A FRAMEWORK FOR EXAMINING DIRECT FOREIGN INVESTMENT IN THE PROCESSED FOOD INDUSTRY

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Introduction

Handy and Seigle cite a number of reasons why processed food firms choose to invest directly in foreign markets rather than produce in the domestic market and trade. By locating within foreign markets, firms reduce transportation costs and more effectively deal with local regulatory agencies. Also, firms are better able to keep abreast of the economic conditions in the local market and better tailor the product to the market. Reed and Marchant add that firms invest directly to exploit technological or managerial advantages. On the other hand, firms transacting in an unfamiliar market may be at a comparative disadvantage (Handy and McDonald).

Trade theory teaches that economies with widely different factor endowments experience gains from trade, yet Foreign Direct Investment (FDI) occurs predominantly between economies with similar endowments. Recent theoretical work suggests FDI is inversely related to the disparity of factor endowments, and positively related to the degree of uncertainty associated with the quality of output (Ethier). However, uncertainty is treated in a specialized and narrow manner in this static model, making the analysis less than general. Another line of argument suggests the degree of substitution between capital and labor partly determine the demand for foreign capital. An increase in the foreign wage discourages investment abroad unless labor can be substituted for capital. Also, an increase in foreign labor's productivity increases the productivity of foreign capital unless there is a strong substitution of capital for labor (Cushman). While lags are included to capture some dynamics, the lack of an explicit optimization framework prohibits the treatment of uncertainty.

The present paper attempts to bridge the gap between some of these theoretical arguments and to explain some stylized observations on FDI in the food processing industry. The analysis provides a justifiable reason for uncertainty: the unknown future state a foreign market. Four results of the analysis are noteworthy.

First, if operating in a foreign market reduces the adjustment cost of capital, firms will be more responsive to changes in economic conditions in the market and more likely to invest abroad. Capital is defined below as any input other than the raw farm commodity, so an increase in labor productivity in the foreign market can reduce the adjustment cost of capital. Second, if foreign investment provides added economies of scale, firms will be more responsive to the state of the foreign market, and more likely to undertake foreign investment. Third, as a firm gains experience in producing and marketing in a foreign market, the firm lowers its marginal costs and becomes more responsive to the market. This result provides a formal argument not only as to why foreign investment occurs predominately between similar economies, but also why joint ventures or some other arrangement might be pursued prior to investment abroad. Fourth, if locating a plant in a foreign market provides more precise information on the state of the foreign market, firms will be more responsive to the information.

At the heart of the analysis is a dynamic and stochastic model of a multinational food firm. The comparative dynamic results provide a framework for interpreting time series data on direct foreign investment. A sensitivity analysis on key parameters provides a ranking of the factors motivating FDI in the food processing industry.

Economic Model

The theory below formally describes the optimization problem of a multinational food processing and marketing firm. The comparative dynamic exercises solve for the change in the response to economic signals when the parameters of the objective function change, as they might if a firm built a plant in a foreign market.

In the simplest version of the problem, the manager of a multinational food processing plant located in the home market has complete information and chooses a sequence of farm inputs, $\{f_t\}$, so as to

$$(1) \quad \max E\,(\textstyle\sum_{t=0}^{\infty}\beta^t\pi_t) \mid I_o$$

where,

$$(2) \quad \pi_t = p_t\alpha\, f_t - w_t f_t - (h/2)\,f_t^2 - (d/2)\,(f_t - f_{t-1})^2.$$

and where β is a discount factor; and where E_o is a mathematical expectations operator taken with respect to the distribution of (p_{t-j}, w_{t-j}, f_{t-1-j}) for $j \geq 0$, and conditioned on an information set, I, available to managers at time 0. The solution to this problem induces a distribution of current period input demand (i.e., f_t).

Equation (2) indicates the manager of a plant that produces and markets food in the home market begins each period t by deciding on the level of farm inputs, f, to process into food, q, according to the production process given by $q = \alpha f$, where α is a technical parameter. The plant receives revenues $p_t\alpha f_t$ when it markets the good in time t, where p_t is the home market's price of food in time t. The firm pays $w_t f_t$ in time t for farm input, where w_t is the price of the farm input.

