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# Endogenous Market Structures in International Trade with Incomplete Information

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**Abstract**

*This paper introduces incomplete information into Horstmann and Markusen's [1992] model where the determination of the equilibrium market structure is endogenized. Market structure is derived as Nash equilibrium in a simple model with international trade and foreign direct investments. I show that depending on the "quality" of information firms have regarding the environment, e.g., demand conditions, equilibrium market structure can be different from the full information one. Because industry market structure is affected by the information firms have, in addition to tax and trade policies, governments can use informational campaigns to affect industry market structure if by doing so country welfare improves. (JEL: F, D4, D8)*

## I. Introduction

International markets can be supplied via exports or foreign direct invest-

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ments (FDI) production.[1] A firm with a plant in its home market can export to a foreign market and/or engage in FDI production by establishing another plant and producing in the foreign market; that is, the firm becomes a multinational firm. Multinational enterprises (MNEs) have been studied using imperfect competition models, where a given market structure is assumed. Horstmann and Markusen [1992] develop a model that endogenizes the determination of the equilibrium industry market structure given international trade and foreign direct investments. Industry market structure equilibrium is the outcome of plant location decisions by firms. Location decisions are affected by underlying firm production technologies. They show conditions under which the equilibrium is (1) an exporting equilibrium, firms deciding to service their domestic and foreign markets with one plant; (2) an MNE duopoly, with both firms having two plants, one in their home market, the other in their foreign market; or (3) a single MNE monopoly with the firm servicing the two markets.[2] They also show how the equilibrium market structure can change due to firm reactions to changes in tariff or tax policies; for example, small tax changes generate large welfare changes because of the shift in the equilibrium market structure.

I extend their analysis by introducing incomplete information into their model. I consider the case where firms are uninformed about exact demand conditions prior to deciding how many plants to have; that is, they only have a probability distribution as to the size of their markets.[3] After deciding on how many plants to have, firms learn the size of their respective local markets; they then decide on their production levels for both markets. I ask whether the market structure equilibrium changes under incomplete information.

As an example, I consider a situation where the complete information market structure equilibrium is an exporting duopoly. Under incomplete

1. Entry into foreign markets can also be made via licensing arrangements or franchising, subcontracting, the opening of sales subsidiaries or joint ventures. This paper considers two forms: exports and FDI production.
2. Horstmann and Markusen [1992] point out that their model can give rise to market structures assumed in imperfect competition trade models, for example, an exporting duopoly as in Brander and Spencer [1985] and Eaton and Grossman [1986]; or a two-plant multinational monopoly as in Helpman [1984] and Markusen [1984].
3. An alternative approach is to consider the case where firms do not know the exact cost of production prior to deciding how many plants to have.

information, if firms underestimate demand "too much" in both markets, I obtain the no entry equilibrium. If firms overestimate demand sufficiently in both markets, I get the MNE duopoly equilibrium. If demand is overestimated "too much" in one market, I obtain the asymmetric equilibrium where the uninformed firm has more plants compared to the complete information case. If demand is underestimated "too much" in one market, I get a single-firm, one-plant equilibrium. Who builds depends on the variance of the probability distribution of demand. For "high" and "low" values of the variance, the uninformed firm will always enter.

Since the quality (mean and variance of the probability distribution of demand) of information firms have affect their expected profits and therefore industry market structure equilibrium, there might be a role for governments to play in the spread of information to get the desired industry structure equilibrium consistent with maximum total country welfare. If the cost side is studied, this implies that governments can engage in informational campaigns about production costs in their countries via investment promotion offices abroad.

In the next section, I present the basic theoretical model under complete information (HM's model). This is extended in section III by considering incomplete information prior to the first stage number of plants decision. I compare output, profits and market structure equilibrium under complete and incomplete information. In section IV, I consider an example from Horstmann and Markusen and show that the equilibrium market structure they get under complete information changes with the introduction of incomplete information. Section V concludes.

## II. Basic Model: Complete Information Case

Consider Horstmann and Markusen's [1992] full information model with two segmented markets, I and II. Segmented markets are assumed so that output decisions that affect one market do not affect the other. Each country is home to a local firm. Country I (II) is home to firm 1 (2). Each firm produces for its own local market and can service its foreign market either through exports or by opening another plant in the foreign market. HM assumed that firm outputs are imperfect substitutes; since this assumption is not crucial in the analysis, for simplicity I assume that outputs are perfect substitutes.

Both firms consider a two stage problem where in the first stage, both simultaneously decide on the number of plants to have. Both can decide to either have two plants (one in their home markets, another located in the foreign market), one plant (located in each firm's home country) or each may decide not to enter both markets for a total of nine possible outcomes. Given the number of plants they choose in the first stage, in the second stage, both simultaneously decide on their levels of production in each market given costs and demand parameters to maximize total firm profits. Firm 1's production for its local market is denoted by $x^D$; its exports to country $II$ by $x^E$ and its FDI production in country $II$ by $x^F$. Denote firm 2's production for its local market by $y^D$; its exports to country $I$ by $y^E$ and its FDI production in country $I$ by $y^F$.

