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Exports versus FDI: do firms use FDI as a mechanism to smooth demand volatility?

Yang-Ming Chang · Philip G. Gayle

Abstract   In this paper, we first develop a simple two-period model of oligopoly to show that, under demand uncertainty, whether a firm chooses to serve foreign markets by exports or via foreign direct investment (FDI) may depend on *demand volatility* along with other well-known determinants such as size of market demand and trade costs. Although fast transport such as air shipment is an option for exporting firms to smooth volatile demand in foreign markets, market volatility may systematically trigger the firms to undertake FDI. We then use a rich panel of US firms' sales to 56 countries between 1999 and 2004 to confront this theoretical prediction and show strong evidence in support of the prediction

Keywords   Exports · Foreign direct investment · Demand volatility · Fast transport · Trade costs

JEL Classification   F2 · F12 · F23

1 Introduction

In the face of a fast-changing global economy, firms have to make decisions concerning whether they want to serve foreign markets by exports or locate their plants in host countries (i.e., foreign direct investment (FDI)). Considerable contributions have been made in explaining the economic

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determinants of exports versus FDI.[1] Among the important determinants are the advantages of low-cost inputs in host countries, the disadvantage of high trade costs, the tariff-jumping arguments for FDI, and the growing market size and demand that induce FDI versus exports. Helpman (2006) presents a systematic review of the literature concerning how international trade and investment affects the organizational forms of business firms in serving foreign markets.

The purpose of this paper is to examine how demand uncertainty interacts with trade costs and costs to set up a production facility abroad, in determining a firm's decision on serving foreign markets by exports or via FDI. To rule out possible effects associated with market size and growing demand, we examine the independent role that *demand volatility* plays by analyzing the mean-preserving effect of "changes in risk" associated with market demand on a firm's choice between exports and FDI. This is a potentially interesting and important departure from the existing literature that looks at exports and FDI from the perspectives of growing market demand and lower input costs in host countries.

First, we develop a simple two-period theoretical model of oligopoly to show that, under demand uncertainty, whether a firm chooses to serve foreign markets by exports or via FDI may depend on demand volatility. Although fast transport such as air shipment is a variable cost option for exporting firms to smooth volatile demand in foreign markets, high transport costs and imperfect information about local market conditions may systematically trigger firms to undertake FDI. FDI allows the firms to avoid transport costs and to directly take advantage of available local information on market conditions, but there involves start-up costs. We wish to characterize export versus FDI decisions in terms of trade and start-up costs in the presence of demand volatility.

Specifically, our theoretical analysis reveals that exporting firms subject to demand volatility in foreign markets may decide to serve the markets via FDI, rather than through fast transport such as air shipments. This finding contrasts the monopolistic exporter model of Schaur (2006) which does not allow for FDI and foreign competition. Market demand volatility in foreign markets not only affect a firm's transportation decisions (optimal air shipments vs. optimal ocean shipments), but also the firm's decision on exports versus FDI. Our simple uncertainty model of oligopolisitic competition is able to show the trade-off between exports and FDI under market demand uncertainty when transportation or time costs are important in trade across national borders.

Second, we use a rich balanced panel data set of US firms' sales to 56 countries between 1999 and 2004 to formally evaluate whether the predictions of our theoretical model are consistent with the data. In the empirical analysis, we allow for nonlinearity in the estimated effects of market demand volatility on FDI versus exports. We find that our empirical results indeed render a strong support to the model prediction that demand volatility in foreign markets may systematically trigger domestic firms to undertake FDI.

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[1] See, e.g., Caves (1971), Buckley and Casson (1981), Lipsey and Weiss (1984), Horstmann and Markusen (1987, 1996), Goldberg and Kolstad (1995), Blonigen (2001), Aizenman (2003), Head and Ries (2003), Rob and Vettas (2003), Bernard and Jensen (2004), Ekholm et al. (2004), and Helpman et al. (2004).

The remainder of the paper is organized as follows. Section 2 develops a two-period theoretical model of oligopoly under demand uncertainty to characterize the export and FDI decisions of a firm in serving foreign markets. In Sect. 3, we examine the role of demand volatility and compare the choice of exports versus FDI. Section 4 presents the empirical model used to test our theoretical predictions. We describe the data used for estimation in Sect. 5, while empirical results are presented and discussed in Sect. 6. Section 7 contains concluding remarks.

2 The theoretical model

We consider the case of competition between two firms ("domestic" and "foreign") in a foreign country where market demand is volatile. The domestic firm (firm 1) can serve the foreign market either by direct foreign investment or by exports. If the domestic firm decides to undertake FDI by locating its plant in the foreign country, the firm avoids bearing transport costs but has to pay a start-up cost. If, instead, the domestic firm chooses to export, the firm avoids paying a start-up cost but has to incur transport costs. We wish to examine export and FDI decisions by the firm in terms of its start-up costs and transport costs with the presence of market demand volatility.

For analytical simplicity, we assume that the good produced by the domestic and foreign firms are homogeneous. The (inverse) demand for the product in the foreign country market is given by

$$p = \tilde{\theta} - \gamma Q, \tag{1}$$

where p is price, $\tilde{\theta}$ is a random variable that captures the local demand uncertainty, γ is a positive parameter, and Q is the total quantity sold by the two firms to consumers in the market. We define demand volatility as an uncertain situation under which there is an increase in the variance of market demand without affecting its mean level. To explicitly characterize demand volatility for the purpose of our analysis, we assume that the random variable $\tilde{\theta}$ in Eq. 1 is governed by the following discrete probability distribution:

$$\tilde{\theta} = \begin{cases} \alpha + V & \text{with probability} \quad \frac{1}{V} \\ \alpha & \text{with probability} \quad 1 - \frac{1}{V} \end{cases}, \tag{2}$$

where parameter α is positive and parameter V is greater than 1. It is easy to verify that the mean and variance of $\tilde{\theta}$ are given, respectively, as $E\left(\tilde{\theta}\right) = \alpha + 1$ and $\sigma^2\left(\tilde{\theta}\right) = V - 1$. This probability distribution thus has the feature that an increase in V increases the variance of market demand without affecting its mean level (i.e., there is a pure increase in demand volatility). This simple approach allows us to focus on the independent effect of changes in demand volatility—an effect completely separated from the market size effect or the effect associated with growing market demand (as reflected by changes in α).[2] The aim of our analysis is

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[2] Rob and Vettas (2003) examine entry into a foreign market where demand exhibits uncertain growth. In contrast, we concentrate on demand volatility by controlling the growth in market demand. That is, assuming that market size as reflected by α remains unchanged, we analyze the mean-preserving effect of changes in risks associated with market demand on a firm's choice of exports or FDI.

to examine how changes in demand volatility (V) affect the domestic firm's optimal decision between exports and FDI.