In addition, the plant consumes capital for any scale of production, and it consumes capital when it adjusts production levels from the previous period. Consider the term $(h/2)f_t^2$ in equation (2). Here h is a returns to scale parameter that defines the capital consumption function, $(h/2)f_t^2$. In particular if $h = 0$, the firm faces long-run constant returns to scale (Clark and Reed); and for $h > 0$, the firm faces long-run decreasing returns to scale. Consider the function, $(d/2)(f_t - f_{t-1})^2$ in equation (2). Here d is a cost-of-adjustment parameter of the function which maps input adjustment, $(f_t - f_{t-1})$, into capital consumption, $(d/2)(f_t - f_{t-1})^2$. The larger the cost-of-adjustment parameter d, the more capital is consumed for a given change in the level of operation. If capital rents at the fixed unit cost g, $g(h/2)f_t^2$

and $g(d/2)(f_t - f_{t-1})^2$ represents capital costs. The quadratic specifications of the cost-of-adjustment and scale economy terms in equation (2) deliver a closed-form solution that facilitates a comparative dynamic analysis.

To close the problem, the manager is assumed to have complete information in the sense that she sees current period output and input prices, and can form an expectation on these future prices. E denotes a mathematical expectations operator taken with respect to the distribution of all of the variable sequences of the problem. The complete information set, I_t, available to the firm at time t is

$$(3) \quad I_t = \{p_t, p_{t-1}, \ldots, w_t, w_{t-1}, \ldots, f_{t-1}, f_{t-2}, \ldots\}.$$

h, d $\geq$ 0 represent the sufficient conditions for a solution to the dynamic programming problem given by equations (1)-(3) (Sargent, 1987a). Given the sufficient conditions, the home firm's solution follows (Sargent, 1987a):

$$(4) \quad f_t = \lambda f_{t-1} + \frac{\lambda}{d} \sum_{i=0}^{\infty} (\beta\lambda)^i \, E(\alpha p_{t+i} - w_{t+i}) \,|\, I_t$$

where,

$$\lambda = \frac{1}{2\beta} \left(-\varphi - (\varphi^2 - 4\beta)^{1/2}\right)$$

and

$$\varphi = \frac{-(d(1+\beta) + h)}{d}.$$

Propositions 1 and 2 describe how a foreign plant's response to input and output price might differ from the home plant's response if two key parameters differ.

PROPOSITION 1:

Given the firm's optimization problem presented in equations (1) to (3), the input demand, and hence the output response of firms to the current period effective price, $(\alpha p_t - w_t)$, is inversely related to the magnitude of the d parameter.

PROOF: See Appendix.

PROPOSITION 2:

Given the firm's optimization problem presented in equations (1) to (3), the input demand and output response of firms to the current period effective price, $(\alpha p_t - w_t)$, is inversely related to the value of the h parameter.

PROOF: See Appendix.

Propositions 1 and 2 describe two reasons why firms might undertake foreign direct investment. First, if owning and operating a firm in a foreign market reduces adjustment costs, the parameter d falls and Proposition 1 states the firm becomes more responsive to economic conditions than the home firm. Because a new plant usually embodies state-of-the-art technology, capital adjustment cost of a foreign plant would arguably fall. Proposition 1 indicates that such a firm would be more responsive than a home firm (that trades or pursues a joint venture) to economic conditions in the foreign market. Second, if a plant realizes scale economies by locating in the foreign market, it will be more responsive to local conditions than a home firm. This may explain why food processing and marketing firms attempt to locate in 'large' markets.

Handy and McDonald note that domestic firms might initially be disadvantaged because of the lack of experience and knowledge of the local markets. However, as firms gain experience, this diseconomy may be partly overcome. The following learning-by-doing example formally captures the feature that marginal costs fall over time as the firm becomes more established in the market. In particular, suppose the firm's problem is

(5) $\max E\ (\sum_{t=0}^{\infty}\beta^{t}\pi_{t}) \mid I_{0}$

where,

(6) $\pi_t = p_t\alpha\ f_t - w_t f_t - (h/2)f_t^2 - (d/2)(f_t - f_{t-1})^2 + c[f_{t-1} + \ldots + f_{t-T}]\ f_t.$

The learning-by-doing specification of equation (6) represents a variation of the discrete time problem proposed by Sargent (1987a). The specification captures the notion that marginal costs of current output fall with cumulated, but finite past output. The specification is a discrete time version of the model used by Spence, who viewed the learning curve as a barrier to entry and solved for the number of entrants under different learning-by-doing parameters. In contrast to the study by Spence, the analysis below simply states that firms with higher values of c can more effectively compete in foreign markets.