I assume linear inverse demand functions: in country $I$, this is $P_I = a_I - bx^D - by^i$, where $i = E, F$; and in country $II$, this function is $P_{II} = a_{II} - by^D - bx^i$. Assume an identical constant marginal production costs for both firms in each market. Exports are subject to transportation cost $s$ per unit. HM distinguish between two types of fixed costs: firm-specific fixed costs $F$ and plant-specific fixed costs $G$.[4] Any new or additional plants require only the plant-specific fixed costs, $G$. This distinction implies that location or host country specific characteristics can affect foreign firms' mode of entry choices into that country. For example, the stricter a host country's environmental, work-labor or safety standards are, the higher is $G$ or the higher firms' investments on plant specific fixed costs to meet these standards. $G$ could also be interpreted as expenditures net of investment incentives extended by governments to firms.[5]

4. Firm-specific fixed costs are fixed costs incurred at the firm or company level so that they do not depend on the number of plants of the firm. Examples are advertising, headquarter services, R&D expenditures, etc.

5. HM show that this is an important distinction since market structure equilibrium may change depending on the size of the plant-specific fixed cost vis-a-vis the firm-specific fixed cost and transport cost. For any given firm-specific fixed cost and transport cost, a two-firm, two-plant MNE equilibrium is obtained for "low" values of plant-specific fixed cost. The two-firm, one-plant equilibrium emerges when plant-specific costs are large relative to firm-specific fixed and transport cost.

Here firms are fully informed as to the exact size of demand in both markets. Since production decisions are made after the decision on how many plants to have, the problem is solved backwards. First, I consider firm profit maximization for each of the nine possible outcomes. Upon getting profit levels, the Nash equilibrium of the first stage of the game is determined. To see how firm profits at each outcome are determined, consider the two-firm, two-plant MNE duopoly case. Firm 1 chooses $(x^D, x^F)$ to maximize

$$\Pi_1((x^D, y^F), (x^F, y^D)) = [(a_I - bx^D - by^F - m)x^D] + [(a_{II} - bx^F - by^D - m)x^F] - F - 2G, \tag{1}$$

where the first pair of elements in the $\Pi_1(\cdot)$ function are firm 1 and 2 production in market $I$ respectively and the second pair are firm production levels in market $II$; the first sum on the right hand side is profits from market $I$, firm 1's domestic market; and the second sum is profits from market $II$, its foreign market. $F$+2$G$ are total fixed costs for having two plants. Firm 2 solves a similar maximization problem. Output levels are:

$$x^D = \frac{a_I - m}{3b};\ x^F = \frac{a_{II} - m}{3b};\ y^D = \frac{a_{II} - m}{3b};\ y^F = \frac{a_I - m}{3b}. \tag{2}$$

Notice that both firms will share the market equally in both markets. Substituting these to the firms' objective functions give us

$$\Pi_j((x^D, y^F), (x^F, y^D)) = \frac{(a_j - m)^2}{9b} + \frac{(a_k - m)^2}{9b} - F - 2G, \tag{3}$$

**Table 1**
**Firms' Profits under Incomplete Information**

| Firm 2 / Firm 1 | 2 plants | 1 plants | 0 plants |
|---|---|---|---|
| 2 plants | $\Pi_1 = 1/9b[E(\tilde{a}_I - m)^2 + 1/4V(\tilde{a}_I) + E(\tilde{a}_I^2) - \tilde{a}_I^2 + (\tilde{a}_{II} - m)^2] - F - 2G$<br>$\Pi_2 = 1/9b[E(\tilde{a}_{II} - m)^2 + 1/4V(\tilde{a}_{II}) + E(\tilde{a}_{II}^2) - \tilde{a}_{II}^2 + (\tilde{a}_I - m)^2] - F - 2G$ | $\Pi_1 = 1/9b[E(\tilde{a}_I - m)^2 + 1/4V(\tilde{a}_I) + E(\tilde{a}_I^2) - \tilde{a}_I^2 + 2sE(\tilde{a}_I) + (\tilde{a}_{II} - m)^2] - F - 2G$<br>$\Pi_2 = 1/9b[E(\tilde{a}_{II} - m)^2 + 1/4V(\tilde{a}_{II}) + E(\tilde{a}_{II}^2) - \tilde{a}_{II}^2 + (\tilde{a}_1 - m - 2s)^2] - F - G$ | $\Pi_1 = 1/4b[E(\tilde{a}_I - m)^2 + (\tilde{a}_{II} - m)^2] - F - 2G$<br>$\Pi_2 = 0$ |
| 1 plant | $\Pi_1 = 1/9b[E(\tilde{a}_I - m)^2 + 1/4V(\tilde{a}_I) + E(\tilde{a}_I^2) - \tilde{a}_I^2 + (\tilde{a}_{II} - m - 2s)^2] - F - G$<br>$\Pi_2 = 1/9b[E(\tilde{a}_{II} - m)^2 + 1/4V(\tilde{a}_{II}) + E(\tilde{a}_{II}^2) - \tilde{a}_{II}^2 + 2s\tilde{a}_{II} + (\tilde{a}_1 - m)^2] - F - 2G$ | $\Pi_1 = 1/9b[E(\tilde{a}_I - m)^2 + 1/4V(\tilde{a}_I) + E(\tilde{a}_I^2) - \tilde{a}_I^2 + 2sE(\tilde{a}_I - m) + s^2 + (\tilde{a}_{II} - m - 2s)^2] - F - G$<br>$\Pi_2 = 1/9b[E(\tilde{a}_{II} - m)^2 + 1/4V(\tilde{a}_{II}) + E(\tilde{a}_{II}^2) - \tilde{a}_{II}^2 + 2s(\tilde{a}_{II} - m) + s^2 + (\tilde{a}_I - m - 2s)^2] - F - G$ | $\Pi_1 = 1/4b[E(\tilde{a}_I - m)^2 + (\tilde{a}_{II} - m - s)^2] - F - G$<br>$\Pi_2 = 0$ |
| 0 plant | $\Pi_1 = 0$<br>$\Pi_2 = 1/4b[E(\tilde{a}_{II} - m)^2 + (\tilde{a}_I - m)^2] - F - 2G$ | $\Pi_1 = 0$<br>$\Pi_2 = 1/4b[E(\tilde{a}_{II} - m)^2 + (\tilde{a}_I - m - s)^2] - F - G$ | $\Pi_1 = 0$<br>$\Pi_2 = 0$ |