We assume that both the domestic and foreign firms know the distribution of market demand. However, they do not have perfect information about which demand (high or low) will actually realize in the market until the beginning of the second period. The timing of production and competition is as follows: In the first period when market demand is unknown, the domestic firm maximizes its expected profit by producing and exporting a certain amount of the product via ocean shipment, given the probability distribution as shown in Eq. 2. In the second period when market demand is known, this profit-maximizing firm has to decide whether it wants to ship some extra amount of its product, depending on whether the demand is high or low. Any such shipment needed to smooth demand must be done using the relatively more expensive, but fast, air shipment. As in Schaur (2006), we assume that the domestic firm lives for two periods and that market competition for the good is active only in the second period. In the setting we consider, the domestic firm thus produces the good in the first period and sells it to the foreign market in the second period while competing with the foreign rival. But unlike Schaur (2006), we allow for the possibility that the domestic firm may choose to use FDI as a mechanism to smooth demand volatility, as well as oligopolisitic competition in the foreign market.

2.1 Domestic firm chooses to export

We first discuss the case where the domestic firm chooses to serve the foreign market by exporting. In this case, ocean shipment and air shipment are two options available to the exporter to transport its product to the foreign market. Following Schaur (2006), ocean shipment is assumed to take one period to arrive, whereas air shipment arrives immediately when market demand is known in the second period. The (constant) freight rates for ocean and air transport are given, respectively, as f_o and f_a, where $f_o < f_a$.[3] Denote x_o as the amount of the domestic firm's product shipped to the foreign market over the ocean in the first period. The amount shipped by air depends on the demand actually realized in the foreign market in period 2.

Using backward induction, we begin our analysis with the second period when market demand is known. At the beginning of the second period, the amount x_o shipped by the domestic exporter via ocean shipment has arrived at the destination. The exporter then has to decide whether it is necessary to ship some more via air shipment. If market demand is high, the amount shipped by air is q_h, otherwise no air shipment is needed. Let the output produced by the foreign firm be denoted as y_h.

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[3] As in Schaur (2006), we assume that the shipping industries (ocean and air) are characterized by perfect competition such that their competitive freight rates are exogenous to exporting firms. A recent contribution by Hummels et al. (2007) attempts to test the effect of market power by shipping industries on transportation costs. Using shipping data from US and Latin American imports, they find that shipping firms charge higher markups on goods for which import demands are relatively inelastic, as well as on those goods for which their marginal costs of shipping constitute a smaller percentage of delivered prices. This is an interesting direction for future research.

In this case, profit functions of the domestic firm (as an exporter) and its foreign competitor (firm 2) are given, respectively, as

$$\pi_{1,h} = [\alpha + V - \gamma(x_o + q_h + y_h)]q_h - (c_1 + f_a)q_h - (c_1 + f_o)x_o,$$
$$\pi_{2,h} = [\alpha + V - \gamma(x_o + q_h + y_h)]y_h - c_2 y_h,$$

where c_1 and c_2 are (constant) marginal costs of production for the domestic and foreign firms, respectively. It is easy to verify that the Nash equilibrium outputs are

$$q_h = \frac{\alpha + V - 2(c_1 + f_a) + c_2 - \gamma x_o}{3\gamma}, \tag{3}$$

$$y_h = \frac{\alpha + V + (c_1 + f_a) - 2c_2 - \gamma x_o}{3\gamma}, \tag{4}$$

noting that these would occur with probability $\frac{1}{V}$. It follows from Eqs. 3 and 4 that $q_h < y_h$ if $(c_1 + f_a) > c_2$.

Let the output by the foreign firm be denoted as y_ℓ in the low demand state. In this case, the profit function of the foreign competitor becomes:[4]

$$\pi_{2,\ell} = [\alpha - \gamma(x_o + y_\ell)]y_\ell - c_2 y_\ell.$$

It is straightforward to show that the equilibrium output for the foreign firm when demand is low is:

$$y_\ell = \frac{\alpha - c_2 - \gamma x_o}{2\gamma}, \tag{5}$$

noting that this would occur with probability $1 - \frac{1}{V}$. An examination of Eqs. 3–5 reveals that, *ceteris paribus*, an increase in the amount shipped by ocean shipment in period 1 leads the domestic exporter and its foreign competitor to lower their output levels in period 2. An increase in the air freight rate lowers the extra amount shipped by air shipment. It remains to determine the optimal amount x_o that will be shipped by ocean shipment in the first period.

In the first period, the domestic firm determines x_o that maximizes its expected profit function as follows:

$$E(\pi_1) = \frac{1}{V}\{[\alpha + V - \gamma(x_o + q_h + y_h)]x_o - (c_1 + f_a)q_h\}$$
$$+ \left(1 - \frac{1}{V}\right)[\alpha - \gamma(x_o + y_\ell)]x_o - (c_1 + f_o)x_o. \tag{6}$$

The first-order condition (FOC) for the domestic exporter is:

$$\frac{\partial E(\pi_1)}{\partial x_o} = \frac{1}{V}\left[\alpha + V - \gamma(x_o + q_h + y_h) - \gamma\left(1 + \frac{\partial q_h}{\partial x_o} + \frac{\partial y_h}{\partial x_o}\right)\right]$$
$$+ \left(1 - \frac{1}{V}\right)\left[\alpha - \gamma(x_o + y_\ell) - \gamma\left(1 + \frac{\partial y_\ell}{\partial x_o}\right)\right] - (c_1 + f_o) = 0. \tag{7}$$

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[4] Since firm 1 does not have to make any air shipment when demand is *low*, industry output in the low demand state is simply $x_o + y_\ell$.

Substituting Eqs. 3–5 into the FOC and solving for x_o yields:

$$x_o = \frac{V(3\alpha - 6c_1 + 3c_2 - 6f_o + 2) + 4c_1 - \alpha - c_2 + 4f_a}{2(3V - 1)\gamma}. \tag{8}$$

Substituting x_o in Eq. 8 into Eqs. 3–5 yields the reduced-form solutions for the Nash equilibrium outputs:

$$q_h = \frac{V(3\alpha - 6c_1 + 3c_2 - 12f_a + 6f_o - 4) + 6V^2 - \alpha - c_2}{6(3V - 1)\gamma}, \tag{9}$$

$$y_h = \frac{6V^2 + \beta(3\alpha + 12c_1 - 15c_2 + 6f_a + 6f_o - 4) - \alpha - 6c_1 + 5c_2 - 6f_a}{6(3V - 1)\gamma}, \tag{10}$$

$$y_\ell = \frac{V(3\alpha + 6c_1 - 9c_2 + 6f_o - 2) - \alpha - 4c_1 + 3c_2 - 4f_a}{4(3V - 1)\gamma}. \tag{11}$$