In the above specification, the c parameter measures the extent to which learning-by-doing in the foreign market reduces marginal costs. Plants located in markets similar to the home plant (e.g., U.S. builds a plant in Western Europe) are assigned 'large' values of c. The value of c measures the comparative advantage of producing and marketing in a particular foreign market. Proposition 3 demonstrates that the larger this comparative advantage, the larger the long-run (steady-state) response of the firm.

PROPOSITION 3:
Given the firm's optimization problem presented in equations (5) and (6), the long-run (steady-state) response to the effective price is positively related to the value of the c parameter.
PROOF: See Appendix.

Proposition 3 is a long-run result that provides a formal reason as to why firms invest in foreign markets similar to the home market: it lowers marginal costs. Firms located in an economy similar to the home economy would enter with a higher value of c than firms located in a very different economy. Joint ventures of the home firm with a foreign firm could be interpreted as an activity that increases the c parameter, and would give the firm a comparative advantage should it choose to invest in the market.

Another reason firms invest directly in foreign markets is that it enables them to more accurately gauge economic conditions in the market so it can respond more quickly to changing economic conditions (Handy and Seigle; Reed and Marchant). The ability of a firm to make better inference on underlying economic conditions from available data leads to an interesting signal extraction problem.

In particular, suppose firms have less than complete information on input prices, w_t, or demand shifts, s_t in the sense firms cannot observe these sequences directly. What firms do observe is data that measure w_t or s_t with error or with 'noise'. The idea below is that as firms locate geographically closer to a market the variance of the noise component of the data diminishes, so the 'noisy' signal becomes a more reliable indicator of the unobserved input price or demand shift. The result below demonstrates that as the variance of the noise diminishes, firms are more responsive (in terms of input demand and output response). The more reliable the signal received by the firm, the greater is the firm's supply response. In perhaps the most noteworthy application of this principle, Lucas (1973) studied the response of an economy in which agents receive price signals rather than direct observations on price.

To highlight the signal extraction aspect of the problem, set c = 0 in the above specification, and assume the firm is a monopoly facing a market demand function,

$$p_t = A_o - A_1 \alpha f_t + s_t.$$

Again s_t denotes the demand shift, and A_i are demand function parameters. In contrast to the above two problems, firms have available a less-than-complete information set, Ω_t which will be defined below. These assumptions imply the firm chooses the farm input sequence to

(7) $\max E(\sum_{t=0}^{\infty}\beta^t\pi_t)|\Omega_o$

where,

(8) $\pi_t = -A_1\alpha^2 f_t^2 + \theta_t f_t - (h/2)f_t^2 - (d/2)(f_t - f_{t-1})^2$

and where $A_o = 0$ and $\theta_t \equiv (\alpha s_t - w_t)$. θ_t is a state of nature variable consisting of a linear combination of the demand shifter and input prices. Firms know the θ_t sequence follows

(9) $\theta_{t+1} = \rho\theta_t + \epsilon_{t+1}$.

ε_{t+1} is a random variable satisfying $E\varepsilon_t = 0$ for all t, $E\varepsilon_t^2 = \sigma_\varepsilon^2$, and $E\varepsilon_t\varepsilon_s = 0$ for $s \neq t$. Firms never observe the true input prices and shifts in demand because these data are received with noise. However, they do see

(10) $z_t = \theta_t + u_t$,

where u_t is a random variable satisfying $Eu_t = 0$ for all t, $Eu_t^2 = \sigma_u^2$, and $Eu_tu_s = 0$ for $s \neq t$, and $E\varepsilon_t u_s = 0$ for all s and t. The question is: how does the reduction of noise in the data alter a firm's response to the data? Formally, how does a firm respond to z_t when σ_u^2 falls?

To close the model, firms in this formulation of the problem have a less-than-complete information set

(11) $\Omega_t = \{z_t, z_{t-1}, \ldots, f_{t-1}, f_{t-2}, \ldots\}$.

on which expectations are conditioned. This set contrasts with the complete information set, which for this problem would be

(12) $\Omega_t = \{\theta_t, \theta_{t-1}, \ldots, f_{t-1}, f_{t-2}, \ldots\}$.

In this setup firms know $(\sigma_u^2, \sigma_\varepsilon^2, \rho)$.

