (45d) I get:

$$\frac{\mathrm{d}p_{\varphi j}}{\mathrm{d}x} = \left[\frac{p_{\varphi j}}{x}\right]\left[\tilde{\delta}_{p_{\varphi j},x} + \mathrm{S}_{f_j}\left(\tilde{\delta}_{f_j,x} + \delta_{f_j,\mathrm{N}^c}\delta_{\mathrm{N}^c,x}\right)\right] \tag{46d}$$

$$\frac{\mathrm{d}p_{\varphi j}}{\mathrm{d}x}\frac{x}{p_{\varphi j}} = \tilde{\delta}_{p_{\varphi j},x} + \mathrm{S}_{f_j}\left[\tilde{\delta}_{f_j,x} + \delta_{f_j,\mathrm{N}^c}\delta_{\mathrm{N}^c,x}\right] \tag{46e}$$

$$\delta_{p_{\varphi j},x} = \tilde{\delta}_{p_{\varphi j},x} + \mathrm{S}_{f_j}\tilde{\delta}_{f_j,x} + \mathrm{S}_{f_j}\delta_{f_j,\mathrm{N}^c}\delta_{\mathrm{N}^c,x} \tag{46f}$$

From equation 2a I obtain:

$$\frac{\mathrm{d}q_{\varphi j}}{\mathrm{d}x} = \frac{\partial q_{\varphi j}}{\partial x} + \frac{\partial q_{\varphi j}}{\partial p_{\varphi j}} \frac{\mathrm{d}p_{\varphi j}}{\mathrm{d}x} \tag{47a}$$

Factorizing by $\frac{q_{\varphi j}}{x}$ and multiplying and dividing the second term in equation (**??**) I get:

$$\frac{\mathrm{d}q_{\varphi j}}{\mathrm{d}x} = \left[\frac{q_{\varphi j}}{x}\right] \left[\frac{\partial q_{\varphi j}}{\partial x} \frac{x}{q_{\varphi j}} + \left(\frac{\partial q_{\varphi j}}{\partial p_{\varphi j}} \frac{p_{\varphi j}}{q_{\varphi j}}\right) \left(\frac{\mathrm{d}p_{\varphi j}}{\mathrm{d}x} \frac{x}{p_{\varphi j}}\right)\right] \tag{47b}$$

By equation (2a) I know that $\frac{\partial q_{\varphi j}}{\partial p_{\varphi j}} \frac{p_{\varphi j}}{q_{\varphi j}} = -\sigma$.

$$\frac{\mathrm{d}q_{\varphi j}}{\mathrm{d}x} = \left[\frac{q_{\varphi j}}{x}\right] \left[\frac{\partial q_{\varphi j}}{\partial x} \frac{x}{q_{\varphi j}} - \sigma \left(\frac{\mathrm{d}p_{\varphi j}}{\mathrm{d}x} \frac{x}{p_{\varphi j}}\right)\right] \tag{47c}$$

$$\frac{\mathrm{d}q_{\varphi j}}{\mathrm{d}x} = \left[\frac{q_{\varphi j}}{x}\right] \left[\tilde{\tilde{\delta}}_{q_{\varphi j},x} - \sigma \left[\tilde{\tilde{\delta}}_{p_{\varphi j},x} + \mathrm{S}_{f_j} \left(\frac{\mathrm{d}f_j}{\mathrm{d}x} \frac{x}{f_j}\right)\right]\right] \tag{47d}$$

$$\tag{47e}$$

Substituting equation (45d) into equation (47d) I obtain:

$$\frac{\mathrm{d}q_{\varphi j}}{\mathrm{d}x} = \left[\frac{q_{\varphi j}}{x}\right] \left[\tilde{\tilde{\delta}}_{q_{\varphi j},x} - \sigma\tilde{\tilde{\delta}}_{p_{\varphi j},x} - \sigma \mathrm{S}_{f_j}\tilde{\tilde{\delta}}_{f_j,x} - \sigma \mathrm{S}_{f_j}\delta_{f_j,\mathrm{N}^c}\delta_{\mathrm{N}^c,x}\right] \tag{47f}$$

$$\frac{\mathrm{d}q_{\varphi j}}{\mathrm{d}x} \frac{x}{q_{\varphi j}} = \tilde{\tilde{\delta}}_{q_{\varphi j},x} - \sigma\tilde{\tilde{\delta}}_{p_{\varphi j},x} - \sigma \mathrm{S}_{f_j}\tilde{\tilde{\delta}}_{f_j,x} - \sigma \mathrm{S}_{f_j}\delta_{f_j,\mathrm{N}^c}\delta_{\mathrm{N}^c,x} \tag{47g}$$

$$\delta_{q_{\varphi j},x} = \tilde{\tilde{\delta}}_{q_{\varphi j},x} - \sigma\tilde{\tilde{\delta}}_{p_{\varphi j},x} - \sigma \mathrm{S}_{f_j}\tilde{\tilde{\delta}}_{f_j,x} - \sigma \mathrm{S}_{f_j}\delta_{f_j,\mathrm{N}^c}\delta_{\mathrm{N}^c,x} \tag{47h}$$

$$\frac{\mathrm{d}r_{\varphi j}}{\mathrm{d}x} = \frac{\mathrm{d}p_{\varphi j}}{\mathrm{d}x} q_{\varphi j} + p_{\varphi j} \frac{\mathrm{d}q_{\varphi j}}{\mathrm{d}x} \tag{48a}$$

