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INTERACTIONS BETWEEN DOMESTIC AND FOREIGN INVESTMENT

Guy V.G. Stevens and Robert E. Lipsey

Abstract

This paper studies both the domestic and foreign fixed investment expenditures of a sample of U.S. multinational firms. In addition to explaining empirically each type of investment, an important goal is to determine whether there are significant interactions between expenditures in the different locations.

Two types of interaction -- one, financial, and the other, production-based -- are explored theoretically and empirically. The financial interaction is the result of a model which assumes a risk of bankruptcy and its associated costs; under these circumstances, the firm faces an increasing cost of capital as a function of its debt/equity ratio. Domestic and foreign investment will be interdependent, since, in competing for finance, each affects the cost of capital in the other location. Production interactions can arise when, because of start-up costs or other factors that produce nonlinear cost functions, it may become profitable to shift production from the home to the foreign location.

The hypotheses are tested on a unique sample of micro-economic data covering the domestic and foreign operations of seven multinational firms for a period of 16 to 20 years. In general the firm-level investment functions fit reasonably well for both domestic and foreign expenditures. An interdependence between domestic and foreign investment was confirmed frequently through the finance side, but only once via production.

INTERACTIONS BETWEEN DOMESTIC AND FOREIGN INVESTMENT

Guy V.G. Stevens and Robert E. Lipsey[1]

I. Introduction

Rarely do studies or discussions of U.S. investment spending consider the fact that many U.S. firms are multinationals -- doing business in a number of countries simultaneously. This is so despite the fact that fixed investment expenditures abroad by U.S. multinationals reached over 35 percent of their domestic expenditures in 1977, and more than 20 percent of total domestic nonresidential private fixed capital formation.[2]

The purpose of this paper is to study both the domestic and foreign fixed investment expenditures of a sample of U.S. multinationals. In addition to explaining empirically each type of expenditure, we are

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1. The authors are, respectively, Senior Economist, Division of International Finance, Federal Reserve Board; and Professor of Economics, Queens College and the Graduate Center, City University of New York, and Research Associate at the National Bureau of Economic Research. We are indebted to the McGraw-Hill Company and, particularly, to Dr. Douglas Greenwald for supplying the basic data on which this study was based, and to Professor Robert Eisner for help in using the data for earlier years. Ksenia Kulchycky and Stanley Lewis provided able research assistance and programming at the National Bureau, while Catherine Fitzgerald, John Keniley and Aileen Liu did the same at the Federal Reserve Board. The acquisition and processing of the data at the National Bureau were carried out under contract #J9K 60021 from the U.S. Department of Labor, Bureau of International Labor Affairs. This paper represents the views of the authors and should not be interpreted as reflecting those of the Board of Governors of the Federal Reserve System, the National Bureau of Economic Research, or the U.S. Department of Labor.

2. For the relevant data on fixed investment expenditures of foreign affiliates of U.S. multinationals, see U.S. Department of Commerce (1981) and U.S. Department of Commerce (1985). The data for 1977 are reported above, rather than data for later years, because 1977 falls toward the end of the sample period for the regression results reported below.

particularly interested in determining whether there are significant interactions between investment expenditures in the different locations.

Earlier work in this area by Stevens (1969) and Severn (1972) found significant evidence of interactions between domestic and foreign investment. However, both studies were hampered by short time series and data limitations. The first problem necessitated reliance on cross-section regressions and the second frequently required the calculation of important variables as residuals (domestic investment, for example).

The present study attempts to augment and improve upon its predecessors by making theoretical improvements in the investment functions to be fitted, and by utilizing a unique sample of more current data. Permission to use data on the foreign and domestic operations of a sample of manufacturing firms gathered by the McGraw-Hill Company, under conditions that preserved the confidentiality of the data, allowed us to construct time-series for seven firms that spanned from sixteen to more than twenty years. Thus, for the first time, regressions are available for individual firms, covering a time-period starting in 1960 and continuing to the late 1970s.

II. Types of Interaction and the Evidence to Date

The degree and type of interaction one expects between domestic and foreign investment depends on the multinational firm's objective function and the constraints imposed upon it by financial markets and its production process. Concerning the former, it is possible to conceive of firms that so segregate and isolate their foreign operations that there can be no effect whatsoever of foreign operations on domestic. Statements or hypotheses such as "every tub on its own bottom" imply that foreign operations interact minimally with domestic. On the other hand, a more contemporary view of the multinational firm as an integrated, worldwide profit maximizing entity allows much more scope for interdependence. The important implication of interdependence or interaction is that variables related to one location will affect decisions in the others. Thus, for example, with interdependence a wholly new set of variables will appear in domestic investment functions, variables related to the firm's foreign operations.

Even if the multinational firm maximizes worldwide profits, certain further conditions must be fulfilled before interdependence, as defined above, occurs. Consider, for example, the case of a multinational facing a perfect market for finance and producing in two plants, one at home and one abroad, each of which is totally independent of the other in terms of inputs and outputs. In such a case, by definition there can be no interaction through the production side; moreover, the perfect financial market implies that the firm can raise unlimited amounts of capital at a constant rate of interest. Under such conditions it is intuitively clear, and can be easily proved [Stevens (1969)], that worldwide profit maximization implies no interdependence between domestic and foreign investment.

Relax any of the above stringent assumptions, however, and interdependence will occur. Suppose, for example, that because of the possibility of bankruptcy and the existence of costs associated with this state, the firm faces an increasing cost of capital -- say as a function of its debt/equity ratio. In this case, an increase in investment in either location will, **ceteris paribus**, raise the cost of capital for investment in the other location; thus the two decisions will be interdependent. Since our data are particularly useful for testing for this sort of interaction, the relevant theory and empirical tests are developed at some length in succeeding sections. Severn and Stevens based their tests for interdependence on similar financial interactions, finding for their sample periods considerable evidence of domestic variables (domestic output and cash flow) affecting foreign investment, and some evidence of foreign variables affecting domestic investment.

While interactions through the financial side are the ones we will emphasize, there are others that can operate through the production side. A number of quite different possibilities exist. If the domestic location produces components that are used as inputs to the foreign subsidiary's production operation, an increase in foreign demand will also increase demand for the domestically-produced component, thereby inducing domestic investment. On the other hand, if the increase in foreign demand is so large that it permits, or makes economical, a shift from assembly to complete production abroad, it could lead to a **decline** in the production of components at home and therefore to lower domestic investment. We attempt to test for these types of interaction, although our data are not well suited for the task; despite the availability of foreign and domestic sales, we have no data on an individual firm's production or costs in different locations, nor on exports from one location to another.

III. Theoretical Developments

In this section we attempt to develop theoretically two types of model that lead to interdependence between domestic and foreign investment. The most effort will go toward deducing the implications of a worldwide profit maximization model where the firm is subject to an increasing cost of debt as a function of the debt/equity ratio. A second model, that can be combined with the first, looks at the factors that are related to the switch-over of production from domestic plants to foreign subsidiaries.

Stevens (1969) developed a rudimentary model of investment interaction caused by a financial constraint. Because of the theoretical difficulties, the model excluded the possibility of debt finance, assuming that total investment was limited to the multinational firm's internally generated funds -- retained earnings plus depreciation. Moreover, the dividend decision was not integrated into the analysis, so the model never handled the intemporal aspects of profit maximization. In a recent paper, Stevens (1986) developed, in the context of a single location firm, a model that eliminated the drawbacks of the earlier model. In this section this latter model will be generalized to a multilocation firm which maximizes an appropriately discounted sum of worldwide profits, solving for the optimal paths of investment in each location and for overall debt and dividends. Because of the increasing cost of debt, to be motivated below, the model exhibits interdependence between domestic and foreign investment.

In Stevens (1986) the increasing cost of debt is based on the premise that lenders (as opposed to the firm's owners) foresee that increases in the firm's debt/equity ratio raise the risk of bankruptcy, and thus require a progressively higher interest rate as the debt/equity ratio rises. In that article, where the firm operates in only a single location, the firm's objective is to maximize the discounted stream of dividends (DIV) paid to shareholders. That objective, when appropriate substitutions and linearizations are made using the firm's cash flow identity, leads to the function appearing on the right hand side of equation (1):

$$\int_0^\infty e^{-\rho t}DIV(t)dt = \int_0^\infty e^{-\rho t}\{(1-\tau)[\alpha K - \beta K^2 - (\rho+\psi D/qK)D - q\delta K] - q\dot{K} + \dot{D}\}dt. \quad (1)$$

where: ρ = the firm's discount rate and the initial cost of debt
τ = the tax rate on corporate profits
q = the price of capital goods
δ = the depreciation rate of the capital stock
K = the level of the real capital stock (the firm's only asset)
D = the nominal value of the firm's debt
α, β, ψ = parameters related to the firm's demand curve and production function
$\dot{K}$, $\dot{D}$ = the rate of change of K and D respectively.