Equations (7)-(11) specify the less-than-full information problem of the monopoly firm. Provided $\{A_1\alpha^2 + (1/2)h + (1/2)d\} > 0$, and $d > 0$, the solution is

(13) $f_t = \gamma\, f_{t-1} + \frac{\gamma}{d} \sum_{i=0}^{\infty} (\beta\gamma)^i E(\theta_{t+i}|\Omega_t)$.

This solution is not a decision rule because the expression depends on the present and future expectations of unobserved variables. Defining $M_t \equiv E_t(\theta_t|\Omega_t)$, the above assumptions imply

$$\sum_{i=0}^{\infty} (\beta\gamma)^i E(\theta_{t+i}|\Omega_t) = \left(\frac{1}{1-\beta\gamma\rho}\right) M_t$$

so the decision rule is

(14) $f_t = \gamma\, f_{t-1} + \mu M_t$

where $\mu = \gamma[d(1 - \beta\rho\gamma)]^{-1}$. Standard formulas (Kalman filter) deliver a law of motion for M_t,

(15)
$$\begin{aligned} M_t &= (\rho - \rho K_t)\, M_{t-1} + \rho K_t \theta_t + \rho K_t u_t \\ &= (\rho - \rho K_t)\, M_{t-1} + \rho K_t z_t \end{aligned}$$

where

(16) $$K_t = \frac{\rho^2 \Sigma_{t-1} + \sigma_\varepsilon^2}{\rho^2 \Sigma_{t-1} + \sigma_u^2 + \sigma_\varepsilon^2}$$

and

(17) $\Sigma_t \equiv E(\theta_t - M_t)^2 = (\rho - \rho K_t)^2 \Sigma_{t-1} + (1-K_t)^2 \sigma_\varepsilon^2 + K_t^2 \sigma_u^2$.

Equations (14) and (15) define the responsiveness of input demand to changes in available data. Equations (16) and (17) indicate this response changes as the variance of the noise in the data changes. Proposition 4 states this result more formally.

PROPOSITION 4. The response of input demand to observed data, z_t, is inversely related to the variance of the noise in the data, σ_u^2.
PROOF: See Appendix.

The economic intuition behind this proposition is clear enough: the more reliable the available data, the more firms rely on the data, and the more vigorously firms respond to changes in the data. If locating within a foreign market provides more reliable economic data, Proposition 4 indicates the firm will be more responsive to this data.

Analysis of the pair of equations given by (15) and (17) establishes the following two properties. First, for any value of ρ, and starting with an initial value of $\Sigma \geq 0$, leads to a convergent sequence of $\{\Sigma_t\}$ as $t \to \infty$. Second, $K \equiv \lim_{t\to\infty} K_t$ is less than unity in absolute value (Sargent, 1987a).

Defining $\eta \equiv (\rho - \rho K)$, and noting the definition of μ given above, the convergent, less-than-full information solution is

$$f_t = \gamma f_{t-1} + \mu M_t$$

$$(18) \quad M_{t+1} = \eta M_t + \rho K\theta_{t+1} + \rho K u_{t+1}$$

$$\theta_{t+1} = \rho\theta_t + \varepsilon_{t+1}.$$

Because of the added volatility introduced into the environment, firms with less-than-full information may be faced with higher costs than firms with full information. The less-than-full-information system given by (18) can be expressed as

$$(19) \quad (1-\gamma L)(1-\rho L)(1-\eta L) f_t = \mu\rho K\varepsilon_t + \mu\rho K(1-\rho L) u_t,$$

where L denotes the lag operator (i.e., $L^i x_t = x_{t-i}$ for any integer i). In contrast, the full-information representation is

(20) $(1-\gamma L)(1-\rho L)f_t = \mu\varepsilon_t$.

Representations (19) and (20) describe how the serially correlated input demand is related to the one or two uncorrelated shocks in the systems. In both cases, the persistence of input demand following a shock is determined by the magnitude of the ρ and γ parameters. In other words, the persistence of input demand (and output and prices) is positively related to the serial correlation of input price and demand shifts. The persistence of input demand also varies positively with adjustment costs because it is costly to change inputs, and γ is positively related to the d parameter (see Proposition 1). There is an additional source of persistence in the less-than-full-information solution (given by (19)). This added persistence arises from the inability of firms to measure the underlying economic variables; and it adds volatility to input demand. In particular, the η parameter varies directly with σ_u^2, the variance of the noise in the data. The less reliable the data on economic conditions, the more volatile will be input demand. Equation (19) indicates noisy data creates confusion on the part of firms as they respond to a transitory shock, u_t, as though it were the persistent shock, ε_t. In both the full- and partial-information solutions, the model implies input demand follows a higher-than-first-order difference equation, so the response of input demand to a shock can accumulate and then diminish.[1]