where $j = 1, 2$ and $j \neq k$. Since they face the same cost conditions and share the market equally, their profit levels are also the same in both markets. Profit levels for all the other outcomes can be derived from Table 1, where under complete information, $E(\tilde{a}_j) = a_j$ and $V(\tilde{a}_j) = 0, j = 1, 2$.

In the next section, I introduce incomplete information into the problem and ask how output and profit levels of both firms change; and given these changes, examine how equilibrium market structure changes from complete to incomplete information.

## III. An Extension: Incomplete Information

In the previous section, firms 1 and 2 are assumed to know the exact size of both their local and foreign markets prior to the first stage decision. In this section, the basic model in section *II* is extended by assuming that both firms are uninformed as to the exact size of their markets at the beginning of the two-stage game.

The following summarizes the timing of the game *I* consider in this section: (1) nature determines demands in both markets, this is unobserved by both firms. (2) Firms 1 and 2 decide on the number of plants they will have based on their expectations about demand size; this is the first stage of the game.[6] (3) Firm 1 observes exact demand conditions in country *I* and not demand conditions in country *II*; at the same time, firm 2 observes exact demand conditions in country *II* and not demand conditions in country *I*; both only have probability distributions on the size of their foreign markets.[7] (4) Firm 1 decides on how much to produce for country *I* and for country *II* to maximize its total profits; firm 2 faces a similar maximization problem.

6. This is not a highly unlikely assumption, since firms generally decide to enter (and the entry mode) or not enter a market without knowing the exact size of demand or based only on their expectations of demand size. However, at times, for any demand specifications, firms may decide to enter as exporters only since appropriation of FDI is possible under weak host country property rights laws. This possibility is not considered in this paper.

7. If firms observed the size of their local markets prior to the first stage decisions, a more complex problem results where firms can use this additional information to their advantage; *i.e.*, we can have a signalling problem, where firms through their first stage choices signal the size of their respective local markets.

In the following sub-sections, *I* present the second stage optimization problem of the firms given their first stage entry mode decisions.

### *A. Two firm, Two-plant MNE Duopoly*

In this sub-section, I consider the case where firms 1 and 2 decide to supply their foreign markets via FDI production; each has a plant in both their respective home and foreign markets.

Consider the output decisions of firm 1 in the second stage of the game. As mentioned above, firms come to know the exact size of their respective local markets; and they only have probability distributions on the size of their foreign markets. This means that when firms decide on their domestic output levels, these are functions of the size of the market. Firm 1's output for the local market (country *I*) depends on the size of the local market. Firm 1's strategy is therefore to produce $\sigma: A_I \rightarrow R^1_+$, where $\sigma$ is the amount produced for the local market and is a function of the size of demand in the country, $a_I \in A_I$. Firm 1 simultaneously decides on $x^F \in R^1_+$, where $x^F$ is the amount of FDI production in country *II* by firm 1. Similarly, the in the second stage of the game, firm 2 decides on its output levels. It produces $\tau$: $A_{II} \rightarrow R^1_+$, where $\tau$ is the amount produced by firm 2 for its local market; this is a function of the size of the market $a_{II} \in A_{II}$. For country *I*, it produces $y^F \in R^1_+$, where $y^F$ is the amount of FDI production by firm 2.