The quadratic function of K is a reduced form for the firm's total revenues, assuming a downward sloping linear demand curve and linear homogenous production function. The interest rate the firm pays on its debt is $(\rho+\psi D/qK)$, an increasing function of the debt to total assets ratio (directly related to the debt/equity ratio). Hereafter D/qK will often be denoted by the symbol Φ.

The firm's problem is to choose optimal paths of capital and debt so as to maximize (1). New equity in excess of profits is excluded; fixed investment must be financed by either debt or retained earnings.[3] Using optimal control methods to maximize equation (1), two necessary conditions must be satisfied -- two differential equations in the two unknowns, K and D. The first equation is just a form of the firm's

3. Except for some relatively small transactions involving take-overs, none of the firms discussed below made stock flotations during the sample period.

sources and uses of funds identity: [4]

$$q\dot{K} - \dot{D} = (1 - \tau)[\alpha K - \beta K^2 - (\rho + \psi\Phi)D - q\delta K] - DIV. \qquad (2)$$

The second necessary condition equates the marginal revenue product of capital to the marginal cost of finance. For that form of the model depicted in equation (1), the condition becomes:

$$\alpha - 2\beta K - q\delta = q(\rho + 2\psi\Phi - \psi\Phi^2), \text{ or, more familiarly,}$$

$$\alpha - 2\beta K = q(\rho + \delta + 2\psi\Phi - \psi\Phi^2), \qquad (3)$$

where the term $q(\rho+\delta)$ is the traditional neoclassical cost of capital.

In Stevens (1986) it is shown that the two necessary conditions lead to a particular type of investment function. For that part of the optimal path of capital where there are no jumps in the exogenous variables or parameters, the firm's investment can be represented as a stock adjustment process, with the rate of adjustment a variable function of the firm's internally generated cash flow. In this paper, however, we shall not rely on this derived investment function, which holds for only part of the optimal path, but on the identity (2) and the marginal conditions (3). Two types of empirical tests will be performed. First, we will test directly equation (3) and its variant for a multinational

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4. See Stevens (1986), pp. 7-11. In our simplified system, the left hand side of equation (2) is an expression for profits after taxes minus dividends, i.e. retained earnings. Since we assume that there are no flotations of equity, and no assets other than fixed capital, equation (2) states the identity that the value of asset changes equals the change in the value of debt plus retained earnings. This identity holds exclusive of capital gains.

firm. Since this equation contains two endogenous variables, simultaneous equation methods must be used. Alternatively, we will use both equations (2) and (3) and solve, at least approximately, for the optimal capital stock and investment in each location as a function of strictly exogenous variables.

Optimality Conditions for a Multinational Firm

A multinational firm is distinguished from the firm described above simply by the fact that it operates in more than one location.[5] To generalize the previous model in the simplest way, we assume that the firm operates in two locations, one domestic (d) and one foreign (f), with no production interdependencies.

In this simplest of generalizations, operating profits in the domestic location are as described above, with the addition of the subscript, d:

$$\alpha_d K_d - \beta_d K_d^2 - q\delta K_d. \tag{4}$$

Foreign operating profits are written similarly, except that an exchange rate (x) is needed to translate profits originally expressed in foreign currency into dollars:

$$x[\alpha_f K_f - \beta_f K_f^2] - q\delta K_f. \tag{5}$$

5. Technically this definition does not distinguish a multinational firm, which operates in more than one country, from a multi-locational firm in a single country. One way to do this is to make at least one location deal in a foreign currency. However, the major theoretical distinction, for this article at least, is between a single and multi-locational firm.

In the above formulation the assumption is made, for expository convenience, that capital goods are priced in dollars, independent of exchange rate changes, at dollar price q. Similarly, without any information to the contrary, we assume that the rate of depreciation, δ, is the same for domestic and foreign operations.

In addition to the above net revenues, the firm must pay interest on its debt. Here we assume that firm has exactly the same borrowing opportunities as in the original model; debt is raised for the multinational firm **as a whole** at the same total cost as before: $(\rho+\psi\Phi)D$.

The multinational firm's objective is to maximize an integral similar to equation (1) -- with the addition of foreign operating profits. An optimal path is chosen for debt and both domestic and foreign capital. Three necessary conditions can be derived, a sources and uses of funds identity that is a slight generalization of equation (2), and two marginal conditions similar to equation (3):

$$\alpha_d - 2\beta_d K_d = q(\rho + \delta + 2\psi\Phi - \psi\Phi^2), \tag{6}$$

$$x(\alpha_f - 2\beta_f K_f) = q(\rho + \delta + 2\psi\Phi - \psi\Phi^2). \tag{7}$$

The interdependence of domestic and foreign investment is revealed by noting that the marginal revenue products in both locations are equated to the same quantity on the right hand side of equations (6) and (7) -- the marginal cost of capital for the firm as a whole -- **and** that this marginal cost of capital is an endogenous variable, a function of the debt/assets ratio (Φ), which, in turn, is affected by each change in K_d or K_f. Equations (6) and (7), along with the associated differential equation similar to (2), form a nonlinear system, since

K_f and K_d appear in th denominator of Φ; hence it cannot be solved directly. In testing empirically for interactions, we can try to solve a linearized version of the system and test it directly, or we can test the marginal conditions (6) and (7).

Foreign Investment Related to Export Displacement

The preceding theory deals exclusively with interdependence through the firm's financial constraint. Another form of interdependence that must at least be addressed in a study which hopes to explain the behavior of foreign investment over time is investment that comes about because a firm can produce goods in one location for sale in another. During recent years this has usually meant that increasing shares of U.S. firms' worldwide sales are produced in foreign subsidiaries. Such investment reflects differences between markets in costs of production and rates of growth of demand.

In Appendix A we develop a model that lays out in a rough way the major considerations that determine the amount of investment that is caused by the shift of production facilities from one location to another. Ideally, this part of the model should be integrated with the preceding theory of financial interdependence. At present, because of the nonlinearities involved, this is infeasible. Instead, as a first approximation, the investment demand resulting from production shifts will be added to the investment demand derived above.

The two major considerations in a model explaining shifts in the location of production are: (1) the determination of the optimal output level at which it becomes cheaper to produce in a new location and the change of this level through time; and (2) the determination through time of the number of locations where it becomes profitable to shift from exports from the United States to local production, and the quantity of foreign sales associated with each such location.

In the literature on the multinational firm it is typical to describe a scenario where a parent firm first supplies a location via exports and then, as the market size increases, gradually shifts over to local production. Reasons to produce in the local area are the avoidance of tariffs and nontariff barriers, transportation costs, the reduction of labor costs, and the advantages of producing close to the market; reasons against producing abroad are the possible loss of economies of scale, the fixed costs of setting up a new production facility in an unfamiliar location, and the risks of dealing with foreign currencies and foreign governments and institutions. In the appendix we describe a rudimentary model that illustrates the determination of the optimal point of switch-over given fixed set-up costs, differences in the price of labor, and the existence of tariffs and transportation costs.

Empirically, little can be done to estimate such switch-over points accurately for a given firm; we have no information on the distribution of the firm's output among different foreign locations and, therefore, on the foreign costs and tariffs it faces; moreover, when we go beyond the determination of the switch-over point, we have no information on the distribution of sales among the firm's different subsidiaries, and thus no knowledge concerning the magnitude of the firm's foreign sales that are greater than or near the switch-over point. Despite these extensive limitations, a rough measure of the foreign investment caused by switch-overs is developed in Appendix A and then tested. The variable is a function of the firm's aggregate foreign sales, their growth, and an estimate of the difference in the cost of production between U.S. and foreign locations. It proves to be significantly related to foreign investment for one of the seven firms.

IV. The Sample and Sources of Data

The key to testing hypotheses on interdependence is of course a source of data that breaks down a multinational's activities into domestic and foreign operations. Equations (6) and (7) alone show that data are required for domestic and foreign capital stocks, demand side variables (related to the α's) and, naturally, investment expenditures. The equations also show the need for firmwide variables such as the overall debt/assets ratio, Φ. Later the need for a number of other variables such as prices, wage rates, and overall firm cash flow will be noted.

Through the cooperation of the McGraw-Hill Company we were able to gain access, under conditions that protected confidentiality, to a unique body of data that provided the breakdown we needed between foreign and domestic sales, investment, and fixed assets. Since the 1950s, the McGraw-Hill Company has gathered data on the domestic and foreign investment and operations of a large number of U.S. corporations. Previously, Eisner (1978) studied extensively the domestic investment of this sample.