Factorizing by $\frac{p_{\varphi j} q_{\varphi j}}{x}$ I obtain:

$$\frac{\mathrm{d}r_{\varphi j}}{\mathrm{d}x} = \left[\frac{p_{\varphi j} q_{\varphi j}}{x}\right] \left[\frac{\mathrm{d}p_{\varphi j}}{\mathrm{d}x} \frac{x}{p_{\varphi j}} + \frac{\mathrm{d}q_{\varphi j}}{\mathrm{d}x} \frac{x}{q_{\varphi j}}\right] \tag{48b}$$

Substituting equations (46e) and (47g) in equation (48b) I obtain:

$$\frac{\mathrm{d}r_{\varphi j}}{\mathrm{d}x} = \left[\frac{r_{\varphi j}}{x}\right]\left[\tilde{\delta}_{q_{\varphi j},x} - (\sigma-1)\left[\tilde{\delta}_{p_{\varphi j},x} + \mathrm{S}_{f_j}\left(\frac{\mathrm{d}f_j}{\mathrm{d}x}\,\frac{x}{f_j}\right)\right]\right] \tag{48c}$$

Substituting equation (45d) in equation (48c) I obtain:

$$\frac{\mathrm{d}r_{\varphi j}}{\mathrm{d}x} = \left[\frac{r_{\varphi j}}{x}\right]\left[\tilde{\delta}_{q_{\varphi j},x} - (\sigma-1)\left(\tilde{\delta}_{p_{\varphi j},x} + \mathrm{S}_{f_j}\tilde{\delta}_{f_j,x} + \mathrm{S}_{f_j}\delta_{f_j,\mathrm{N}^c}\delta_{\mathrm{N}^c,x}\right)\right] \tag{48d}$$

$$\frac{\mathrm{d}r_{\varphi j}}{\mathrm{d}x}\,\frac{x}{r_{\varphi j}} = \tilde{\delta}_{q_{\varphi j},x} - (\sigma-1)\left(\tilde{\delta}_{p_{\varphi j},x} + \mathrm{S}_{f_j}\tilde{\delta}_{f_j,x} + \mathrm{S}_{f_j}\delta_{f_j,\mathrm{N}^c}\delta_{\mathrm{N}^c,x}\right) \tag{48e}$$

$$\delta_{r_{\varphi j},x} = \tilde{\delta}_{q_{\varphi j},x} - (\sigma-1)\left(\tilde{\delta}_{p_{\varphi j},x} + \mathrm{S}_{f_j}\tilde{\delta}_{f_j,x} + \mathrm{S}_{f_j}\delta_{f_j,\mathrm{N}^c}\delta_{\mathrm{N}^c,x}\right) \tag{48f}$$

From equation (19a), entry into market 1 can be generalized by $\underline{\varphi}_1(\vec{x}, \mathrm{N}^c(\vec{x}))$. A shock to x implies:

$$\frac{\mathrm{d}\underline{\varphi}_1}{\mathrm{d}x} = \frac{\partial\underline{\varphi}_1}{\partial x} + \frac{\partial\underline{\varphi}_1}{\partial\mathrm{N}^c}\,\frac{\partial\mathrm{N}^c}{\partial x} \tag{49a}$$

$$\frac{\mathrm{d}\underline{\varphi}_1}{\mathrm{d}x} = \left[\frac{\underline{\varphi}_1}{x}\right]\left[\frac{\partial\underline{\varphi}_1}{\partial x}\,\frac{x}{\underline{\varphi}_1} + \left(\frac{\partial\underline{\varphi}_1}{\partial\mathrm{N}^c}\,\frac{\mathrm{N}^c}{\underline{\varphi}_1}\right)\left(\frac{\partial\mathrm{N}^c}{\partial x}\,\frac{\mathrm{N}^c}{x}\right)\right] \tag{49b}$$

$$\frac{\mathrm{d}\underline{\varphi}_1}{\mathrm{d}x} = \frac{\underline{\varphi}_1}{x}\left[\tilde{\delta}_{\underline{\varphi}_1,x} + \delta_{\underline{\varphi}_1,\mathrm{N}^c}\delta_{\mathrm{N}^c,x}\right] \tag{49c}$$

$$\frac{\mathrm{d}\underline{\varphi}_1}{\mathrm{d}x}\,\frac{x}{\underline{\varphi}_1} = \tilde{\delta}_{\underline{\varphi}_1,x} + \delta_{\underline{\varphi}_1,\mathrm{N}^c}\delta_{\mathrm{N}^c,x} \tag{49d}$$