The added volatility under the less-than-full information scenario implies firms may face higher total adjustment costs than if they were endowed with full information. The result provides insight into Handy and McDonald's finding of a positive correlation between firms that invest in research and development and firms that invest directly in foreign markets. The above result suggests that firms engaging in

[1]The ideas presented above are made by Townsend for a different, but similar model.

foreign direct investment have first-hand knowledge of the advantages of reducing noise in market data.

An Illustration

The previous section describes four reasons why food processing firms might choose to undertake foreign direct investment. The results were unified by a common principle: if a foreign market provides opportunities for firms to produce and market food more efficiently, locating in that market enables the multinational to be more responsive to the market's economic conditions. This section illustrates these principles with two numerical examples and a sensitivity analysis.

The problem faced by a multinational food processing firm with complete information is to choose the sequence of farm inputs, $\{f_t\}$, so as to:

$$(21) \quad \max E\,(\textstyle\sum_{t=0}^{\infty}\beta^t\pi_t)\,|I_0$$

subject to

$$w_{t+1} = v_1 w_t + v_2 w_{t-1} + \varepsilon_{1,t+1} \qquad (\textit{commodity price})$$

$$s_{t+1} = v_3 s_t + v_4 s_{t-1} + \varepsilon_{2,t+1} \qquad (\textit{demand shift})$$

where

$$\pi_t = -A_1\alpha^2 f_t^2 - w_t f_t - (h/2)f_t^2 - (d/2)(f_t - f_{t-1})^2 + c[f_{t-1} + f_{t-2} + f_{t-3} + f_{t-4}]f_t.$$

and

$$I_t = \{w_t, w_{t-1}, \ldots, s_t, s_{t-1}, \ldots, f_{t-1}, f_{t-2}, \ldots\}.$$

Notice this specification includes the economies of scale term, the costs of adjustment term, and the learning-by-doing term. The values of the five structural parameters chosen for this analysis are $[h, d, \alpha, A_1, c]' = [0.5, 2.5, 1.0, 2.0, 0.1]'$; and the value of the four state parameters chosen for this analysis are $[\nu_1, \nu_2, \nu_3, \nu_4]' = [1.1, -0.18, 0.7, -0.28]'$. The reduced-form solution for farm inputs that solves this particular dynamic programming problem is[2]

$$f_t = 0.307 f_{t-1} + 0.016 f_{t-2} + 0.015 f_{t-3} + 0.012 f_{t-4}$$
$$- 0.175 w_t + 0.010 w_{t-1} + 0.171 s_t - 0.015 s_{t-1}.$$

Hence, a one unit increase in current farm price (w_t) decreases current input demand by 0.175, and a one unit increase in the current demand shifter (s) increases input demand by 0.171 (and output by 0.171).

The five structural parameters and the four state parameters formally describe a food processing firm located in a home market. Presumably another set of nine parameters will describe a new, state-of-the-art food processing firm located in a foreign market. The obvious question is: how much more responsive will the new firm be in the new market? This question motivates the comparative dynamics exercise.

The numeric parameters of the above reduced form represent the response of firms to lagged farm input (f_{t-j}), current and lagged farm price (w), and current and lagged demand shift (s). Table 1 reports the percentage change in each of the eight reduced form parameters due to a one percent increase in three (of the five) parameters of the firm's objective function. A positive sign indicates the input demand (and output supply) response becomes more elastic; a negative sign indicates the input demand response becomes less elastic as each of the three parameters of the objective function increase.

The results of Table 1 suggest reductions in the cost-of-adjustment most significantly alters the multinational's ability to respond to input prices and demand shifts. In particular, the results of Table 1 suggest that for each one percent reduction in cost of adjustment, the multinational will be approximately 22.36 percent more

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[2] Evidently, this set of parameters satisfy the transversality conditions, as the Ricatti equations converge to a solution in a small number of iterations (see Sargent, 1987b).

responsive to current period farm price, and approximately 23.86 percent more responsive to current period shifts in consumer demand.