Firm 1 chooses $\sigma(a_I)$ and $x^F$ to maximize $\Pi_1((\sigma(\cdot), y^F), (x^F, \tau(\cdot)))$. Notice that firm 1's profits are comprised of two parts: from country *I*, a function of $(\sigma(\cdot), y^F)$ and from country *II*, a function of $(x^F, \tau(\cdot))$. Subtracting $2G+F$ from $\Pi_1((\sigma(\cdot), y^F), (x^F, \tau(\cdot)))$, one obtains

$$\int_{A_I} (a_I - b\sigma(a_I) - by^F - m)\sigma(a_I) f(a_I) da_I + \int_{A_{II}} (a_{II} - b\tau(a_{II}) - bx^F - m) x^F f(a_{II}) da_{II}, \qquad (4)$$

the first element of the sum are profits from the local market and the second element are profits from the foreign market. Notice that the integration is over the range of $A_I$ and $A_{II}$ for firm 1's profits from market *I* and market *II*, respectively. Since firm 1 will never know the exact size of market *II*, equation (4) can be re-written as

$$\int_{A_I}(a_I - b\sigma(a_I) - by^F - m)\sigma(a_I)f(a_I)da_I \\ +[E(\tilde{a}_{II}) - bE(\tau(\tilde{a}_{II})) - bx^F - m]x^F, \tag{5}$$

where the first element of the sum is the same as equation (4) and profits from market *II* are based on expected values of market *II* demand size.

Firm 2 solves a similar problem. It chooses $\tau(a_{II})$ and $y^F$ to maximize $\Pi_2((\sigma(\cdot), y^F), (x^F, \tau(\cdot)))$. Subtracting $2G+F$ from this, one gets

$$[E(\tilde{a}_I) - by^F - bE(\sigma(\tilde{a}_I)) - m]y^F \\ +\int_{A_{II}}(a_{II} - b\tau(a_{II}) - bx^F - m)\tau(a_{II})f(a_{II})da_{II}, \tag{6}$$

where the first element of the sum are expected profits from country *I* and the second element are profits from country *II*. Taking first order conditions, I obtain the following reaction functions:

$$\sigma(a_I) = \frac{a_I - by^F - m}{2b};\quad x^F = \frac{\bar{a}_{II} - bE(\tau) - m}{2b};$$
$$\tau(a_{II}) = \frac{a_{II} - bx^F - m}{2b};\quad y^F = \frac{\bar{a}_I - bE(\sigma) - m}{2b} \tag{7}$$

Denote $E(\tilde{a}_j) = \tilde{a}_j$, $j = I$ and $II$; $E(\sigma(\tilde{a}_I)) = E(\sigma)$ and $E(\tau(\tilde{a}_{II})) = E(\tau)$. Notice that firms' foreign market reaction functions are functions of $\tilde{a}_I$ and $\tilde{a}_{II}$ and not $a_I$ and $a_{II}$ because of incomplete information. Solving the relevant reaction functions result in the following output levels:

$$\sigma = \frac{a_I - m}{2b} - \frac{\bar{a}_I - m}{6b};\quad x^F = \frac{\bar{a}_{II} - m}{3b};$$
$$\tau = \frac{a_{II} - m}{2b} - \frac{\bar{a}_{II} - m}{6b};\quad y = \frac{\bar{a}_I - m}{3b} \tag{8}$$

Firm output levels in both markets depend on the expected values of demand. The larger (smaller) are these expected values, the larger (smaller) the output levels of firms. Complete information implies $\tilde{a}_j = a_j$, $j = I$ and *II*. Notice that these values collapse to those in equation (2) under complete information. Substituting these levels to the firms' profit functions, I get the following expected firm profits

$$\Pi_j = \frac{1}{9b}[E(\tilde{a}_j - m)^2 + \frac{1}{4}V(\tilde{a}_j) + E(\tilde{a}_j^2) - (\bar{a}_j)^2 + (\bar{a}_k - m)^2] - F - 2G, \tag{9}$$

where $j = 1, 2$ and $j \neq k$. This is the firms' profits under incomplete information.[8] Under complete information, the variance term is zero and the third and fourth terms cancel. Firm expected profits are higher for larger values of demand expectations and variances, see equation (9). Additional terms like these affect firms' profits in most of the nine possible outcomes of the two-stage game. If these values are "large" or "small" enough, they may affect the equilibrium of the game.