The following game tree in Fig. 1 summarizes the structure of the exporting game which we formally described above. The game tree shows that there are effectively three players in the game, *nature*, firm 1 (the domestic firm) and firm 2 (the foreign firm). Nature chooses the demand states (high or low), while firms choose output levels. The dashed ovals in the game tree represent information sets for which the player moving at such an information set does not know at which point in the set he is playing from. For example, when firm 1 chooses output x_o in the first period it does not know whether nature has chosen high or low demand. Similarly, since firms 1 and 2 choose output simultaneously in the second period in the event that demand is high, when firm 1 is choosing q_h it does not observe firm 2's choice of y_h.
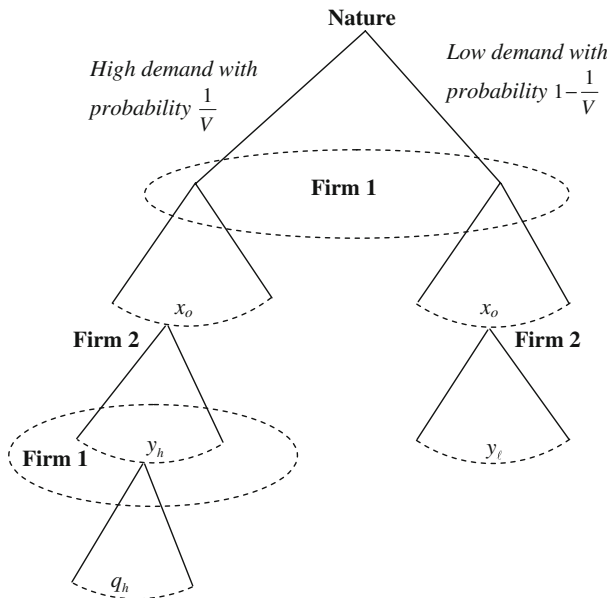

Fig. 1 Game tree for the exporting game

The findings of the analysis allow us to state the following proposition.

Proposition 1: *The domestic firm's optimal ocean shipment decreases while its optimal air shipment increases as demand volatility increases, that is,* $\frac{\partial x_o}{\partial V} < 0$ *and* $\frac{\partial q_h}{\partial V} > 0$.

Proof: Using Eqs. 8 and 9, it is straightforward to show that

$$\frac{\partial x_o}{\partial V} = \frac{3f_o - 6f_a - 3c_1 - 1}{(3V - 1)^2 \gamma} \quad \text{and} \quad \frac{\partial q_h}{\partial V} = \frac{3V(3V - 2) + 3c_1 + 3(2f_a - f_o) + 2}{3(3V - 1)^2 \gamma}.$$

Since by the assumptions that $V > 1$ and $f_a > f_o$, it follows that $\frac{\partial x_o}{\partial V} < 0$ and $\frac{\partial q_h}{\partial V} > 0$. Q.E.D.

Proposition 1 establishes that it may be optimal for an exporting firm to use more expensive, but relatively fast, air shipments to smooth increasingly volatile demand. Note, however, that this proposition follows from a model that does not consider the possibility that the exporting firm could instead undertake FDI and locate a plant in the foreign country which can immediately respond to volatile demand.

It is also interesting to use the exporting game to examine how the composition of ocean and air shipments is affected by changes in their freight rates, other things being equal. This leads to Proposition 2.

Proposition 2: *The domestic firm's optimal ocean shipment increases while its optimal air shipment decreases as the freight cost of air shipment increases, that is,* $\frac{\partial x_o}{\partial f_a} > 0$ *and* $\frac{\partial q_h}{\partial f_a} < 0$.

Proof: Using Eqs. 8 and 9, it is straightforward to show that

$$\frac{\partial x_o}{\partial f_a} = \frac{4}{2(3V - 1)\gamma} \quad \text{and} \quad \frac{\partial q_h}{\partial f_a} = \frac{-12V}{6(3V - 1)\gamma}.$$

Since by the assumption that $V > 1$, it follows that $\frac{\partial x_o}{\partial f_a} > 0$ and $\frac{\partial q_h}{\partial f_a} < 0$. Q.E.D.

Proposition 2 indicates that for a given level of demand volatility, an increase in the freight cost of air shipment increases the optimal amount shipped by ocean but decreases the optimal amount shipped by air when air shipment is required. In other words, when air freight cost increases, the firm will optimally adjust its levels of ocean and air shipments such that it relies less on the relatively expensive air shipment. Our simple analysis thus shows that changes in freight rate structure play an important role in affecting the composition of shipments.[5]

Substituting the Nash equilibrium outputs in Eqs. 9–11 into Eq. 6, we obtain the expected profit of the domestic exporter as follows:

$$E(\pi_1) = \frac{2(c_1 + f_a)(2c_1 - \alpha - V - c_2 + 2f_a) + x_o^2(1 - 3V)\gamma^2 + x_o[4c_1 - \alpha - c_2 + 4f_a + V(3c_2 + 3\alpha - 6c_1 - 6f_o + 2)]\gamma}{6\gamma V}.$$

(12)

We can further derive the reduced-form solution for the exporter's expected profit by substituting the expression for x_o in Eq. 8 into Eq. 12.

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[5] For studies on trade costs and transport costs see, e.g., Hummels (2001, 2006) and Anderson and Wincoop (2004). In particular, Hummels (2006) documents that the freight cost of air shipment has fallen and the freight cost of ocean shipment has risen over time.

In what follows, we formally describe the FDI game, and then we analyze the full game which endogenizes the domestic firm's choice between exporting and FDI.

2.2 Domestic firm chooses FDI

We proceed to examine the alternative case in which the domestic firm decides to serve the foreign market via FDI. Under FDI, the firm avoids bearing transport costs but has to pay a start-up cost, which is denoted as F. To allow for the possible effect of changes in demand volatility (V) on the start-up cost, we assume that $F = \phi V^2$, where $\phi > 0$. Note that FDI start-up cost is an increasing and strictly convex function of demand volatility.[6] The idea is that as the potential host country's market demand gets more volatile, this increases the riskiness and thus the opportunity cost of financing the set-up of a production facility in the host country. The positive parameter ϕ is used to capture factors not related to demand volatility that might influence the start-up cost (e.g., collecting local labor market information).