The results of Table 2 apply to the case in which the firm never sees actual farm prices or consumer demand shifts, but observes these data with error. In particular, it observes data on farm prices, z_{1t}, and it observes data on demand shifts, z_{2t}. Again, these data measure the actual input price and actual demand shift with errors u_{1t} and u_{2t}. The question is: how does the response to z_1 and z_2 change when the variance of the noise in the data changes?

To answer this question, consider the above described firm as observing noisy data on demand shifts and farm prices in the foreign market. More formally, consider the optimization problem in which the firm is assumed to choose the sequence of farm inputs $\{f_t\}$ so as to:

$$(1) \quad \max E\,(\Sigma_{t=0}^{\infty}\beta^t\pi_t)\,|\Omega_0$$

subject to

$$w_{t+1} = \nu_1 w_t + \nu_2 w_{t-1} + \varepsilon_{1,t+1}$$

$$s_{t+1} = \nu_3 s_t + \nu_4 s_{t-1} + \varepsilon_{2,t+1}$$

where π_t is defined exactly as in the full information problem, but the information set, Ω_t, in this case is

$$\Omega_t = \{z_{1,t}, z_{1,t-1}, \ldots, z_{2,t}, z_{2,t-1}, \ldots, f_{t-1}, f_{t-2}, \ldots\}.$$

where,

$$z_{1,t} = w_t + u_{1,t}$$
$$z_{2,t} = s_t + u_{2,t}.$$

This less-than-full information problem differs from the full information specification above in that data on input price (i.e., $z_{1,t}$) rather than the input price, and data on demand shifts (i.e., $z_{2,t}$) rather than the demand shift are elements of the firm's information set.

To complete the specification of the less-than-full information problem, one must describe the moments of the error terms. The measurement error vector corresponding to demand shifts and input prices, $u_t \equiv [u_{1,t}\ u_{2,t}]'$ is assumed to satisfy $E(u_{1,t}\ u_{1,s}) = E(u_{2,t}\ u_{2,s}) = E(u_{1,t}\ u_{2,s}) = 0$ for $s \neq t$, and $E(u_t u_t') = \Psi$ for all t. While contemporaneously correlated, these errors are serially uncorrelated. Diagonal elements of Ψ measure the variance of the noise in the data observed by firms. To address the question of how firms respond to changes in the uncertainty of observed data, the model framework measures changes in the coefficients of a reduced form due to changes in the two diagonal elements of Ψ. Furthermore, define $\varepsilon_t = [\varepsilon_{1,t}\ \ \varepsilon_{2,t}]'$, and suppose $E(\varepsilon_{1,t}\ \varepsilon_{1,s}) = E(\varepsilon_{2,t}\ \varepsilon_{2,s}) = E(\varepsilon_{1,t}\ \varepsilon_{2,s}) = 0$ for $s \neq t$, and $\Lambda = E(\varepsilon_t\ \varepsilon_t')$. Elements of the u_t vector are assumed to be orthogonal to elements of the ε_s vector for all s and t. Using the same values of the nine parameters that described the complete-information problem above, and assigning

$$\Psi = \begin{bmatrix} 0.7 & 0.3 \\ 0.3 & 0.2 \end{bmatrix} \qquad \Lambda = \begin{bmatrix} 0.3 & 0.4 \\ 0.4 & 0.8 \end{bmatrix},$$

the equilibrium input demand function for this less-than-complete information version of the problem is

$$\begin{aligned} f_t = {} & 0.307 f_{t-1} + 0.016 f_{t-2} + 0.015 f_{t-3} + 0.012 f_{t-4} \\ & - 0.175\ E(w_t|\Omega_t) + 0.010\ E(w_{t-1}|\Omega_{t-1}) \\ & + 0.171\ E(s_t|\Omega_t) - 0.015 E(s_{t-1}|\Omega_{t-1}). \end{aligned}$$

with

$$\begin{aligned} E(w_t|\Omega_t) = {} & .694\ E(w_{t-1}|\Omega_{t-1}) - .147\ E(w_{t-2}|\Omega_{t-1}) - .135 E(s_{t-1}|\Omega_{t-1}) \\ & + .024\ E(s_{t-2}|\Omega_{t-2}) + .406\ z_{1,t} - .033\ z_{1,t-1} + .135\ z_{2,t} - .023\ z_{2,t-1} \end{aligned}$$

$$\begin{aligned} E(s_t|\Omega_t) = {} & .056\ E(w_{t-1}|\Omega_{t-1}) - .021\ E(w_{t-2}|\Omega_{t-1}) + .367 E(s_{t-1}|\Omega_{t-1}) \\ & - .156\ E(s_{t-2}|\Omega_{t-2}) - .056\ z_{1,t} + .021\ z_{1,t-1} + .733\ z_{2,t} - .124\ z_{2,t-1} \end{aligned}$$