For this paper we have chosen a sub-sample of seven of these firms that provided unbroken data series, or for which we could estimate such series from related ones, for a period of at least 15 years; for a number of the firms the relevant series run for 20 years or more. We have confined our empirical work to such a small number of firms for several reasons. One is that since the McGraw-Hill survey was voluntary, the responses were irregular for many firms. Quite a few were therefore eliminated by our requirement that the time series be unbroken for a minimum of 15 years. Second, a number of firms had to be excluded from the sample because of mergers or large acquisitions. Finally, we looked on the empirical aspect of the study as more of an experimental testing of the model than a definitive exploration of the subject.

With such a small sample it is of course impossible to claim that any of the findings presented below necessarily hold for the economy as a whole. However, there is at least some basis for believing that the results are more important than a sample size of seven would indicate. Among the firms in the sample are some of the largest American multinationals; in a typical year, 1977, the sample accounted for over $15 billion in foreign sales, 6 1/2 percent of the total as reported by the Department of Commerce. The firms are important in the following industries: motor vehicles, chemicals, food products, heavy machinery, and textiles.

In Appendix B we discuss a number of technical issues concerning the data: the issue of deflation for price changes, particularly for the foreign data; and the construction of real capital stock measures, alternative cost-of-capital variables, and the firm's debt to total assets ratio.

V. Empirical Results (I): Tests of the Marginal Conditions

The marginal conditions (6) and (7), which are functions of the endogenous variables, K and D, can be solved as follows for the optimal capital stock, K*:

$$K_i^* = \{x_i\alpha_i - q(\rho + \delta + 2\psi\Phi - \psi\Phi^2)\}/2x_i\beta_i \ , \tag{8}$$

where subscripted variables pertain to the particular location, domestic or foreign, and where unsubscripted variables are common to all locations; the latter are either firm-wide parameters, such as q, ρ, and δ, or the overall firm debt/assets ratio, Φ. Multiplication by the exchange rate, x_i, changes a variable expressed in foreign currency units into U.S. dollars; in the case of the United States, the exchange rate is understood to be 1.

Equation (8) has a family resemblance to equations for a neoclassical firm's desired capital stock, e.g. as in Jorgenson (1963) or Bischoff (1971). This will be seen especially below, when output variables are substituted for the parameter α_i.

Distributed Lags

In principle the above form could be estimated directly. In such a case, two stage least squares or some other simultaneous equation technique would have to be employed because of the endogeneity of both K and Φ. In practice, however, it is likely that some adjustment to equation (8) will be required in order to allow for the likelihood of lagged adjustment and for the replacement of α_i by more fundamental determinants.

Since equation (8) is a function for the optimal or desired **stock** of capital, K*(t), if no further adjustments were made, the equation would imply an investment function of the form: I(t) = K*(t) - K(t-1) + δK(t-1), where the last term is replacement investment. Combining the last two terms leads to a coefficient on the lagged capital stock of δ-1, which must be less than zero. We test for lagged adjustment in two ways. A simple Koyck lag distribution leads to the estimating equation: $I(t) = \lambda[K*(t) - K(t-1)] + \delta K(t-1)$, with a composite coefficient on K(t-1) of (δ-λ); this coefficient is likely to be, but is not required to be less than zero. Alternatively, as pioneered by Jorgenson (1963), one may postulate a series of building lags, where equation (8) is interpreted as determining the **desired** capital stock and changes in the desired capital stock are added to the backlog of ongoing investment projects:

$$I(t) = \sum_i \lambda_i [K^*(t) - K^*(t-1)] + \delta K(t-1). \tag{9}$$

This formulation leads to an estimating equation that is a distributed lag in the **changes** of the variables determining the level of the desired capital stock.

Expectations

Expectations may enter the model in a number of ways, despite the fact that the underlying theory developed in Stevens (1986) is couched in terms of perfect foresight. Even if the lags between the approval of a project and the completion of its construction are short, the firm must still look somewhat ahead in projecting the demand for the project's output; thus α and, to some extent, β must be forecast. Moreover, because the capital stock cannot readily be traded on a rental market, the investment decision really must take account of forecasts of demand for a number of years, covering the anticipated life of the project. Such considerations are important, but very difficult to handle analytically in the type of model we are discussing here. However, we feel it is better to handle them in an **ad hoc** manner than to ignore them completely.

Because it is not our goal to investigate expectation formation, we have attempted to be eclectic in considering alternative approaches. We have tested some formulations where the expected value for a given variable is assumed to be a distributed lag of past values of the variable or, in some cases, its determinants. We have also tested for rational expectations formulations, where we use the property of rational expectations that the expected value for a future variable differs from the realized value by a random error. However, within this class, we have chosen not to use certain estimation methods, such as those proposed by Hansen and Singleton (1982); not only do such methods require the assumption of rational expectations, but they have also been shown to require quite stringent assumptions about the error terms in the equations and the instruments used for the estimation. (See Garber and King (1983)).

Proxies for Expected Demand Conditions As shown in Stevens (1986), the intercept α in equations (6)-(8) is a composite of demand function and production function parameters. The fundamental quantity to which α is related is the firm's total revenues, PQ. For output, Q, we assume for simplicity a linear relationship between Q and the capital stock -- either because of fixed proportions in production or because the relative prices of labor and capital are not expected to change. Thus on the production side the assumption is $Q = cK$. The firm is assumed to possess some market power in both domestic and foreign markets; hence the firm's price (divided by a relevant index of competitive prices, P_c) is related to Q through a linear demand curve: $P/P_c = a - bQ$. Substituting for Q in terms of K implies $PQ/P_c = acK - bcK^2$, a quadratic in K as shown in equations (1) and (2) above. The term α in the marginal conditions (6) through (8) equals the product of the demand curve parameter, a, the production function parameter c, and the competitive price. We expect that the demand curve parameter will change much more over time than c; this latter, for convenience, will be assumed to remain constant. Thus we shall assume that the variation in α will come exclusively from the intercept in the demand curve, a, and P_c.

In a steadily growing market, the firm should be able to sell a steadily increasing level of output, Q, at a constant price; this phenomenon would be reflected by a steadily increasing level for the demand-curve intercept, a, now a function of time, a(t). If the market grew in a truly steady fashion, a(t) could be adequately represented by a time trend. Other variables that might enter into the determination of a(t) would include GNP and GNP per capita in the relevant market. Estimates of future values for a(t) would be related to forecasts for GNP and population.

In fact, however, the use of such economy-wide variables works poorly for firms at the micro level. We conjecture this is because there are many firm-specific elements in a given micro demand curve. And we argue below that some of these elements can be captured by using lagged values for the firm's output and price -- firm variables which can be constructed for our sample.

The key here is that for the demand curve, $P_t/P_{ct} = a_t - b_tQ_t + u_t$, no matter how a or u bounces around, in every period the observable quantity (P/P_c+bQ) can be used as an estimate of the unobservable (a+u).[6] Suppose, for example, that the intercept a(t) is really a linear function of a number of variables, x_i, many of which cannot be measured. Using matrix notation:

$$P_t/P_{ct} = \mathbf{A_t X_t} - b_t Q_t + u_t, \tag{10}$$

where **A** is the vector of coefficients for the vector of independent variables, x_i. Suppose further, for simplicity, that we know that the x_i's follow an autoregressive process, $x_{it} = x_{it-1} + w_{it}$, and that the expected value of u and all w's is zero. Then the expected value of $P_t/P_{ct} + bQ_t$, which can be used as a forecast of a(t), would be equal to:

$$E(P_t/P_{ct}) + bE(Q_t) = \mathbf{AX_{t-1}} + \mathbf{AE(w_t)} + E(u_t) = \mathbf{AX_{t-1}}. \tag{11}$$

We have no direct empirical measures of the exogenous vector, **X**, but, using equation (10), we can make a substitution for it in terms of prior observations for P and Q. Thus, we also have:

$$E(P_t/P_{ct}) + bE(Q_t) = P_{t-1}/P_{ct-1} + bEQ_{t-1} - u_{t-1}. \tag{12}$$

Thus, in this simplified example the introduction of lagged output and prices can give us a fix on the unobservable vector of x's -- at the cost of introducing serial correlation in the u's.

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6. See the data appendix for the construction of our empirical estimates for prices and quantities. Of course we recognize that "b" is an unknown parameter; however, it will be shown below that it can be estimated along with other parameters.