When market demand is high, the quantities of the good sold by the domestic and foreign firms are X_h and Y_h, respectively. The profit functions of the domestic and foreign firms are given, respectively, as

$$\Pi_{1,h} = [\alpha + V - \gamma(X_h + Y_h)]X_h - c_1 X_h - \phi V^2$$
$$\Pi_{2,h} = [\alpha + V - \gamma(X_h + Y_h)]Y_h - c_2 Y_h.$$

The Nash equilibrium outputs are

$$X_h = \frac{\alpha + V - 2c_1 + c_2}{3\gamma}, \tag{13}$$

$$Y_h = \frac{\alpha + V + c_1 - 2c_2}{3\gamma}, \tag{14}$$

noting that these would occur with probability $\frac{1}{V}$. When market demand turns out to be low, the quantities of the good sold by the domestic and foreign firms are X_ℓ and Y_ℓ. The profit functions of the domestic and foreign firms become

$$\Pi_{1,\ell} = [\alpha - \gamma(X_\ell + Y_\ell)]X_\ell - c_1 X_\ell - \phi V^2,$$
$$\pi_{2,\ell} = [\alpha - \gamma(X_\ell + Y_\ell)]Y_\ell - c_2 Y_\ell.$$

The Nash equilibrium outputs are

$$X_\ell = \frac{\alpha - 2c_1 + c_2}{3\gamma}, \tag{15}$$

$$Y_\ell = \frac{\alpha + c_1 - 2c_2}{3\gamma}, \tag{16}$$

noting that these would occur with probability $\left(1 - \frac{1}{V}\right)$. Next, we calculate the expected profit of the domestic firm under FDI, which is

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[6] We thank an anonymous referee for this valid point, which significantly affects the domestic firm's choice between exports and FDI. As indicated by the referee, causal observations suggest that a significantly high level of market demand volatility may lead to low or no FDI.

$$E(\Pi_1) = \frac{1}{V}\{[\alpha + V - \gamma(X_h + Y_h)]X_h - c_1 X_h\}$$
$$+ \left(1 - \frac{1}{V}\right)\{[\alpha - \gamma(X_\ell + Y_\ell)]X_\ell - c_1 X_\ell\} - \phi V^2. \qquad (17)$$

Substituting Eqs. 13–16 into the expected profit function in Eq. 17, and arranging terms, yields

$$E(\Pi_1) = \frac{V - 4c_1(1 + \alpha - c_1 + c_2) + (\alpha + c_2)(\alpha + c_2 + 2)}{9\gamma} - \phi V^2. \qquad (18)$$

We then have the following proposition.

Proposition 3: *At an interior Nash equilibrium[7] the expected profit from the FDI option increases with market size. However, the expected profit under FDI decreases with demand volatility as long as $2\phi > \frac{1}{9\gamma}$.*

Proof: It is easy to verify that $\frac{\partial E(\Pi_1)}{\partial \alpha} = \frac{2(\alpha + c_2 + 1 - 2c_1)}{9\gamma} > 0$ since $X_\ell > 0$ implies that $\alpha - 2c_1 + c_2 > 0$. Second, $\frac{\partial E(\Pi_1)}{\partial V} = \frac{1}{9\gamma} - 2\phi V < 0$ for all $V > 1$ as long as $2\phi > \frac{1}{9\gamma}$. Q.E.D.

Proposition 3 indicates that the size of market demand and the volatility of market demand have independent distinct effects on the incentive to undertake FDI.

The following game tree in Fig. 2 summarizes the structure of the full game. In the full game, firm 1's strategy involves choosing the optimal mode (export vs. FDI) to supply its goods to the foreign market. A comparison of firm 1's expected profit under exporting versus its expected profits under FDI serves to characterize firm 1's optimal mode of supply in a subgame perfect Nash equilibrium of the full game. In the following section, we pay particular attention to the role that market demand volatility plays when comparing firm 1's expected profits.

3 Exports versus FDI: a numerical analysis

Due to the complexity of the reduced-form expression for expected profit under the export game, an explicit analytical comparison with the expected profit expression under the FDI game appears to be infeasible. As such, we conduct a comparison between the expected profits by assuming numerical values for some parameters. Admittedly, such an approach does not allow for drawing general theoretical conclusions. Nevertheless, it provides a heuristic and novel thinking that leads to the subsequent sections of the paper in presenting an empirical specification for testing the model predictions. We will show that results from the numerical analysis are consistent with actual data.

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[7] Note that corner solutions (zero production and therefore zero profit) are possible in either of the product market competition games (export or FDI). However, for the purposes of this paper we believe that it is most interesting to analyze interior solutions, where production and profit levels are strictly positive under FDI and export options alike.
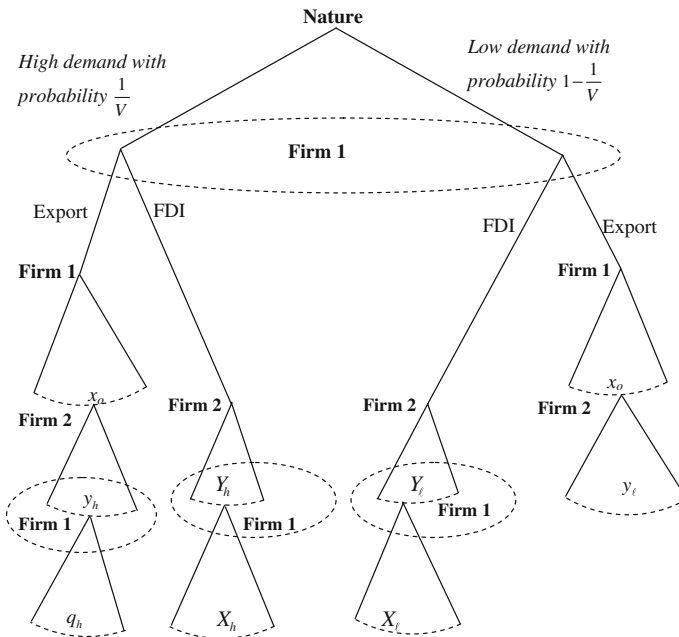
Fig. 2 Game tree for the full game

The assumed parameter values reported in Table 1 are carefully chosen to ensure the existence of a stable Nash equilibrium both in the game where the domestic firm is an exporter and the game where the domestic firm is a direct foreign investor.

Figure 3 plots the domestic firm's expected profits as a function of demand volatility (V) when it is an exporter $\left(\pi_1^{\text{Export}}\right)$ versus when it uses FDI $\left(\Pi_1^{\text{FDI}}\right)$. Demand volatility is measured on the horizontal axis, while the domestic firm's expected profits are measured on the vertical axis. The figure shows that the expected profit function under export is decreasing and convex in V, while the expected profit function under FDI is decreasing and concave in V. This analysis allows us to state the following result:

Result: There exist equilibria in which the expected profit functions under export and FDI intersect twice in the permissible range for volatility ($V > 1$). Such equilibria admit two distinct volatility thresholds (V_1 and V_2, where $V_1 < V_2$) that make expected profits identical for both the export and DFI decisions. As such, we have three possibilities:

Table 1 Assumed parameter values

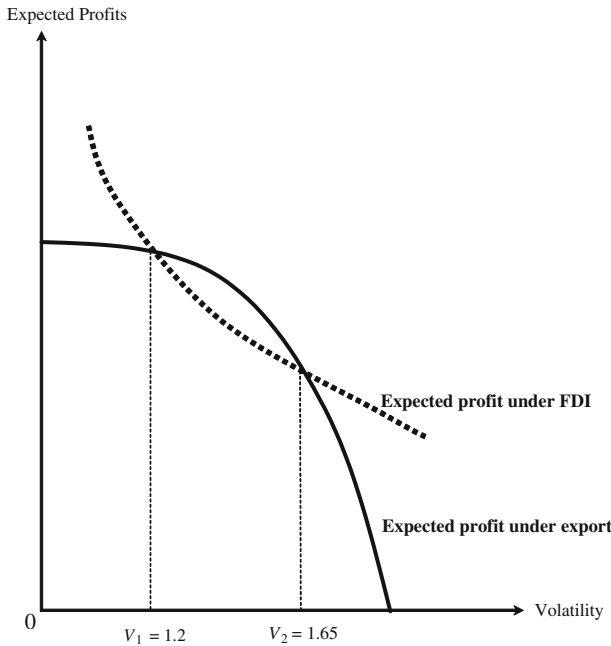| α	γ	c_1	c_2	f_a	f_o	ϕ
1.5	1	0	0	0.75	0.25	0.15

Fig. 3 Expected profits as functions of demand volatility when the functions intersect

(i) $\pi_1^{\text{Export}} > \Pi_1^{\text{FDI}}$ when $V < V_1$;

(ii) $\Pi_1^{\text{FDI}} > \pi_1^{\text{Export}}$ when $V_1 < V < V_2$; *and*

(iii) $\pi_1^{\text{Export}} > \Pi_1^{\text{FDI}}$ when $V > V_2$

The above result indicates that for relatively low levels of demand volatility ($V < V_1$), it is more profitable for the domestic firm to export and use fast transport to smooth demand volatility rather than to use FDI as the mechanism to smooth demand volatility. However, as demand volatility increases beyond a certain threshold but is at a "moderate" level ($V_1 < V < V_2$), it becomes more profitable to use FDI to smooth volatile market demand rather than using fast transport under the export option. When demand volatility is critically high ($V > V_2$), however, the FDI option turns out to be dominated by the export option. This case arises because a significantly high level of demand volatility in the foreign market may substantially raise the start-up cost of installing a production facility there due in part to the high opportunity cost associated with financing such risky investment.

We want to point out that there also exist equilibria in which the profit functions under export and FDI do not intersect in the permissible range of demand volatility levels. In fact, as illustrated in Fig. 4, one such situation occurs if we change the assumed value of ϕ from 0.15 to 0.2 (increase in start-up cost of FDI that is unrelated to demand volatility), but leave the other parameter values unchanged. In this case no volatility thresholds exist and export is always the preferred mode of supply.
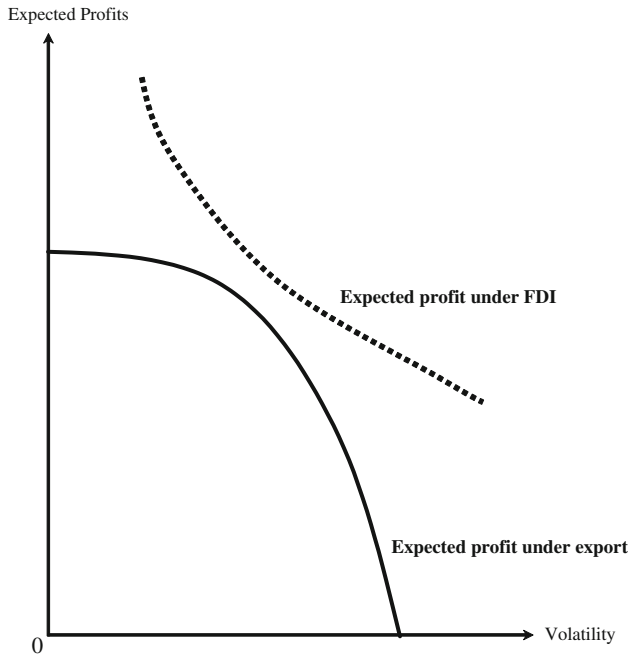
Fig. 4 Expected profits as functions of demand volatility when the functions do not intersect

The numerical examples illustrate that the theoretical model by itself cannot unconditionally tell us whether foreign demand volatility influences the export–FDI decision. To advance our understanding of the issue we must formally analyze actual data. However, as suggested above, the theoretical analysis does provide motivation and context for the subsequent empirical analysis.

4 The empirical model

In this section, we outline the empirical model used to evaluate the plausibility of theoretical predictions derived in the previous sections. First, and most important, we empirically evaluate if foreign market demand volatility levels influence firms' export–FDI decisions. Second, in the event that volatility levels do influence firms' export–FDI decisions, we empirically evaluate two predictions derived from our theoretical model:

(i)   Firms are likely to supply foreign markets via FDI when foreign market demand volatility is higher than a certain threshold, but if demand is less volatile than the threshold firms will rather export and possibly use fast transport to smooth the demand volatility.
(ii)   There is an even higher volatility threshold beyond which export again becomes a more profitable mode of supply compared to FDI.

Industry or firm-specific data are ideal for a direct test of the theoretical predictions described above. Unfortunately, we only have access to data aggregated up to the country level, so rather than directly testing the theoretical predictions, it is more accurate to say that our empirical analysis attempts to identify patterns in country-level data that are consistent with our theoretical predictions. Data availability constraints also led to our focus on US firms' sales of goods to foreign countries.

We use the following empirical model:

$$\frac{\text{FDI}_{it}}{\text{FDI}_{it} + \text{Export}_{it}} = \beta_0 + \beta_1 \log(\text{GDP}_{it}) + \beta_2(\text{Volatility}_{it}) + \beta_3(\text{Volatility}_{it})^2$$
$$+ \beta_4(\text{Volatility}_{it})^3 + \mu_i + \delta_t + \varepsilon_{it}, \tag{19}$$

where FDI_{it} is the sales (in millions of dollars) of US multinational firms in foreign country i in year t,[8] Export_{it} is the value of US exports (in millions of dollars) to foreign country i in year t,[9] $\log(\text{GDP}_{it})$ is the log of the value of country i's gross domestic product (GDP) in year t measured with respect to year 2000 dollars, Volatility_{it} is the standard deviation of country i's annual real GDP growth rate time series up to period t, μ_i and δ_t are country- and time-specific fixed effects, respectively, while ε_{it} is a random error term that is assumed to satisfy the classical assumptions of an error term in a standard linear regression model.

At first glance it might seem odd that our theoretical model is couched in the context of a discrete "either–or" decision (export or FDI) for a firm, but our empirical model in Eq. 19 posits a continuous relationship between the share of US goods sold to a foreign country via FDI $\left(\frac{\text{FDI}_{it}}{\text{FDI}_{it}+\text{Export}_{it}}\right)$, and the foreign country's market volatility among other factors. How can the seeming mismatch between theoretical and empirical models be reconciled? We now discuss such reconciliation.