The above results provide a measure of the firm's response to available, but noisy data, z_1 and z_2. The results indicate the firm's response to expected farm price (i.e., $(\partial/\partial Ew_t|\Omega t)f_t$) in the current period is -0.175, and its response of expected farm price to available data on farm price (i.e., $(\partial/\partial z_{1t})\ E(w_t|\Omega_t)$) is .406. Hence this firm's response to available farm price data (i.e., $(\partial/\partial z_{1t})f_t$) is -.071 (= -.175 x .406).

Table 2 reports the percentage change in these responses when the variance of the noise associated with input (farm) price **and** demand shifts increase by one percent. A positive sign indicates the response coefficient becomes more elastic; a negative sign indicates the response coefficient become less elastic with respect to an **increase** in the variances of both noise components. In particular, the results of Table 2 suggest that for each one percent increase in both the variance of noise in the farm price **and** the variance of noise in the demand shift, firms reduce their response to current period farm price by 0.5 percent, and reduce their response to current period consumer demand shifts by 0.25 percent.

It is important to emphasize that the magnitude of the results presented in Tables 1 and 2 depend on the assigned values of the structural parameters. The results do suggest that econometric estimates of the structural parameters could provide important information regarding changes in responsiveness of firms that invest in foreign markets.

Conclusions

This paper studies four features of direct foreign investment that might motivate a food processing and marketing firm to open a plant in a foreign market. These reasons are: the state-of-the art technology may reduce capital adjustment costs; the firm may realize economies of scale in the market; a firm located in a foreign market similar to the home market may be able to learn more quickly than a firm located in a dissimilar market; and a firm will receive more accurate information on the foreign market by locating in the market. The dynamic and stochastic problems specified in this paper assigned key parameters to each of these reasons. The sensitivity analysis attributes changes in responsiveness of a firm located in a foreign market to each of the four reasons. For the pre-assigned structural parameters, the results of Table 1 and 2 indicate that modernization of the plant provides the strongest argument for foreign direct investment. Although the results of the sensitivity analysis depend on the values of the pre-assigned structural parameters, the methodology suggests econometric estimates of the structural parameters may provide important insight into the motivation of food firms locating in foreign markets.

It appears that estimation of this set of parameters is within reach (Gallant, Burmeister and Wall, Townsend). Research is currently underway that is designed to estimate the distribution of the parameters describing domestic food processing firms. With this distribution a more detailed sensitivity analysis might be performed.

Table 1. Percentage change in reduced-form coefficients due to a one percent increase in objective function coefficients[3]

	Objective Function Coefficients:		
	h (Scale Economies)	d (Cost-of-Adjust)	c (Learning by-Doing)
Reduced Form Coefficients			
λ_1	-6.571	52.16	6.979
λ_2	-8.700	-26.37	104.7
λ_3	-7.909	-31.64	102.8
λ_4	-6.424	-43.44	101.3
ω_1	-9.632	-22.36	9.048
ω_2	-16.30	20.27	26.44
ω_3	-9.273	-23.86	7.317
ω_4	-15.91	19.72	23.49

[3]The reduced form is:

$$f_t = \lambda_1 f_{t-1} + \lambda_2 f_{t-2} + \lambda_3 f_{t-3} + \lambda_4 f_{t-4} + \omega_1 w_t + \omega_2 w_{t-1} + \omega_3 s_t + \omega_4 s_{t-1}.$$

Entries are percent changes in the reduced form coefficients due to a one percent increase in each of the three parameters of the firm's objective function. A positive sign indicates the reduced form input demand response becomes more elastic; a negative sign indicates the input demand response becomes less elastic with an increase. The results are computed by weighting numeric derivatives by the ratio of the original coefficients. These elasticities are computed around the point $[h, d, \alpha, A_1, c]' = [0.5, 2.5, 1.0, 2, 0.1]'$, and $[\nu_1, \nu_2, \nu_3, \nu_4]' = [1.1, -0.18, 0.7, -0.28]'$.