### B. Two Plants for Firm 1, One Plant for Firm 2

Consider the case where firm 1 is an MNE; it chooses $\sigma(a_I)$ and $x^E$ to maximize $\Pi_1((\sigma(\cdot), y^E), (x^F, \tau(\cdot)))$. Firm 2 has only one plant, and therefore exports $y^E$ to market $I$. As above, firm 1's profits are comprised of two parts: from country $I$, a function of $(\sigma(\cdot), y^F)$ and from country $II$, a function of $(x^F, \tau(\cdot))$. Subtract $2G+F$ from $\Pi_1((\sigma(\cdot), y^F), (x^E, \tau(\cdot)))$ to get the following

$$\int_{A_I} (a_I - b\sigma(a_I) - by^E - m)\sigma(a_I) f(a_I) da_I + [E(\tilde{a}_{II}) - bE(\tau(\tilde{a}_{II})) - bx^F - m]x^F, \tag{10}$$

this is similar to equation (5) with $y^E$ instead of $y^F$. Firm $II$ chooses $\tau(a_{II})$ and $y^E$ to maximize $\Pi_2((\sigma(\cdot), y^F), (x^F, \tau(\cdot)))$. Subtracting $2G+F$ from this, one obtains the following

$$[E(\tilde{a}_I) - by^E - bE(\sigma(\tilde{a}_I)) - m - s]y^E + \int_{A_{II}} (a_I - b\tau(a_{II}) - bx^F - m)\tau(a_{II}) f(a_{II}) da_{II}, \tag{11}$$

where $s$ is the transport cost of exporting; the first (second) element of the sum are profits from country $I$ ($II$). The following reaction functions are from solving the first-order conditions:

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8. Derivations are in Appendix A.

$$\sigma(a_I) = \frac{a_I - by^E - m}{2b}; \quad x^F = \frac{\overline{a}_{II} - bE(\tau) - m}{2b};$$

$$\tau(a_{II}) = \frac{a_{II} - bx^F - m}{2b}; \quad y^F = \frac{\overline{a}_I - bE(\sigma) - m - s}{2b}. \tag{12}$$

Solving the relevant reaction functions give us the following output levels:

$$\sigma = \frac{a_I - m}{2b} - \frac{\overline{a}_I - m}{6b} + \frac{s}{3b}; \quad x^F = \frac{\overline{a}_{II} - m}{3b};$$

$$\tau = \frac{a_{II} - m}{2b} - \frac{\overline{a}_{II} - m}{6b}; \quad y^F = \frac{\overline{a}_I - m - 2s}{3b}. \tag{13}$$

Comparing these levels with those in equation (8), firm 1's output is higher in market $I$ and 2's output is at the same level; this implies that firm 1's market share in market I is higher. This is because firm 2 has to bear the transport cost of exporting to market $I$. Notice that the higher these transport costs are, the smaller the market share of firm 2. Since markets are segmented, firms' outputs in market $II$ are similar to those in the two-firm, two-plant outcome. Substituting output values to the firms' profit functions give us

$$II_1 = \frac{1}{9b}[E(\tilde{a}_I - m)^2 + \frac{1}{4}V(\tilde{a}_I) + E(\tilde{a}_I^2) \\ - (\overline{a}_I)^2 + 2s\overline{a}_I + (\overline{a}_{II} - m)^2] - F - 2G, \tag{14}$$

for firm 1; and for firm 2,

$$II_2 = \frac{1}{9b}[E(\tilde{a}_{II} - m)^2 + \frac{1}{4}V(\tilde{a}_{II}) + E(\tilde{a}_{II}^2) \\ - (\overline{a}_{II})^2 + (\overline{a}_{II} - m - 2s)^2] - F - G. \tag{15}$$

Here, demand expectations and variances also affect firms' profits. Similar derivations can be made for all other outcomes of the game; profit levels are summarized in Table 1. As mentioned, the equilibrium market structure is the result of the two-stage optimization problem faced by the two firms. For most of the outcomes above, how different firm expected profits are compared to H-M's full information case depend on both $E(\cdot)$ and $V(\cdot)$. I consider symmetric cases where the demand probability distributions in both markets are the same and asymmetric cases where the demand probability distributions are different.

For symmetric cases, for any given strategy of firm $j$ ($j=1, 2$), firm $k$'s ($j \neq k$) two-plant and one-plant strategies dominate its zero-plant strategy, if expected demand is "big" enough *vis-a-vis* the fixed costs (given $s$ and $m$). Whether the two-plant strategy dominate the one-plant strategy or vice versa, depends on $G$ *vis-a-vis* $s$. For some value of $F$, $m$ and $s$, if expected demand, $E(\cdot)$, is "high" enough *vis-a-vis* $G$, the two-firm, two-plant MNE duopoly equilibrium is obtained. If $E(\cdot)$ is "low" enough, then the zero-plant strategy dominates the two-plant and one-plant strategies, which give rise to the no entry equilibrium. For intermediate levels of $E(\cdot)$, I get the two-firm, one-plant equilibrium. Only $E(\cdot)$ matters for these symmetric cases.