The seeming mismatch between theoretical and empirical models is due to some simplifying assumptions made in deriving the theoretical model, which we do not use in the empirical model due to data limitations. For example, the theoretical model assumes only one firm deciding whether or not to supply a foreign market via exports or FDI. In reality several firms are making such an export–FDI decision and this decision is influenced by multiple factors which are potentially firm-specific, industry-specific and destination country-specific. At any given point in time due to firm-specific and industry-specific factors, there are likely varied export–FDI choices across US firms that are selling their goods to a particular foreign country. In other words, for country-level data (which is what we have) it is unlikely to observe $\frac{\text{FDI}_{it}}{\text{FDI}_{it}+\text{Export}_{it}} = 0$ or $\frac{\text{FDI}_{it}}{\text{FDI}_{it}+\text{Export}_{it}} = 1$, instead we should observe

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[8] Two reasons we use sales of US multinational affiliate firms in foreign countries to measure FDI are: (1) This FDI measure is more consistent with how export is measured (sales of goods), thus allowing us to compute FDI's share (we subsequently discuss the link between this share and our theoretical model) of US goods sold to a foreign country; (2) This measure of FDI is popular in the literature (Markusen 2002).

[9] Unfortunately, we have no way of decomposing the export measure into exports for final consumption versus exports of intermediate goods between subsidiary firms. In light of the focus of this research, ideally we want our export measure to only include export of goods for final consumption.

$0 < \frac{\text{FDI}_{it}}{\text{FDI}_{it} + \text{Export}_{it}} < 1$. We may also think of $\frac{\text{FDI}_{it}}{\text{FDI}_{it} + \text{Export}_{it}}$ as a measure of the probability that a typical firm chooses to supply the relevant foreign market via FDI.

At "low" foreign economy volatility levels, assuming each US firm makes export–FDI decisions according to our theoretical model, a sufficiently large number of US firms (though not necessarily all US firms due to firm-specific and industry-specific factors) may find export more profitable than FDI to smooth the volatile demand. In this case our empirical model should reveal that a typical firm is more likely to choose export rather than FDI as the mode of supplying the foreign market and therefore we expect $\beta_2 < 0$. At "moderate" levels of foreign demand volatility an increasing number of US firms (though not all US firms) may find FDI more profitable than exports to smooth the volatile demand. If this increasing number of US firms becomes sufficiently large, then the empirical model should reveal that a typical firm is more likely to choose FDI rather than export as the mode of supplying the foreign market and therefore we would expect $\beta_3 > 0$. Last, if volatility gets sufficiently high, an increasing number of US firms may again find export more profitable than FDI to smooth the volatile demand. If this number of US firms becomes sufficiently large, our empirical model should reveal that a typical firm is more likely to choose export rather than FDI as the mode of supplying the foreign market and therefore $\beta_4 < 0$. Our empirical model is therefore designed to pick up these country-wide patterns in the data, which are linked to our theoretical model.

The discussion above implies that, together, β_2, β_3 and β_4 suppose to identify two distinct volatility thresholds if they exist in the data. The thresholds reflect the possible mode of supply switches in the data—first from export to FDI when volatility levels transition from "low" to "moderate", and then from FDI to export when volatility levels transition from "moderate" to "significantly high".

The rationale for including $\log(\text{GDP}_{it})$ in the regression is that it is well documented that the larger is the foreign market, firms are more likely to service this foreign market via an affiliate of the multinational enterprise (MNE) located in the foreign market rather than to service the foreign market via exports (Carr et al. 2001; Markusen 2002; Markusen and Maskus 2002). As such, the estimated value of the coefficient β_1 is expected to be positive. There are several other reasons why a firm may choose to supply a foreign market by locating a plant in the foreign market (FDI) as opposed to exporting final goods to the foreign market. For example, the specific foreign country may have relatively high trade costs (tariffs and or non-tariff barriers), the foreign country may be located far from the home country, relative factor endowments of the foreign country which influence input prices may differ from the home country, and foreign country-specific governmental policies may be relatively favorable to multinational firms.[10] All these foreign country-specific reasons why a firm may choose to supply a foreign market by locating a plant in the foreign market (FDI) as opposed to exporting final goods to the foreign market are controlled for in the regression by μ_i. Furthermore, δ_t is used to control

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[10] For a more detailed discussion of reasons why a firm may choose to supply goods to a foreign market via FDI versus exports, see Markusen (2002).

for global economic conditions that may change over time which might influence a firm's decision whether to supply a foreign market via FDI versus exporting. When estimating the regression, we use a full set of country and time dummies to control for μ_i and δ_t, respectively.

5 Data

The data used for estimation are drawn from several sources. Data on US multinational firms' sales in foreign countries are drawn from Sales by US Majority Owned Foreign Affiliates tables published by the US Bureau of Economic Analysis. Data on US exports are published by the US International Trade Commission. Foreign countries' time series data on real GDP are drawn from US Department of Agriculture International Macroeconomic Data Set. The sample used for estimation is a balanced panel of 56 countries from 1999 to 2004 yielding a sample size of 336. Table 2 provides a list of the 56 countries, organized by region, in the data set.

Table 3 reports summary statistics for real GDP. The summary data reveal that for the countries in our sample, the mean GDP across Asia and Pacific countries is consistently higher than almost all other region means over the review period. However, the variance in size of GDP across countries in this region is the highest, as measured by the standard deviation statistic. By contrast, the mean GDP for countries in the Other Western Hemisphere region is consistently the lowest in our sample. The variance in size of GDP across countries in this region is also the lowest. As can be seen in Table 2, the countries in our sample that fall in the Other Western Hemisphere region are Caribbean countries. Canada is the only country in our sample for the North America region.

Table 4 reports summary statistics for our volatility measure of the real GDP growth rate. A country's volatility measure in period t is computed by taking the standard deviation of the country's annual time series real GDP growth rate from 1969 up to period t, where $t = 1999, 2000, 2001, 2002, 2003, 2004$. In other words, the idea

Table 2 List of the 56 countries in the data set by region

Region	Countries
Europe	Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, Netherlands, Norway, Poland, Portugal, Russia, Spain, Sweden, Switzerland, Turkey, United Kingdom
Asia and Pacific	Australia, China, Hong Kong, India, Indonesia, Japan, South Korea, Malaysia, New Zealand, Philippines, Singapore, Taiwan, Thailand
South America	Argentina, Brazil, Chile, Colombia, Ecuador, Peru, Venezuela
Central America	Costa Rica, Honduras, Mexico, Panama
Other Western Hemisphere	Barbados, Bermuda, Dominican Republic
Africa	Egypt, Nigeria, South Africa
Middle East	Israel, Saudi Arabia, United Arab Emirates
North America	Canada

Table 3 Summary statistics for real GDP (billions of 2000 dollars)