The right hand side of equation (12) will be our empirically observable estimate for the demand curve intercept a(t); it should be recalled that the variable α figuring prominently in the marginal conditions (8) equals a(t) times the product of the production function constant c and the competitive price P_c. It should also be noted from the previous discussion that the variable β in equation (8) equals the product of the parameters bc and P_c.

Making the above substitutions for α and β in the marginal conditions (8), leads to a revised version of the optimal or desired stock of capital in terms of empirically observable variables:

$$K_{it}^{d} = a_0 + \frac{a_1 P_{it-1}}{P_{ct-1}} + a_2 Q_{it-1} - \frac{a_3 q(\rho + \delta + 2\psi\Phi - \psi\Phi^2)}{x_i P_{ct}} \qquad (13)$$

It should be recalled that we interpret equation (13) as a desired capital stock equation, and that, because of building and expectational lags, the estimated equations may include lagged values or first differences of the variables appearing in it.

Empirical Results (I)

The best equations for each firm, in the sense of maintaining the form determined by equation (13), but allowing the data to affect the degree of lagged adjustment, appear in Appendix C. Tables I and II in this section summarize these results for the tests of the marginal conditions as represented by equation (13). For each firm the following statistics are reported in each table: the sample period, the regression type -- whether the lag distribution is of the Koyck variety (KL), an unconstrained distributed lag (DL), or a polynomial distributed lag (PDL), and whether an instrumental variables estimation method was used (IV) -- key regression statistics, and a summary of the signs and levels of significance of the coefficients of the variables. In the few cases in these two tables where a variable appears as a distributed lag, the level of significance refers to that for an F test for the significance of the lag as a whole; moreover, a series of pluses and minuses indicates the sign of each component of the distributed lag. For the most part, the variables in the tables correspond to those in equation (13); the hypothesized sign is noted below the heading of the column. The output variable is domestic output for the domestic investment equation, and foreign output for the foreign one. The lagged capital stock (K) appears in both adjustment equations: in the Koyck, the coefficient may be either positive or negative, as explained above, although a negative coefficient seems more likely; in DL or PDL regressions the coefficient should be positive, equal to the depreciation rate, δ. The variable CCAP refers to the general class of neoclassical cost-of-capital measures, variations, as explained in the data appendix, on the simplest form: $q(\rho+\delta)/p$. The debt/assets ratio, Φ, the key in this series of tests for determining whether there was any interaction between domestic and foreign investment, can be entered into the equation in a number of alternative ways -- all of which appear in the tables. The terms Φ and Φ^2 can be entered individually (or in some cases separately) or, alternatively, the hypothesis that the coefficient on the term in Φ is two times the negative of the squared term can be imposed simply by entering the composite expression: $\Phi+\Phi(1-\Phi)$. The particular form of the Φ term entered in the tables is for the best fitting equation.

TABLE I. DOMESTIC INVESTMENT FUNCTIONS: INVERTED MARGINAL CONDITIONS[1]

Firm	Period	Reg[2] Type	Domestic Output(+)	K (-,+)	CCAP (-)	Debt/Assets Ratio (Φ): Φ (-)	Φ^2 (+)	$\Phi+\Phi(1-\Phi)$ (-)	Other[3] Variables	R^2	DF	ρ	D.W.
#1	61-79	KL	+ (5.7)	- (0.2)	+ (0.2)			- (3.5)	$-K_0$ (1.4)	.96	10	-.52	1.88
#2	60-79	KL	+ (2.6)	- (0.04)	- (3.1)			-- (7.3) F(2/12)	$-K_0$ (1.5)	.89	11	.68	1.59
#3	62-79	PDL	-++	+ (3.0)	-- (5.2) F(2/8)	- (2.8)			+DV74 (5.0)	.91	8	.56	1.87
#4	60-75	KL	+ (0.6)	- (1.5)	- (1.0)	- (1.1)	+ (1.9)		$-K_0$ (0.8)	.70	7	.68	2.21
#5	60-79	KL	+ (9.4)	- (2.2)	+ (1.5)			- (5.4)	+DV65 (4.9)	.95	12	-.50	2.16
#6	62-79	KL	+ (2.0)	- (1.7)	- (0.5)			- (2.0)	$-K_0$ (2.8) -DV64 (3.8)	.87	11	--	1.53
#7	60-75	KL	+-+	+ (0.5)	+ (2.4)			- (1.8)		.95	9	--	1.91

1. The sign of the estimated coefficient for a particular variable in the equation for a particular firm is indicated by a "+" or a "-" in the row corresponding to that firm; if a distributed lag is estimated for the variable, the sign of each term in the lag is indicated. The theoretically preferred sign for a coefficient is noted below the variable name at the top of the table; t and F ratios appear in parentheses.
2. Regression types are indicated as follows: KL = Koyck lag; PDL = polynomial distributed lag.
3. In the column labeled "Other Variables," K_0, an estimate of the initial capital stock, is the coefficient of the variable $(1-\delta)^{t-1}$; DV refers to a dummy variable which has a value 1 for the year indicated.

TABLE II. FOREIGN INVESTMENT FUNCTIONS: INVERTED MARGINAL CONDITIONS[1]

Firm	Period	Reg Type[2]	Foreign Output(+)	K (-,+)	CCAP (-)	Debt/Assets (Φ): Φ (-)	Debt/Assets (Φ): Φ^2 (+)	Debt/Assets (Φ): $\Phi+\Phi(1-\Phi)$ (-)	Other Vars.[3]	R^2	DF	ρ	D.W.
#1	62-79	KL	+ (0.1)	+ (0.3)	+ (1.7)			- (2.0)	-DV72 (1.7)	.47	11	.76	1.24
#2	61-79	KL,IV	+ (1.9)	- (1.2)	+ (0.4)			- (1.9)		.59	14	--	2.19
#3	61-79	KL	+ (3.9)	- (1.7)	- (1.9)			- (2.4)		.96	13	-.45	2.14
#4	60-75	KL	+ (3.6)	- (0.6)	- (0.2)	- (3.1)				.91	10	-.83	2.58
#5	60-79	KL	+ (5.2)	- (2.1)	- (3.0)			- (4.2)		.71	15	--	2.14
#6	60-79	KL	+ (1.6)	+ (0.3)	+ (0.2)			- (1.7)		.28	15	--	1.91
#7	61-75	KL	+++ (12.1) F(3/8)	- (4.5)	- (3.0)			- (2.0)		.87	8	--	2.16

1. For the meaning of the pattern of pluses and minuses see the first footnote of Table I, above.
2. The following symbols are used above to indicate different regression types: KL = Koyck lag; IV = instrumental variables.
3. In the column labeled "Other Var.", DV72 is a dummy variable which has the value 1 in 1972.

The variables that appear in the column headed by "Other" include, among others, various dummy variables that, for domestic equations, take care of isolated large residuals. These dummy variables did not change the character of the equation, but did allow the estimation of a reasonable autocorrelation coefficient and Durbin-Watson statistic. The variable, K_0, refers to the use of the alternative capital stock variable and time trend, as described in the data appendix. The output price relative, expressed as P_i/P_c in equation (13), was rarely significant and did not affect the significance of the other key variables; frequently it was dropped in estimating individual equations and no equation using it appears in the tables. Finally, all tests for the effect of a switch-over from exports to foreign production proved negative in this set of regressions. (However, the switch-over variable proved significant in one case in the reduced-form regressions presented below.)

The key empirical result for this set of regressions is that the variable indicating an interdependence in investment spending, the debt/assets ratio, is significant in some form at the 5 percent level (for a one-tailed test) in 13 of the 14 regressions reported in tables I and II. Only in the foreign investment regression for firm #6 is the t value slightly below that required for significance (1.753). The other part of the firm's cost of capital was hypothesized to be the CCAP term, equal to some function of the sum of the nominal interest rate and the depreciation rate. This was significant with the correct sign in only five of the fourteen regressions; and a number of the coefficients were significantly positive. No improvements for these variable could be generated by using a measure of the real interest rate or by correcting for changes in the U.S. tax rates and depreciation guidelines.[7]

The relevant output terms were uniformly of the correct sign and significant in 4 of the 7 domestic regressions (with some significant positive terms in the distributed lags of two others), and 5 (almost six) of the foreign regressions. The coefficients on the lagged capital stock were also usually of the predicted sign (except for two cases); however, only 4 of the 14 coefficients were significant.

VI. Empirical Results (II): Tests of a Reduced Form Investment Function

The marginal or Euler equations, (6) and (7), that formed the basis of the empirical tests in the previous section exhibit the interaction between domestic and foreign investment only indirectly. All interactions are mediated through the effect of investment on the debt/assets ratio, which in turn affects the common interest rate appearing in each investment's cost of capital. If one can solve the equation system, (6), (7) and (2), the interactions between domestic and foreign investment can be tested more directly. Parameters and variables pertaining to one location will directly affect investment levels in the other. It is the purpose of this section to test such a model.