Consider the asymmetric case where demand is sufficiently "overestimated" only in one market. For any given strategy of the informed firm, the uninformed firm's two-plant and one-plant strategies dominate its zero-plant strategy; and for some $F$, $m$ and $s$, its two-plant strategy dominates its one-plant strategy. Hence, it is possible to get an asymmetric equilibrium where the uninformed firm has more plants compared to the full information case. As above, the size of the variance does not seem to affect the equilibrium market structure. However, for $E(\cdot)$ sufficiently "underestimated" in one market, both $E(\cdot)$ and the size of $V(\cdot)$ matters. For any given strategy of a firm's rival, there are no dominant strategies for the uninformed firm. In addition to the factors mentioned above, the size of the demand variance affect whether a given strategy will be chosen over another. For example, given very low estimates of demand in one market, where under complete information the zero-plant strategy dominates the other two strategies, under incomplete information, the one-plant strategy may dominate the zero-plant strategy if the variance is "sufficiently" big. Note that in four of the nine cases, the variance term appears and higher values increases expected profits. Hence, depending on its magnitude affect strategy choice and market structure.

As discussed above, $E(\cdot)$ and $V(\cdot)$ affect the level of firm expected profits or payoffs. Changing payoffs can affect the equilibrium of the game or the equilibrium market structure; this in turn affect the countries' total welfare.

Depending on whether country welfare improves or not, there might be a role for governments to conduct informational campaigns about domestic market demand conditions abroad to get the desired industry structure consistent with maximum total welfare.

## IV. Discussion

HM assigned values to the parameters to derive firm profits and Nash equilibria given the different outcomes discussed above. They considered different values for the firm-specific ($F$) and plant-specific ($G$) fixed costs given $a_I = a_{II} = 16$, $b = 2$, $m = 0$ and $s = 2$. They show that different values of $F$ and $G$ give rise to different market structure equilibria. They found that, the two firm exporting duopoly tend to be the equilibrium when plant-specific fixed costs are large relative to firm-specific fixed costs. MNE equilibria (MNE monopoly or MNE duopoly) tend to arise when plant-specific fixed costs are low relative to firm-specific fixed costs.

I show that in an incomplete information framework, industry structure is not only a function of the underlying technology given international trade and foreign direct investments; it is also a function of the firms' probability distribution about market demand conditions. In Table 2, I give an example to show different market structure equilibria under alternative assumptions about demand expected values and variances in both markets. I use HM's numerical example above. Under complete information, given demand and cost parameters, I obtain the (1, 1) equilibrium. That is, both firms have one plant each and are exporting to their foreign markets. In the following discussions, I show that the (1, 1) equilibrium can change given different assumptions about market demand probability distributions.

The uniform distribution is used for the firms' probability distribution about demand. Further, I assume that both firms have the same demand probability distribution in both markets. In case II.1 in Table 2, firms' expected value of demand in both markets are equal to the actual or true size of demand and I get the same (1, 1) Nash equilibrium for any range of values; that is, I get the same equilibrium for any value of the demand variance. This implies that so long as firms' expectations about demand are "correct", that is, $E(\tilde{a}_j) = a_j$, $j = 1, 2$, the size of the demand variance does not seem to matter.

**Table 2**

**Market Structure Equilibria under Alternative Values of the Mean and Variance of the Demand Probability Distribution[1]**

| | | | Mean | Variance | Nash Equil |
|---|---|---|---|---|---|
| **Case I. Complete Information** | | | $E(\tilde{a}_I)=a_I=E(\tilde{a}_{II})=a_{II}$ | $V(\tilde{a}_I)=V(\tilde{a}_{II})=0$ | (1,1) |
| **Case II. Incomplete Information** | Symmetric Cases | II.1 | $E(\tilde{a}_I)=E(\tilde{a}_{II})=16$ | $V(\tilde{a}_I)=V(\tilde{a}_{II})>0$ | (1,1) |
| | | II.2 | $E(\tilde{a}_I)=E(\tilde{a}_{II})=24$ | $V(\tilde{a}_I)=V(\tilde{a}_{II})>0$ | (2,2) |
| | | II.3 | $E(\tilde{a}_I)=E(\tilde{a}_{II})=8$ | $V(\tilde{a}_I)=V(\tilde{a}_{II})>0$ | (0,0) |
| | Asymmetric Cases | II.4 | $E(\tilde{a}_I)=16; E(\tilde{a}_{II})=22$ | $V(\tilde{a}_I)=V(\tilde{a}_{II})>0$ | (2,1) |
| | | II.5 | $E(\tilde{a}_I)=16; E(\tilde{a}_{II})=8$ | $V(\tilde{a}_I)=V(\tilde{a}_{II})=1.3$ | (1,0) mixed |
| | | II.6 | $E(\tilde{a}_I)=16; E(\tilde{a}_{II})=8$ | $V(\tilde{a}_I)=V(\tilde{a}_{II})=5.3$ | (1,0) (0,1) mixed |
| | | II.7 | $E(\tilde{a}_I)=16; E(\tilde{a}_{II})=8$ | $V(\tilde{a}_I)=V(\tilde{a}_{II})=21.3$ | (1,0) |

Note: $E(\cdot)$ is expected value; $V(\cdot)$ is variance. 1/ Equilibria are obtained using the following parameters in our model: $a_I=a_{II}=16$, $b=2$, $m=0$, $s=2$, $F=27$, $G=14$ and $\tilde{a}_I$ and $\tilde{a}_{II}$ are assumed to be uniformly distributed over different ranges.