Region	Statistic	Years					
		1999	2000	2001	2002	2003	2004
Europe	Mean	395.97	413.93	421.20	426.99	432.67	444.30
	Std.	(501.66)	(523.34)	(532.49)	(536.01)	(539.34)	(549.69)
South America	Mean	171.59	175.95	176.53	173.38	177.03	189.20
	Std.	(198.63)	(206.43)	(207.55)	(209.69)	(211.92)	(222.28)
Central America	Mean	144.52	153.74	153.62	155.03	157.53	164.51
	Std.	(267.32)	(285.16)	(284.62)	(286.88)	(290.72)	(303.33)
Other Western Hemisphere	Mean	7.73	8.21	8.41	8.69	8.69	8.88
	Std.	(9.21)	(9.95)	(10.32)	(10.81)	(10.73)	(10.92)
Africa	Mean	88.31	92.39	95.23	98.20	102.22	106.57
	Std.	(44.24)	(46.19)	(47.46)	(49.58)	(49.11)	(50.39)
Middle East	Mean	116.62	124.84	126.96	127.62	136.12	143.88
	Std.	(59.24)	(59.48)	(57.54)	(56.48)	(60.58)	(62.81)
Asia and Pacific	Mean	616.67	643.99	657.21	673.75	698.82	732.43
	Std.	(1235)	(1270.85)	(1276.41)	(1275.85)	(1297.20)	(1337.22)
North America	Mean	677.96	714.46	727.17	752.10	767.14	789.39

Table 4 Summary statistics for the volatility of real GDP growth rate

Region	Statistic	Years					
		1999	2000	2001	2002	2003	2004
Europe	Mean	0.0263	0.0265	0.0265	0.0262	0.0261	0.0259
	Std.	(0.0099)	(0.0099)	(0.0102)	(0.0100)	(0.0099)	(0.0100)
South America	Mean	0.0485	0.0478	0.0473	0.0479	0.0479	0.0483
	Std.	(0.0121)	(0.0119)	(0.0117)	(0.0120)	(0.0120)	(0.0123)
Central America	Mean	0.0382	0.0377	0.0375	0.0371	0.0366	0.0362
	Std.	(0.0067)	(0.0065)	(0.0064)	(0.0063)	(0.0061)	(0.0063)
Other Western Hemisphere	Mean	0.0377	0.0371	0.0368	0.0364	0.0363	0.0359
	Std.	(0.0064)	(0.0064)	(0.0065)	(0.0066)	(0.0068)	(0.0069)
Africa	Mean	0.0404	0.0398	0.0392	0.0388	0.0386	0.0381
	Std.	(0.0238)	(0.0234)	(0.0229)	(0.0225)	(0.0227)	(0.0224)
Middle East	Mean	0.0620	0.0614	0.0611	0.0609	0.0603	0.0595
	Std.	(0.0320)	(0.0317)	(0.0305)	(0.0292)	(0.0288)	(0.0285)
Asia and Pacific	Mean	0.0366	0.0361	0.0364	0.0361	0.0358	0.0381
	Std.	(0.0100)	(0.0098)	(0.0102)	(0.0101)	(0.0099)	(0.0224)
North America	Mean	0.0220	0.0219	0.0218	0.0214	0.0212	0.0209

is that in period t a firm deciding whether to use FDI or export to supply its final goods to the foreign country can use information on the history of fluctuations in the foreign country's real GDP growth rate to form expectations about the volatility of market

Table 5 Summary statistics for US multinationals affiliate sales as a proportion of US goods sold to foreign countries

Region	Statistic	Years					
		1999	2000	2001	2002	2003	2004
Europe	Mean	0.851	0.847	0.850	0.865	0.883	0.882
	Std.	(0.070)	(0.089)	(0.083)	(0.075)	(0.062)	(0.061)
South America	Mean	0.723	0.723	0.728	0.755	0.771	0.740
	Std.	(0.082)	(0.081)	(0.094)	(0.096)	(0.079)	(0.085)
Central America	Mean	0.482	0.499	0.527	0.522	0.513	0.509
	Std.	(0.113)	(0.131)	(0.147)	(0.145)	(0.122)	(0.134)
Other Western Hemisphere	Mean	0.750	0.766	0.765	0.771	0.778	0.777
	Std.	(0.342)	(0.337)	(0.325)	(0.331)	(0.319)	(0.311)
Africa	Mean	0.725	0.750	0.724	0.745	0.772	0.764
	Std.	(0.165)	(0.163)	(0.166)	(0.126)	(0.122)	(0.123)
Middle East	Mean	0.407	0.464	0.466	0.398	0.433	0.395
	Std.	(0.119)	(0.144)	(0.209)	(0.134)	(0.162)	(0.136)
Asia and Pacific	Mean	0.670	0.680	0.704	0.714	0.723	0.733
	Std.	(0.156)	(0.143)	(0.125)	(0.118)	(0.124)	(0.118)
North America	Mean	0.632	0.657	0.674	0.668	0.688	0.689

demand in this foreign country. Summary data in the table reveal that volatility is consistently relatively high among countries in the Middle East region, but consistently relatively low among European and North American countries.

Table 5 reports summary statistics on US multinational firm sales as a proportion of US goods sold to foreign countries. Basically, Table 5 presents summary statistics for the dependent variable in the regression. Data in the table reveal that a relatively large proportion of US goods sold to European countries are done via US affiliate firms located in these countries rather than by export. Middle Eastern and Central American countries seem to receive the lowest proportion of US goods via US multinational firms.

The summary statistics in Tables 3, 4 and 5 are only intended to give the reader a "feel" for the data. As pointed out earlier, there are many factors which determine whether a firm chooses to supply goods to a foreign market via FDI versus export. Since summary statistics across these tables do not control for such factors, we cannot rely on data in these tables to draw conclusions on whether or not the data are consistent with our main hypothesis. For such conclusions we must turn to a formal regression analysis.

6 Empirical results

Table 6 reports regression results. All regressions include a full set of country and time dummies even though coefficient estimates for these dummies are not reported in the table. The first column of estimates suggests that firms do increasingly use FDI rather than export to supply their goods to foreign countries as these countries'

Table 6 Regression results for the determinants of the share of US FDI

Independent variables	Dependent variable: $\frac{\text{FDI}_{it}}{\text{FDI}_{it}+\text{Export}_{it}}$				
	(1)	(2)	(3)	(4)	(5) OECD subsample
Constant	0.398 (0.263)	0.489* (0.254)	0.190 (0.302)	0.240 (0.256)	−0.226 (0.449)
$\log(\text{GDP}_{it})$	0.061 (0.047)	0.103** (0.046)	0.116** (0.047)	0.150** (0.047)	0.229** (0.080)
Volatility_{it}	5.50** (1.72)	−14.67** (4.66)	3.372 (10.94)	−14.479** (4.547)	−15.156 (10.96)
$(\text{Volatility}_{it})^2$	–	216.18** (46.65)	−144.88 (203.69)	226.29** (45.600)	425.35** (212.54)
$(\text{Volatility}_{it})^3$	–	–	2232.92* (1226.48)	–	–
GDP growth rate	–	–	–	−0.230** (0.060)	−0.237* (0.142)
R^2	0.98	0.98	0.98	0.98	0.98
Sample size	336	336	336	336	144

A full set of country and time dummies are included when estimating each equation even though these dummy coefficients are not reported. The models are estimated using ordinary least squares. Standard errors are in parentheses

*Statistical significance at the 10% level

**Statistical significance at the 5% level

market size and market volatility increase, but the effect of market size is not statistically significant at conventional levels of significance. There is evidence that foreign demand volatility influences firms' export–FDI decision. However, this first column of estimates do not allow for nonlinearity in the effects of market volatility as our theory warrants.