Basically we want to eliminate the endogenous debt/assets ratio in equations (6) and (7) by expressing it as a function of exogenous variables. Unfortunately this cannot be done directly because the equations are all nonlinear; further complications occur because equation (2), the sources and uses of funds constraint, is a differential

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7. Revised estimates of the cost of capital calculated in Hall (1986) were used without increased success.

equation. The nonlinearity in the marginal conditions is caused by the debt/assets ratio, Φ, equal to D/qK. The differential equation contains the nonlinearities introduced by Φ and the quadratic term K^2.

We linearize the marginal equations by expanding them in a first order Taylor series around the firm's average value for its debt/assets ratio, Φ_0, its capital stock, K_0, and debt, D_0. The linearized version of marginal condition (6) or (7) becomes:

$$x_i\alpha_i - 2x_i\beta_i K_i = c + q(\rho+\delta) + D/q[2q\psi \frac{\Phi_0(1-\Phi_0)}{D_0/q_0}] + K_T[2q\psi \frac{\Phi_0^2(1-\Phi_0)}{D_0/q_0}], \quad (14)$$

where the locational subscript, i, equals d or f (domestic or foreign); and the subscript T refers to the sum of the domestic and foreign levels (in this case the real capital stock). The constant, c, is the sum of the various constants resulting from the Taylor series expansion. Note that all the coefficients on the right hand side of the equation are independent of location. It should also be noted that the coefficient of the total capital stock, K_T, equals Φ_0 times the coefficient of the debt term; this, of course, is because the two variables appear in the marginal conditions in the ratio, D/qK. Finally, it is worth observing that all coefficients in the equation are in nominal units, in the sense that a proportional change in all prices will change the coefficients in the same proportion. The ratio of any two coefficients will, therefore, be in real units; we have discussed in the previous section why α_i and β_i change when prices change.

The third equation in the system, the differential equation (2), can be linearized in at least two ways. For both alternatives, we will turn the differential equation into a difference equation, with $\dot{D}$ replaced by D(t)-D(t-1) and so on. An important question, not unrelated to expectations, is how to treat the terms on the right hand side of equation (2) --retained earnings:

$$(1-\tau)[\alpha K - \beta K^2 - (\rho + \psi\Phi)D - q\delta K] - DIV. \tag{15}$$

If one assumes that the firm looks to the immediate past, either to forecast profits during period t or as the sole source of investment to be undertaken during period t, then expression (15) becomes predetermined during period t, equaling retained earnings (RE) during t-1 or a distributed lag on the retained earnings of even earlier periods. In such a case, this highly nonlinear function can be replaced by RE(t-1) or a suitable distributed lag.

Alternatively, the terms in K and D, equal to gross profits, can be treated endogenously -- corresponding to the case where the firm depends on contemporaneous profits, an endogenous variable, for the financing of investment during period t. Dividends, although clearly endogenous for the firm, will in both cases be assumed exogenous to the investment decision.

In the first case, no linearizations are needed and the sources and uses of funds constraint becomes:

$$D = D(t-1) + q[K_T - K_T(t-1)] - RE(t-1). \tag{16}$$

In the second, where profits are assumed endogenous, a Taylor series expansion similar to those used in equation (14) leads to:

$$D(1+\rho+2\psi\Phi_0) = c + D(t-1) - qK_T(t-1) + K_d(1-\tau)(\alpha_d - 2\beta_d K_{0d} + q\psi\Phi_0^2)$$

$$+ K_f(1-\tau)(\alpha_f - 2\beta_f K_{0f} + q\psi\Phi_0^2). \tag{17}$$

This form of the constraint leads to further nonlinearities, as is discussed below.

We use equation (16) or, alternatively, (17) to eliminate the firm's debt variable in the two marginal equations (14). Concentrating on the substitution using equation (16) for the moment, one arrives at the following system of two equations in the two remaining endogenous variables, K_f and K_d:

$$K_d[2\beta_d+2qA] + K_f[2qA] = \alpha_d - q(\rho+\delta) + [2qA/(1-\Phi_0)](K_T - D/q + RE/q)(t-1)$$
$$(18)$$
$$K_d[2qA] + K_f[2\beta_f+2qA] = \alpha_f - q(\rho+\delta) + [2qA/(1-\Phi_0)](K_T - D/q + RE/q)(t-1),$$

where $A = \psi \dfrac{\Phi_0(1-\Phi_0)}{D_0/q_0} > 0$.

Under usual circumstances this system can be solved for the optimal capital stock in each location, K_d and K_f. And **both** variables will be functions of α_d, α_f, $\rho+\delta$, and the lagged values of retained earnings, debt, and the capital stock for the firm as a whole.

The determinant, Δ, of the matrix of coefficients of K_d and K_f is always positive: $\Delta = (2\beta_d + 2qA)(2\beta_f + 2qA) - 4q^2A^2$. Solving the system for the optimal capital stocks in the domestic and foreign locations, we obtain the following:

$$K_d = c_d + \alpha_d(2\beta_f+2qA)/\Delta - \alpha_f(2qA)/\Delta - q(\rho+\delta)(2\beta_f)/\Delta + X_{t-1}(2\beta_f)/\Delta \tag{19}$$

$$K_f = c_f + \alpha_f(2\beta_d+2qA)/\Delta - \alpha_d(2qA)/\Delta - q(\rho+\delta)(2\beta_d)/\Delta + X_{t-1}(2\beta_d)/\Delta \quad (20)$$

where X_{t-1} is a proxy for the last term in both equations (18).

The signs of the independent variables make sense. Factors increasing the demand curve in the domestic market (α_d) raise the level of desired capital in the domestic market and lower it in the foreign market; the appearance of foreign demand variables (α_f and its determinants) in the domestic capital function, and vice versa for the foreign function, is the direct evidence of interdependence between domestic and foreign investment that was only indicated indirectly in the marginal equations tested above. To reiterate, the reason for the interdependence in this model is the competition of each unit of investment for cheap sources of finance. As long as debt is positive, the cost of capital for an incremental unit of investment is equal in the foreign and domestic markets, and in magnitude is greater than the minimum, risk-free rate, $\rho+\delta$; moreover, an incremental unit of investment in one area affects investment in the other, either by raising the debt/assets ratio or by preventing retained earnings from being used to reduce it. In both cases the incremental unit of investment raises the common cost of capital above what it otherwise would have been.

The equations show, in addition, that there are within- and cross-equation constraints among the coefficients that can be, in principle, exploited in estimation. However, because many of the coefficients will be changed by the substitution of more basic determinants for variable such as α_d and α_f, and because of the imposition of distributed lags in the investment functions, no cross-equation constraints have been imposed or tested for in this study.

When using the second Taylor series expansion of the sources and uses of funds constraint, equation (17), a somewhat different estimating equation results. First, since (17) includes a product of endogenous variables, $K_d \alpha_d$, this term must also be approximated linearly. The resulting system is quite similar to the previous one [equation-set(18)] with respect to the independent variables, except that lagged retained earnings is now eliminated. Otherwise the variables and the signs of the coefficients are identical.

Results (II)

As the significance of the debt/assets term in the first set of regressions was the key indicator of interdependence, so in the reduced form regressions the key indicators are the significance of the internal funds term and of the output term in the competing market. Tables III and IV summarize the results of the individual firm regressions that appear in Appendix C.

The internal funds term performs the best: the FUND variable is significant in six of the seven domestic regressions; for the foreign regressions, the variable is likewise significant in six of seven regressions and nearly significant in all seven.