Table 2. Percentage change in reduced-form coefficients due to a one percent increase in the variance of the noise of farm prices and demand shifts.[4]

Reduced Form Coefficients	Percent Change in Response
ω_1	-0.5448
ω_2	-0.7882
ω_3	-0.2528
ω_4	-0.4639

[4]The reduced form is:

$$f_t = \lambda_1 f_{t-1} + \lambda_2 f_{t-2} + \lambda_3 f_{t-3} + \lambda_4 f_{t-4} + \omega_1 z_{1t} + \omega_2 z_{1t-1} + \omega_3 z_{2t} + \omega_4 z_{2t-1}.$$

where z_1 is the firm's observed data on farm price, and z_2 is the firm's observed data on consumer demand shifts. The results are found by computing the percent difference in the response coefficients before and after the diagonal elements of the Ψ matrix are increased by one percent. These elasticities are computed at the point $[h, d, \alpha, A_1, c]' = [0.5, 2.5, 1.0, 2, 0.1]'$, and $[v_1, v_2, v_3, v_4]' = [1.1, -0.18, 0.7, -0.28]'$.

Appendix

This appendix provides proofs for three propositions stated in the text.

PROPOSITION 1:

Given the firm's optimization problem presented in equations (1) to (3), the input demand, and hence the output response of firms to the current period effective price, $(\alpha p_t - w_t)$, is inversely related to the magnitude of the d parameter.

PROOF:

First, define $x_t = (\alpha p_t - w_t)$, and by setting i = 0 in equation (.) in the text, $(\partial/\partial x_t)\ f_t = \lambda/d$. The following proves $(\partial^2/\partial d\partial x_t) f_t < 0$.

By the arguments of Sargent (1987), $0 < \lambda < 1$. Noting that

$$sgn[\frac{\partial}{\partial d}(\frac{\lambda}{d})] = sgn[d(\frac{\partial\lambda}{\partial d})-\lambda]$$

it suffices to prove the negativity of the right-hand-side term. Given the definitions of λ and ϕ in the text, the proof follows the proof given by Reed (Appendix A).

PROPOSITION 2:

Given the firm's optimization problem presented in equations (1) to (3), the input demand and output response of firms to the current period effective price, $(\alpha p_t - w_t)$, is inversely related to the value of the h parameter.

PROOF:

For the above system, Proposition 2 claims,

$$(\partial/\partial h)(\frac{\lambda}{d})<0.$$

However, the solution and the sufficient conditions imply,

$$sgn[(\partial/\partial h)(\frac{\lambda}{d})] = sgn[\frac{\partial\lambda}{\partial h}]$$

The fact that

$$\frac{\partial\lambda}{\partial h} = -\frac{1}{2\beta}\left[\frac{\partial\varphi}{\partial h}\left(1 + \frac{\varphi}{\varphi^2 - 4\beta^{1/2}}\right)\right],$$

which by inspection is negative.

PROPOSITION 3:

Given the firm's optimization problem presented in equations (5) and (6), and the learning by doing cost efficiency, the long run steady state response to the steady state effective price increases as c increases.

PROOF:

For the above problem, the Euler equations are

$$\beta^T c\, f_{t+T} + \ldots + \beta^2 c\, f_{t+2} + \beta(c+d)E_t f_{t+1} - (\beta d + h + d) f_t + (d+c) f_{t-1}\; c\, f_{t-2} + \ldots$$

Defining,

$$\tau \equiv [h - c(T + \frac{(1-\beta^T)}{1-\beta})]$$

The steady state version of the Euler equations becomes

$$f = (1/\tau)(\alpha p - w)$$

Since $(\partial/\partial c)\tau < 0$, $(\partial/\partial c)(1/\tau) > 0$.

PROPOSITION 4. The response of input demand to observed data, z_t, is inversely related to the variance of the noise in the data, σ_u^2.

PROOF:

The above assumptions imply

$$\frac{\partial f_t}{\partial z_t} = \frac{\partial f_t}{\partial M_t}\frac{\partial M_t}{\partial z_t} = \alpha_1 \rho K$$

so,

$$\frac{\partial}{\partial \sigma_u^2}\left(\frac{\partial f_t}{\partial z_t}\right) = \alpha_1 \rho \frac{\partial K}{\partial \sigma_u^2} < 0$$

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