In column (2) of Table 6, we only allow for a single volatility threshold rather than the two volatility thresholds that our theory suggests. We obtain results consistent with one of our theoretical predictions. Specifically, for measures of foreign market volatility beyond a certain threshold, the results suggest that a sufficiently large number of US firms seem to use FDI to smooth increases in foreign demand volatility rather than using fast air transport under export. This result is inferred from the positive and statistically significant coefficient on the quadratic volatility variable. The negative and statistically significant coefficient on the linear volatility variable likely reflects the strong preference for firms to use the export mode of supply when foreign demand volatility is low. It is noteworthy that the market size effect on the export–FDI decision is now statistically significant at conventional levels of significance. From a theoretical standpoint, this is an indication that the specification in column (2) is more desirable compared to the specification in column (1).

In column (3) of Table 6, we allow for two volatility thresholds by including both quadratic and cubic volatility variables. Given the statistical insignificance of the coefficients on the linear and quadratic volatility variables, and the weak statistical significance on the cubic volatility variable, we can only infer that the data do not support two volatility thresholds. As such, from this point forward we focus on the quadratic specification of volatility that admits only one volatility threshold.

A referee suggested that it is possible that higher GDP growth rates might be associated with higher volatility in GDP growth rate. In addition, FDI might be positively related to expected GDP growth. As such, it is prudent to control for the

possible independent effects of GDP growth on FDI in order to better discern the pure effects of volatility in the growth of GDP on FDI. Column (4) in Table 6 reports the regression estimates when GDP growth rate is included as a regressor. The qualitative results found in column (2) remain robust to the specification in column (4).

A limitation of our data on FDI is that we do not know what portion of multinational firms' affiliate sales are for the market that the affiliate is located in versus the proportion of the affiliate sales that are exported to other countries. In other words, some affiliates are located in certain countries for the purpose of serving as an export platform for the multinational firm. In such a case, the volatility of the local market that will host the affiliate firm is not of primary concern in the location decision. Since our theoretical prediction focuses on the influence of the volatility of the host market on FDI activity, ideally we want to use data where the sales of US affiliate firms are largely for the host country consumers.

It is well-known in the international trade literature that a US affiliate firm located in another high-income developed country is more likely to be primarily serving the host country consumers rather than serving as an export platform (Markusen 2002). An export platform US affiliate firm is more likely to be located in a less developed country. As such, a sample of high-income developed countries that are trading partners with the United States is more appropriate for evaluating our theoretical predictions. In column (5) of Table 6 we restrict the sample to high-income OECD countries.[11]

In the case of the OECD countries subsample, increases in these countries economy volatility seem to be associated with increases in the probability that a typical US firm chooses FDI rather than export as the mode for supplying goods to the OECD country. However, given that volatility is a strictly positive measure, the statistical insignificance of the coefficient on the linear volatility variable and the positive and statistical significance of the coefficient on the quadratic volatility variable are not suggestive of a threshold in the influence of volatility on the export–FDI decision.

7 Concluding remarks

In this paper, we have presented an uncertainty model of international trade in which firms choose to serve foreign markets by exports or via direct foreign investment. We show that by allowing for uncertainty in foreign market demand, other things being equal, a firm's choice between exports and FDI may depend on demand volatility.[12] To ensure that we disentangle the effects of market size or

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[11] These countries include: Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, South Korea, Luxembourg, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

[12] By focusing solely on the role that market demand uncertainty plays in affecting the choice between FDI and exports, we abstract from possible effects associated with exchange rate volatility. Firms may hedge real exchange rate risk by building a foreign plant and supplying the foreign market by either local production or exports depending on the current level of the real exchange rate. For studies on issues concerning FDI under exchange rate volatility, see, e.g., Goldberg and Kolstad (1995) and Aizenman (2003).

growing market demand from the effects of demand volatility on the firm's decision to use exporting versus FDI to supply a foreign market, we employ a probability distribution for the demand states (high or low) which has the feature that the variance is independent of the mean. This allows us to focus on the pure effects of changes in demand volatility, which is an important departure from the trade literature that links the choice between exports and FDI in terms of market demand growth and lower input costs in host countries. We show that the trade-off between exports and FDI depends not only on market demand growth, transport costs and start-up costs, but also on market demand volatility.

Fast transport such as air shipment is an option for exporting firms to smooth volatile demand, but transport costs and imperfect information about market conditions may trigger FDI. FDI allows firms to avoid transport costs and to take advantage of available local information on market conditions. Nevertheless, FDI involves start-up costs. Exporting firms subject to demand volatility in foreign markets may find it optimal to serve the markets through FDI, rather than through exports. Even in the case of export, market demand volatility may also affect a firm's transportation decisions (optimal air shipments vs. optimal ocean shipments) and the competition between domestic and foreign firms. To our knowledge, there are no studies in the literature that explore the role of market demand volatility in interacting with trade costs to affect a firm's optimal choice between exports and FDI in serving foreign markets.

We further use a rich balanced panel data set containing US firms' sales to 56 countries between 1999 and 2004 to confront our theoretical predictions. Allowing for nonlinearity in the estimated effects of foreign market demand volatility on FDI versus exports, we find that increasing volatility may systematically trigger firms to use FDI as an option for smoothing uncertainty in market demand, as compared to the export option. As such, the formal empirical analyses reveal that the data support this theoretical prediction.

Due to complexity of the uncertainty model of oligopoly that involves output decisions in two time periods, we present a numerical analysis to characterize some theoretical results. The generality of the theoretical results requires future study. It should also be mentioned that in our simple theoretical analysis, we discuss "either–or" decisions of a firm without allowing for the combination of exports and FDI. We abstract from the possibility of export-platform FDI, an important business strategy by a multinational enterprise that links the relationship between FDI and the MNE's exports from its host country.[13] Furthermore, we do not examine issues related to strategic trade polices within our two-period framework of international trade under uncertainty. These are interesting issues for future research.

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[13] See, for example, Ekholm et al. (2004) and Helpman (2006).

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