The results for the competing output term are less conclusive than those for internal funds or (earlier) for the debt/assets ratio. Exactly one half of the 14 possible investment functions exhibit a statistically significant negative impact of the output variable in the competing market: four for domestic investment and three for foreign. In addition, for one of the domestic cases the sign of the foreign output term was significantly positive (firm #4), a finding we choose to

TABLE III. DOMESTIC INVESTMENT FUNCTIONS: REDUCED FORM[1]

Firm	Period	Reg[2] Type	Domestic Output (+)	Foreign Output (-)	K (-)or(+)	CCAP (-)	Internal Funds (+)	Other[3] Variables	R^2	DF	ρ	D.W.
#1	61-79	KL	+ (6.8)	- (2.2)	- (1.4)	- (0.6)	+ (3.7)	$-K_0$ (1.1) +DV66 (11.4)	.98	10	-.60	2.09
#2	62-79	KL	+ (6.9)		- (3.5)	- (4.3)	++ (3.9) F(2/11)	-DV72 (2.9)	.96	11	--	1.57
#3	61-79	KL	+ (3.6)	- (1.8)	- (3.3)	- (2.4)	+ (3.4)		.93	13	--	1.98
#4	62-75	KL	+ (1.9)	+ (2.6)	- (4.3)		+ (2.0)	-DV75 (3.0)	.77	8	--	1.55
#5	61-79	DL	++ (2.9) F(2/9)	- (1.6)	- (0.2)	+ (1.6)	+++ (26.9) F(3/9)	$-K_0$ (1.0)	.93	9	--	2.19
#6	61-79	KL	++ (6.5) F(2/11)	- (1.8)	- (2.3)	- (3.1)		$-K_0$ (3.6) -DV64 (3.1)	.91	11	--	2.23
#7	62-75	DL	+ (2.9)	-- (8.4) F(2/6)	+ (3.3)	- (0.8)	+ (3.1)		.84	6	.60	1.74

1. For the meaning of the pattern of pluses and minuses, see footnote 1 of Table I, above.
2. Different regression types in this table are the following: KL = Koyck lag; DL = distributed lag.
3. In the column labeled "Other Variables," K_0, an estimate of the initial capital stock, is the coefficient of the variable $(1-\delta)^{t-1}$; DV refers to a dummy variable with a value of 1 for the year indicated.

TABLE IV. FOREIGN INVESTMENT FUNCTIONS: REDUCED FORM[1]

Firm	Period	Reg[2] Type	Foreign Output (+)	Domestic Output (-)	K (-)or(+)	CCAP (-)	Internal Funds (+)	Other[3] Variables	R^2	DF	ρ	D.W.
#1	62-79	KL	- (7.8)		- (9.8)		+ (6.7)	-DV72 (3.7)	.95	12	-.58	2.32
#2	62-79	KL	++ (3.1) F(2/9)	-+	- (4.1)	- (3.1)	++ (3.7) F(2/9)		.82	9	--	2.40
#3	61-79	KL	+ (3.3)	+ (0.9)	- (3.6)	- (0.5)	+ (3.5)	+SWITCH (4.8) +DV71 (3.2)	.98	11	--	1.98
#4	62-75	KL	+ (2.7)	- (2.8)	- (1.5)	- (2.8)	+ (4.3)		.94	7	-.78	3.21
#5	61-79	KL	+ (2.5)	- (1.9)	- (0.4)	- (2.8)	+ (2.2)		.54	13	--	1.74
#6	61-79	KL	+ (2.4)	- (0.06)	- (0.5)	- (2.1)	+ (1.5)	$+K_0$ (0.2) +DV63 (3.9) +DV67 (4.23)	.84	10	--	1.99
#7	62-75	KL	++ (10.5) F(2/5)	- (2.2)	- (6.1)	- (4.6)	+ (2.5)	$-K_0$ (0.9)	.93	5	-.72	2.80

1. For the meaning of the pattern of pluses and minuses, see footnote 1 of Table I.
2. In column 2, indicating the regression type, KL = Koyck lag.
3. See footnote 3 of Table I for the meaning of variables K_0 and DV; SWITCH is the measure of investment caused by the switch-over of exports from the United States to production abroad.

tentatively interpret as evidence for a production interdependency outweighing the effect through the competition for internal funds.

For the other variables in the investment functions, results are reasonably similar to the debt/assets ratio regressions. The output terms in the own market are generally very important and significant: 7 of 7 for domestic investment and 6 of 7 for foreign. The cost of capital variable, CCAP, was significant with the correct sign in 5 of 7 foreign regressions, but in only 3 of 7 for the domestic market; these results improve a bit on those from the previous set of regressions, but it is surprising to find such a variable doing so poorly in domestic regressions. The capital stock does fairly well, significant in 9 of 14 regressions.

VII. Summary and Conclusions

The primary goal of this paper has been to examine whether the fact that a firm is a multinational affects key decisions such as the level of its domestic fixed investment. Theoretically, this led to an exploration of models that imply an interaction between a multinational's domestic and foreign decisions. We focused on two such possible interactions: through the finance side, where, under certain circumstances, investments in different locations compete for scarce funds; and through the production side, where foreign investment may either displace exports of finished goods or increase exports of components. Empirically, investment functions testing for these interactions were fitted for the domestic and foreign operations of seven large multinational firms.

We found little evidence to support interactions through the production side, although the data were clearly limited in this area. In only one case, the reduced-form foreign investment function for firm #3, was our switch-over variable significantly related to the level of investment. Thus, as several other studies have found in more direct tests of this question, in our sample, foreign investment does not seem to be related to export displacement.[8]

The evidence for an interaction through the financial side was much stronger. For one set of tests, involving the marginal conditions from the world-wide value maximization model, the significance of the debt/assets ratio was the key in assessing the existence of an interdependence between domestic and foreign investment. The ratio was significant in 13 of 14 cases. A second set of tests involved solving the (nonlinear) marginal conditions for an approximate reduced-form investment equation. An interaction between domestic and foreign investment was indicated by a significant effect of foreign output in the domestic investment function (or vice versa) and/or the significance of the measure for consolidated internal funds. The internal funds variable, the measure corresponding to the debt/assets ratio in the marginal conditions, was significant in 12 of the 14 possible regressions, six domestic and six foreign. The evidence from the competing output variables was less compelling. Foreign output was significant in the domestic regressions with a negative sign in four out of seven possible cases,[9] while domestic output was significant in foreign regressions in

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8. See Blomstrom, Lipsey and Kulchycky (1988), Lipsey and Weiss (1981), (1984), and Swedenborg (1979), (1982).

9. This does not count the case, noted above, where foreign sales were significant with a positive sign, a case that suggests an interaction through the production side. (See Table III.)

three cases. Although the evidence from the two types of test is not completely consistent, it does seem to indicate strongly some sort of interaction through the financial side.

Thus, while there is little evidence that production abroad displaces exports and existing domestic capacity, fixed investment abroad does seem to compete with investment at home for most of the firms in our sample. Because of the increasing cost of external finance, a decision to invest and produce more abroad is a decision to invest and produce less at home. This displacement takes place even if there is no exporting or importing between the home and foreign location.

APPENDIX A: THE SHIFT TO LOCAL PRODUCTION

This appendix provides the derivation for the switch-over variable (denoted "SWITCH") that appears in Table IV and is described at the end of section III. The variable attempts to test the hypothesis that part of foreign fixed investment was caused by the shift from serving the foreign market by exports to production abroad.

I. The Optimal Switch-Over Point

The essence of the theoretical problem of determining the optimal point at which to switch production from the home to the foreign location is the minimization over time of the cost of producing a given commodity. Since certain fixed costs (F) occur in setting up production in a new location, and since these are incurred only once, one must compare them to cost savings that may result over the whole life of the firm. Costs at different points of time will be compared by discounting them back to the present.

Total cost of a given real sales level in the foreign country (Q) equals the sum of the costs of the amount produced in the foreign location $C_2(Q_f)$ and the home location, $C_1(Q_h)$. Put in somewhat oversimplified terms, the multinational firm's problem is, for any given path of total sales over time, to minimize discounted costs of production (DC):

$$\text{Min } DC[Q(t)] = \int_0^\infty e^{-\rho t} \left\{C_1[Q_h(t)] + C_2[Q_f(t)]\right\} dt \tag{A1}$$

subject to: $Q(t) = Q_h(t) + Q_f(t), \quad Q_h, Q_f \geq 0.$

Because of the above constraints and the fixed set-up cost that is a part of the foreign cost function, the solution of the **general** form of this problem is a difficult nonlinear programming problem.[1] However, solving the particular problem that seems to best represent the multinational firm's decision is considerably easier. In this case we make the further assumptions that there are set-up costs for the foreign production operation, but none for home production -- since home set-up costs have already been incurred. We will assume that such costs are a fixed in real terms at F; nominal set-up costs will for convenience be assumed to be equal to FP_h, where P_h is a dollar output price for the home market. Moreover, as was customary for the sample period, we assume that the marginal costs of producing abroad (in dollars) are lower than those at home for each level of production, and that they are constant in both locations, independent of the level of output. Over time, as long as foreign marginal costs are kept lower than domestic, the basic result will be independent of any particular rate of inflation or exchange rate change. In the theoretical derivations below, we will assume, for simplicity, that wages, capital costs and exchange rates are constant. Finally, we will assume that there is no dependence of foreign sales on whether production is at home or abroad.