From equation (19a) I know that $\delta_{\underline{\varphi}_1,\mathrm{N}^c} = -\frac{1}{\mathrm{N}^c(\kappa+1)-1}$. Substituting $\delta_{\underline{\varphi}_1,\mathrm{N}^c}$ in equation (49d) I get:

$$\frac{\mathrm{d}\underline{\varphi}_1}{\mathrm{d}x}\,\frac{x}{\underline{\varphi}_1} = \tilde{\delta}_{\underline{\varphi}_1,x} - \frac{\delta_{\mathrm{N}^c,x}}{\mathrm{N}^c\,(\kappa+1)-1} \tag{49e}$$

As implied by equations (18b) and (18c) the total volume of exports can be re-expressed by

$$\mathrm{IMP}_1 = \mathrm{IM}_1(x, \mathrm{N}^c(x))\mathrm{EM}_1(\underline{\varphi}_1(x, \mathrm{N}^c(x))) \tag{50a}$$

Impliying,

$$\frac{\mathrm{dIMP}_1}{\mathrm{d}x} = \mathrm{EM}_1 \left[\frac{\partial \mathrm{IM}_1}{\partial x} + \frac{\partial \mathrm{IM}_1}{\partial \mathrm{N}^c}\frac{\partial \mathrm{N}^c}{\partial x}\right] + \mathrm{IM}_1 \left[\frac{\partial \mathrm{EM}_1}{\partial \underline{\varphi}_1}\frac{\mathrm{d}\underline{\varphi}_1}{\mathrm{d}x}\right] \tag{50b}$$

Factorizing by $\frac{\mathrm{IM}_1\mathrm{EM}_1}{x}$ and multiplying and dividing the second bracket by $\underline{\varphi}_1$ I obtain:

$$\begin{aligned}\frac{\mathrm{dIMP}_1}{\mathrm{d}x} = \frac{\mathrm{IM}_1\mathrm{EM}_1}{x}&\left[\frac{\partial \mathrm{IM}_1}{\partial x}\frac{x}{\mathrm{IM}_1} + \left(\frac{\partial \mathrm{IM}_1}{\partial \mathrm{N}^c}\frac{\mathrm{N}^c}{\mathrm{IM}_1}\right)\left(\frac{\partial \mathrm{N}^c}{\partial x}\frac{x}{\mathrm{N}^c}\right)\right] \\ &+ \frac{\mathrm{IM}_1\mathrm{EM}_1}{x}\left[\left(\frac{\partial \mathrm{EM}_1}{\partial \underline{\varphi}_1}\frac{\underline{\varphi}_1}{\mathrm{EM}_1}\right)\left(\frac{\mathrm{d}\underline{\varphi}_1}{\mathrm{d}x}\frac{x}{\underline{\varphi}_1}\right)\right]\end{aligned} \tag{50c}$$

Substituting equation (49d) into equation (50c) I obtain:

$$\frac{\mathrm{dIMP}_1}{\mathrm{d}x} = \frac{\mathrm{IM}_1\mathrm{EM}_1}{x}\left[\tilde{\delta}_{\mathrm{IM}_1,x} + \delta_{\mathrm{IM}_1,\mathrm{N}^c}\delta_{\mathrm{N}^c,x} + \delta_{\mathrm{EM}_1,\underline{\varphi}_1}\left(\tilde{\delta}_{\underline{\varphi}_1,x} + \delta_{\underline{\varphi}_1,\mathrm{N}^c}\delta_{\mathrm{N}^c,x}\right)\right] \tag{50d}$$

From equation (18b) I know that $\delta_{\mathrm{IM}_1,\mathrm{N}^c} = \frac{\sigma-1}{\mathrm{N}^c(\kappa+1)-1}$ and $\delta_{\mathrm{EM}_1,\underline{\varphi}_1} = -(\kappa+1-\sigma)$. Since $\delta_{\underline{\varphi}_1,\mathrm{N}^c} = -\frac{1}{\mathrm{N}^c(\kappa+1)-1}$, I substitute these three expressions into equation (50d) and I obtain:

$$\frac{\mathrm{dIMP}_1}{\mathrm{d}x} = \frac{\mathrm{IM}_1\mathrm{EM}_1}{x}\left[\tilde{\delta}_{\mathrm{IM}_1,x} - (\kappa+1-\sigma)\,\tilde{\delta}_{\underline{\varphi}_1,x} + \left[\frac{\kappa}{\mathrm{N}^c(\kappa+1)-1}\right]\delta_{\mathrm{N}^c,x}\right] \tag{50e}$$