In case II.2. of the numerical example, both firms are assumed to overestimate demand "too much" in both markets; this leads to a (2, 2) equilibrium where both firms have two plants. This is an intuitive result. Since firms do not get to know the exact size of their foreign markets, they will base their first stage decisions on their demand expectations. Since these are large compared to the actual level, in the equilibrium, there are more plants than under the complete information equilibrium. If firms underestimate demand "too much" in both markets, I get the (0, 0) equilibrium. This is case II.3. Since firms' expected profits are negative, they choose not to enter either market. Even if they get to know the size of demand in their local markets, that is, they get to know that they have underestimated local demand, with "very low" expectations about foreign demand, it is not worth having one plant because expected profits are negative.

In case II.4, firms overestimate demand "too much" in one market only, say, market *II*; I obtain the (2,1) equilibrium. This is true for any value of the variance of demand. Since firm 2 gets to know the exact size of demand in market *II*, it will have the number of plants as in complete information. Firm 1 will have two plants, more than under complete information, since it will not know that it has overestimated foreign demand and its decisions are based on the expectation and variance of market *II* demand.

In the above results, the variances of the probability distributions of demand do not seem to affect the market structure equilibrium. If firms underestimate demand in one market, the equilibrium we get depends on the size of the variance of the demand probability distribution. For example, if demand is underestimated in market *II*, with demand variances at 1.33, see case II.5, we get multiple equilibria: (1,0) and a mixed equilibrium, where firms randomize on having one and no plant.[9] The (1,0) equilibrium is easy to explain. Even if firm 1 does not observe demand in market II, it observes demand in market I and therefore finds it worthwhile to have one plant. Given this strategy by firm 1, firm 2 will choose not to enter, otherwise it gets negative profits. However, if the variance of the demand in market I becomes a little bigger, then we get the following equilibria: (1,0) and (0,1) and a mixed equilibrium, see case II.6. The (0,1) equilibrium becomes possible because firm 2 get to observe that the size of demand in market II is larger than expected, so it will enter, given high expectations about demand in market I. And given this strategy by firm 2, firm 1 is better-off if it does not enter. However, for still larger variance in market I, see case II.7, we lose the (0,1) equilibrium. Since firm 2 will not observe exact market I demand, it will base its decision on a huge demand variance which given the one plant strategy of firm 1, firm 2's best response is not to enter. The above examples are made to give us an idea of how the equilibrium can change given incomplete information. These results imply that how different $E(\tilde{a}_j)$ is from $a_j$, $j=1, 2$ can affect the market structure equilibrium. If the difference $(a_j - E(\tilde{a}_j))$ is negatively "big"

9. I omit mixed equilibria in the analysis.

enough, the incomplete information equilibrium have more number of plants compared to under complete information. If the difference is positively "big" enough, the incomplete information equilibrium have less total number of plants.

Depending on what total country welfare is for the different possible equilibria, there is role for government to "spread" information regarding demand size because this can affect industry market structure equilibrium. If total welfare is higher under the two-firm exporting duopoly (1,1), given asymmetric information, then government informational or promotional campaigns can be conducted to ensure that the industry achieve a (1, 1) equilibrium. Alternatively, if total country welfare, for example, is higher with a (2, 2) equilibrium, then, governments have incentives to misrepresent the actual size of demand for a given good to increase their country's welfare.

## V. Conclusion

Horstmann and Markusen endogenized market structure and showed that there is room for trade/tax policy in shaping industry market structure. First they showed what a particular industry's market structure equilibrium will be given demand and cost conditions. Then, they showed how industry market structure can change due to firm reactions to changes in tariff or tax policies; for example, small tax changes generate large welfare changes by changing the equilibrium market structure. This paper sought to extend their analysis by introducing incomplete information between the two firms. Using their example, I showed that depending on the "quality" of information firms have, equilibrium market structure can be different from the full information one. Therefore, manipulation of market structure via trade or tax policies might not be as straightforward as HM's model predict. Governments, in addition to finding the optimal tax or tariff levels consistent with a desired market structure, also has to consider what and how much information foreign firms have about demand conditions. Informational campaigns are warranted if by doing so total country welfare increases given changes in industry structure.

## Appendix A
## Derivation of Equation (9)

In the second stage of the game, firm 1's strategy is to produce $\sigma: A_I \rightarrow R_+^1$, where $\sigma$ is the amount produced for the local market and is a function of the size of demand in the country, $a_I \in A_I$. It simultaneously decides on $x^F \in R_+^1$, where $x^F$ is the amount of FDI production in country $II$ by firm 1. Similarly, firm 2 decides on $\tau: A_{II} \rightarrow R_+^1$, where $\tau$ is the amount produced by firm 2 for its local market; this is a function of the size of the market $a_{II} \in A_{II}$. For country I, it produces $y^F \in R_+^1$, where $y^F$ is the amount of FDI production by firm 2.