Given the above assumptions, the solution to the problem of finding the optimal time, if any, to switch production from the home to the foreign location is simplified considerably. Since foreign marginal costs are always lower than domestic, once the switch-over is made, there can be no switch in the reverse direction. Second, if the level of switch-over costs were zero, the switch would occur immediately, at time

1. See, e.g., Hadley (1964), p. 136 and pp. 256 ff.

zero. However, with positive switch-over costs, it may pay to postpone the switch-over, balancing the increased costs of continuing to produce at home for a certain time against the saving of pushing the payment of switch-over costs further into the future.

Given the above simplifying assumptions, we can formulate the firm's problem as one of choosing the optimal time, T, of shifting from the home cost function to the foreign one. Below we will add a number of elements to each function, but for now we shall ignore price changes and other complications and assume that, except for switch-over costs, total costs are a (real) constant times output produced in each location. Thus the home cost function, $C_1(Q_h)$, becomes c_hQ_h, where c_h is the constant home marginal cost. A similar function holds for the cost of foreign production. As noted above, when costs are minimized the firm will not be producing in both locations simultaneously. The optimal time to switch to foreign production can be derived by minimizing the following discounted cost integral with respect to the switch-over time, T. This is a special case of the general function (A1):

$$\text{Min } DC[Q(t),T] = \int_0^T e^{-\rho t} \{[c_hQ(t)]\}dt + \int_T^\infty e^{-\rho t} \{[c_fQ(t)]\}dt + e^{-\rho T} F. \quad \text{(A2)}$$

If an interior minimum exists at T*, the first derivative of function DC with respect to T must equal zero, that is:

$$e^{-\rho T*}\{Q(T*)(c_h - c_f) - \rho F\} = 0, \text{ or, } \quad Q(T*) = \rho F/(c_h - c_f). \quad \text{(A3)}$$

Equation (A3) shows, of course, that the optimal T depends on the (exogenous) path of output, Q. Assume for simplicity that Q is expected to increase exponentially over time, $Q(t) = Q(0)e^{gt}$. Then, if $Q(0)$ is large enough such that the left hand side of (A3) is positive at time 0, it will also be positive at every subsequent time; postponing the switch-over only increases the discounted cost integral. In such a case, the optimal strategy is to switch to foreign production immediately. If, on the other hand, $Q(0)$ is small enough such that the marginal condition is negative at time 0, as long as $Q(t)$ increases without bound, there will be a unique T* such that the first order condition will be satisfied. Examination of the second derivative of the integral function DC shows that T* is indeed the cost-minimization time to switch all production to the foreign location. For the case of exponential growth of $Q(t)$ at rate g, the optimal switch-over time is given by:

$$T^* = 1/g \left\{ \ln(\rho F) - \ln Q(0) - \ln(c_h - c_f) \right\}. \tag{A4}$$

Let us now specify the components of the marginal costs, c_h and c_f, more precisely, and, as well, introduce price and exchange rate variability. We will assume Cobb-Douglas production functions in each location, with common elasticities, η, and a common rental cost of capital, c; however, wage rates in dollars are assumed to differ (w_h and xw_f, where x is the exchange rate), as are the overall efficiency coefficients, A_h and A_f. Moreover, as noted above, we assume that there are real costs of starting up production abroad, F, that are measured in units of output, hence priced at P_h. In addition, in order to export from the home location to the foreign market, the firm must incur fixed transportation costs (Trans) per unit of output and must pay an <u>ad</u>

velorum tariff (Tar) per unit of value. Using these elements of cost, the expression $c_h - c_f$ appearing in equations (A3) and (A4) becomes:

$$Q(c_h - c_f) = Q\{A_h w_h{}^{\eta} c^{1-\eta} + \text{Trans} + \text{Tar}\cdot P_h - A_f(xw_f)^{\eta} c^{1-\eta}\}. \tag{A5}$$

Substituting into equation (A3), the optimal level of foreign real sales at which the firm switches to foreign production is:

$$Q^* = \frac{\rho F \cdot P_h}{A_h c^{1-\eta}\{[w_h^{\eta} - A_h/A_f(xw_f)^{\eta}] + \text{Trans} + P_h\text{Tar}\}}. \tag{A6}$$

Rough empirical measures of Q* were constructed using the U.S. and foreign data described at length in the Data Appendix. Our previously constructed measures for domestic prices (P_h) and the cost of capital (c) were used for these particular variables. Data collected by the Bureau of Labor Statistics were used for both the U.S. and foreign wage variables; in the latter case, a weighted average was constructed of countries in which U.S. foreign investment is concentrated. No data were available on transportation costs, tariffs, or the level of the fixed costs of setting up production facilities abroad; if, however, these last costs are relatively constant in real terms over time, the term F will be estimated as part of the coefficient of the Q* variable.

II. Determining the Firm's Fixed Investment Resulting from Switch-Overs

For a particular subsidiary one can apply the standard approach of the investment theory developed in the text to determine the investment resulting from the decision to switch from exports to foreign production. As suggested in the text we would not expect instantaneous adjustment to the new optimal level of the capital stock, expecting some sort of lagged adjustment because of building or other lags.

A major problem, however, is estimating **for the firm as a whole** the magnitude of switch-over-generated investment. If one had sales broken down by each individual market abroad, then in principle one could calculate Q* for each market, determine those for which Q* was less or equal to the existing sales, and then calculate the investment implied for each separate switch-over. Our data, however, did not allow such a disaggregation. It was necessary, therefore, to make a rough estimate of switch-over investment using only data for aggregate foreign sales and the separate calculation of the switch-over point.

Two major factors are responsible for shifts from exports to foreign production: changes in the switch-over point (assumed here to be reductions), and growth in the foreign markets. Since we have no disaggregated information, we must assume that all markets are affected identically by changes in these two factors.

Let us assume that we have arranged the sales of the individual foreign subsidiaries in ascending order, so that total foreign sales can be expressed as either the sum or the integral of the sales of each separate subsidiary. Letting n be the index for a given subsidiary and n_{max} the index for the subsidiary with the largest sales, total foreign sales equals:

$$Q_f(t) = \sum_{n=0}^{n_{max}} Q_n(t), \text{ or } Q_f(t) = \int_0^{n_{max}} Q_t(n)dn. \tag{A7}$$

The switch-over point, as calculated from equation (A6), occurs at some output level Q_t* which corresponds to subsidary n*. Using the integral form above, at time t, the integral from n* to n_{max} is that part of total foreign sales that is either already completly switched to foreign production or is in the process of so doing.

In symbolic terms, total sales switched from home to foreign production at time t, SS(t), equals:

$$SS(t) = \int_{n^*_t(Q^*_t)}^{n_{max}} Q_t(n)\, dn. \tag{A8}$$

Assuming that real sales in the foreign markets are expected to increase at the rate of "g" percent per unit of time, equation (A8) simplifies to the following :

$$SS(t) = \int_{n^*_t(Q^*_t)}^{n_{max}} e^{gt}\, Q_0(n)\, dn. \tag{A9}$$

Assuming also that the variables in (A6), determining the switch-over point are continuous, then Q* is a continuous function of time. We can then differentiate SS(t) to calculate the switch-over of existing foreign sales from home to foreign production: [2]

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2. The expression for SWITCH(t), below, is not the total derivative of SS(t) with respect to time: dSS(t)/dt; this latter includes both the expression in equation (A10) as well as the term:

(Footnote continues on next page)

$$SWITCH(t) = -e^{gt}\, Q(n*_t)\, dn*/dt. \tag{A10}$$

$Q(n*_t)$, the value of the subsidiary's or market's output at the switch-over point, is simply $Q*_t$. The time derivative, $dn*/dt$, the change in the location experiencing a switch-over, or the number of subsidiaries switching during a given time period, depends on the rate of growth of sales (g), the change in Q*, and the slope of the original sales curve, dQ_0/dn, at n*. This derivative is evaluated as follows. By definition:

$$Q* = Q(n*_t) = e^{gt}\, Q_0(n*_t). \tag{A11}$$

Thus, using the inverse function, Q_0^{-1}, $n*_t = Q_0^{-1}[e^{-gt}Q*(t)]$. After some manipulation, it turns out that:

$$dn*/dt = e^{-gt}[dQ*/dt - gQ*]/[dQ_0/dn(n*)] \ . \tag{A12}$$

Since dQ*/dt was assumed to be negative during the sample period, dn*/dt is also negative, i.e. more subsidiaries switch to foreign production during the period.

(Footnote continued from previous page)

$$\int_{n*_t(Q*_t)}^{n_{max}} [\delta e^{gt}\, Q_0(n)/\delta t]\, dn.$$

But the above integral is just the increase in the sales of the foreign subsidiaries that have already established local production operations; the investment necessary to support these increased sales will be captured by the foreign investment function developed in the main body of the paper.