Firm 1 chooses $\sigma(a_I)$ and $x^F$ to maximize $\Pi_1((\sigma(\cdot), y^F), (x^F, \tau(\cdot)))$. Subtracting $2G+F$ from $\Pi_1(\cdot)$, I get

$$= \int_{A_I} (a_I - b\sigma(a_I) - by^F - m)\sigma(a_I) f(a_I) da_I + \int_{A_{II}} (a_{II} - b\tau(a_{II}) - bx^F - m) x^F f(a_{II}) da_{II}$$

$$= \int_{A_I} (a_I - b\sigma(a_I) - by^F - m)\sigma(a_I) f(a_I) da_I + [E(\tilde{a}_{II}) - bE(\tau(\tilde{a}_{II})) - bx^F - m] x^F.$$

Firm 2 solves a similar problem. It chooses $\tau(a_{II})$ and $y^F$ to maximize $\Pi_2((\sigma(\cdot), y^F), (x^F, \tau(\cdot)))$. Likewise, subtracting $2G+F$ from $\Pi_2(\cdot)$, one obtains the following

$$= [E(\tilde{a}_I) - by^F - bE(\sigma(\tilde{a}_I)) - m] y^F + \int_{A_{II}} (a_{II} - b\tau(a_{II}) - bx^F - m)\tau(a_{II}) f(a_{II}) da_{II}.$$

Taking first order conditions, I obtain the following reaction functions:

$$\sigma(a_I) = \frac{a_I - by^F - m}{2b}; \quad x^F = \frac{\bar{a}_{II} - bE(\tau) - m}{2b};$$

$$\tau(a_{II}) = \frac{a_{II} - bx^F - m}{2b}; \quad y^F = \frac{\bar{a}_I - bE(\sigma) - m}{2b}.$$

Denote $E(\tilde{a}_j)=\bar{a}_j$, $j=I$ and $II$; $E(\sigma(\tilde{a}_I))=E(\sigma)$ and $E(\tau(\tilde{a}_{II}))=E(\tau)$. Notice that firms' foreign market reaction functions are functions of $\bar{a}_I$ and $\bar{a}_{II}$ and not $a_I$ and $a_{II}$ because of incomplete information. Solving the relevant reaction functions result in the following output levels:

$$\sigma=\frac{a_I-m}{2b}-\frac{\bar{a}_I-m}{6b};\ x^F=\frac{\bar{a}_{II}-m}{3b};$$

$$\tau=\frac{a_{II}-m}{2b}-\frac{\bar{a}_{II}-m}{6b};\ y=\frac{\bar{a}_I-m}{3b}.$$

Firm output levels in both markets depend on the expected values of demand. The larger (smaller) are these expected values, the larger (smaller) the output levels of firms. Substituting these levels to firm 1's profit function, I get $\Pi_1(\cdot)$

$$=\int_{A_I}\left[a_I-b\left(\frac{a_I-m}{2b}-\frac{\bar{a}_I-m}{6b}\right)-b\left(\frac{\bar{a}_I-m}{3b}\right)-m\right]\left(\frac{a_I-m}{2b}-\frac{\bar{a}_I-m}{6b}\right)f(a_I)\ da_I$$

$$+\left[\bar{a}_{II}-b\left(\frac{\bar{a}_{II}-m}{3b}\right)-b\left(\frac{\bar{a}_{II}-m}{2b}-\frac{\bar{a}_{II}-m}{6b}\right)-m\right]\left(\frac{\bar{a}_{II}-m}{3b}\right)-F-2G$$

$$=\frac{1}{b}\int_{A_I}\left[(a_I-m)-\left(\frac{a_I-m}{2}-\frac{\bar{a}_I-m}{6}\right)-\left(\frac{\bar{a}_I-m}{3}\right)\right]f(a_I)\ da_I+\frac{1}{b}\left(\frac{\bar{a}_{II}-m}{3}\right)^2-F-2G$$

$$=\frac{1}{b}\int_{A_I}\left[\left(\frac{a_I-m}{2}\right)-\left(\frac{\bar{a}_I-m}{6}\right)^2f(a_I)\ da_I\right]+\frac{1}{b}\left(\frac{\bar{a}_{II}-m}{3}\right)^2-F-2G$$

$$=\frac{1}{b}\int_{A_I}\left[\frac{a_I-m}{3}+\frac{1}{6}((a_I-m)-(\bar{a}_I-m))\right]^2f(a_I)\ da_I+\frac{1}{b}\left(\frac{\bar{a}_{II}-m}{3}\right)^2-F-2G$$

$$=\frac{1}{9b}\left[E(\tilde{a}_I-m)^2+\frac{1}{4}V(\tilde{a}_I)+E(\tilde{a}_I)^2-(\bar{a}_I)^2+(\bar{a}_{II}-m)^2\right]-F-2G$$

This is equation (9) in the text. Firm 2's profits can be similarly derived.

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