Substituting equation (A11) for dn*/dt in equation (A10), we obtain the final expression for the magnitude of sales switched-over from home to foreign production during a (small) time interval:

$$SWITCH(t) = [-dQ^*/dt \cdot Q^* + gQ^{*2}]/[dQ_0/dn(n^*)]. \qquad (A13)$$

In our regressions we have made the assumption that the term in the denominator is roughly constant over the sample period -- the slope of the firm's sales curve calculated at successive switch-over points. Allowing this, we have estimates of all the terms in the numerator of equation (A13). Various forms of equation (A13) were used in the regressions as rough measures of the independent effect of switch-overs on foreign fixed investment. Only for firm #3 did such an effect prove to be statistically significant. (See the variable SWITCH in Table IV.)

APPENDIX B: DATA

Section IV in the body of the paper describes the sample and the variables in the data set. All variables provided by McGraw-Hill were expressed in current dollars. This was the case for the firms' foreign, as well as domestic data, thus indicating that the firms had used an exchange rate to transform data in foreign currency units into dollars.

I. Deflators for Domestic Variables

The major domestic variables needing deflation were sales, purchases of plant and equipment, and various measures of consolidated cash flow. The construction of real capital stock measures using deflated purchases of plant and equipment is discussed in a separate section below.

Sales, originally expressed in current dollars, were deflated by the Bureau of Labor Statistics' producer price index for the major industry of domestic operations.

Domestic plant and equipment expenditures were deflated by a weighted average of the implicit price deflators from the national income accounts for producers' durable equipment and for nonresidential structures. Information was sometimes available as to the composition of the firm's plant and equipment (P&E) expenditures and, in such cases, the deflators were weighted accordingly. The deflator constructed for investment expenditures was also used to deflate the various cash flow variables used in section VI. The use of such a deflator is justified theoretically by the appearance in equation (18) of terms such as RE/q and D/q; in these expressions, the nominal value of retained earnings (RE) or corporate debt (D) is divided by the price of capital goods, q.

II. Deflators for Foreign Variables

The problem of deflating variables relating to foreign operations is a formidable one. As noted, all foreign variables, such as aggregate foreign sales, were reported to McGraw-Hill in current dollars. Since most foreign sales were originally denominated in foreign currencies, this meant that the firms translated sales denominated in each foreign currency into dollars by using the current exchange rate and then aggregated across currencies. The description of the procedure underlines the major problem in developing an accurate deflator: many currencies and countries may be represented in the foreign total, and it is impossible to determine the identities of the countries and their relative weights in the total.

Two procedures were used to deflate the foreign data, one rough-and-ready, relying on purchasing power parity (PPP), and the other, more theoretically satisfying, but far more time-consuming and subject to its own sources of error. Fortunately, in the cases of the two firms for which we used both methods, the results were very similar. Based on this evidence, we felt justified in using the easier purchasing-power-parity method.

If purchasing power parity holds, the ratio of the prices of two identical, or closely related commodities will equal the exchange rate: $P_d/P_f = E(\$/f)$, where the latter is measured in dollars per unit of foreign currency ($/f). This of course means that we have a good proxy for the foreign price in the corresponding domestic price divided by the exchange rate. We do not argue that PPP holds in any exact way -- one of us has argued strongly against it in print (Kravis and Lipsey (1978) -- but the assumption that it does seems safer than the only other feasible alternative, which is that exchange-rate movements convey no information about relative price changes. Assuming for the moment that PPP is a reasonable approximation, how do we deflate to the appropriate real measure? Consider the example of foreign sales. We want the real value S_f/P_f; we have the current dollar figure S_fE. To transform this latter value into the proper real terms, one needs to divide by the value EP_f. But from the assumption of PPP, EP_f equals P_d. Hence, under PPP, one deflates the dollar-denominated foreign data by the U.S. **domestic** price deflator.

The alternative is to estimate the geographical distribution of the sales and capital expenditures for each firm and each year in the sample, and to collect price indices and bilateral exchange rates against the dollar for each country. The was done for two firms in order to attempt to determine the effects of the alternative methods of deflation. The first step in this procedure was to estimate a rough distribution of each firm's foreign assets. Naturally the use of such a distribution introduces a new source of error: a new series could not be constructed for each year, and a distribution for assets generally will not be the same as the needed distribution for sales or fixed investment. Using this available distribution, a firm-specific foreign sales and investment deflator was calculated as a weighted average of the individual foreign price levels. For prices we used a consistently defined set of international price statistics from Summers and Heston (1984), covering virtually all the countries and years represented in our sample. Using these data, the required deflator, EP_f, can be constructed directly; in this case P_f is the Summers-Heston foreign price of a consumption bundle. These data show frequent and substantial deviations from PPP.

Fortunately a choice between the methods for deflation was not critical. The results from the alternative methods were quite similar. As it turns out this was probably because the alternative series were very highly correlated; the foreign sales measures had correlation coefficients of 0.97 and 0.88 for firms 1 and 2 respectively; similarly, for foreign plant and equipment expenditures the correlations were 0.98 for both firms.

III. Capital Stock Measures

Two versions of the so-called perpetual inventory method were used to calculate a measure of the real stock of plant and equipment used in the firm's domestic and foreign operations. The methods differed only in the treatment of the initial capital stock which serves as a starting point for the series.

As is well known, the perpetual inventory method derives a value for the real capital stock at a given time t, $K(t)$, by adding deflated gross investment expenditures, $I(t)$, and subtracting the (real) value of depreciation from the value for the capital stock in time t-1. The depreciation rate, δ, is invariably assumed to be a constant, so depreciation equals δ times the value of the capital stock in t-1, $\delta K(t-1)$. Thus the usual difference equation links succesive values of the capital stock and investment expenditures:

$$K(t) = K(t-1) + I(t) - \delta K(t-1).$$

One decision is the choice of depreciation rate. We tried a number of alternatives and found little effect of the choice on the significance of the coefficient of the capital stock or other variables. We settled on the figure of 13 percent, following recent investigators such as Hall (1986) and Jorgenson and Sullivan (1981), who both used 12.7 percent.

Once having chosen a depreciation rate, the only problem -- and a major one -- is choosing a starting value and year for the capital stock. The problem is that it is very difficult, if not impossible, to obtain or derive a value for the **real** capital stock for any year independent of the perpetual inventory method. This holds especially for the firm data used here. Various alternatives have been tried by previous researchers: real capital stock benchmarks derived independently (Jorgenson and Siebert (1968)); the starting of the perpetual inventory calculation far enough before the sample period so that ignoring the starting capital value causes only a small error (Hall (1986), Jorgenson (1963)); avoiding completely the use of a capital stock series by using an equation that deals in first and higher differences (Coen (1971)). Given our data and the rather short sample period, all three of these alternatives were of questionable value.

We had two ways to face this problem. In most, but not all cases the two solutions led to very similar results -- probably because the capital stock variable made a relatively modest contribution to an equation's explanatory ability. The first solution was to start the perpetual inventory calculation with a recent value of the nominal capital stock in each location, usually gross fixed assets in 1959 for foreign operations and somewhat earlier for domestic. This, of course, led to a biased calculation as depreciation from this initial value was subtracted from gross investment for all successive years (until the initial value was totally depreciated). An alternative solution, that led to an unbiased estimate, was based on the fact that the inital capital stock is a constant; therefore, if care is taken, this constant can be estimated directly as a coefficient in the regression. To elaborate, let us express a few terms of a typical capital stock calculation starting from an initial value of K(0):

$$K(1) = I(1) + (1-\delta)K(0),$$

$$K(2) = I(2) + (1-\delta)K(1) = I(2) + (1-\delta)I(1) + (1-\delta)^2 K(0),$$

$$\text{and generally, } K(t) = \Sigma\, I_i (1-\delta)^{t-i} + K(0)(1-\delta)^t.$$

In looking at these expressions, it becomes clear that the real capital stock for any period can be broken up into two parts, the second of which always contains the same unknown: the initial real capital stock K(0). Assuming a value for δ, which we always do in calculating the capital stock, we can substitute for the variable K(t) the weighted average of past real investment levels (weighted by powers of the depreciation rate) and a second variable, $(1-\delta)^t$. This second variable should always be multiplied by the same unknown constant, K(0), but this can be estimated as a coefficient in a least squares regression. Thus a by-product of a regression using these two variables will be an estimate of the unknown initial capital stock, appearing as the estimated coefficient of the variable, $(1-\delta)^t$.

IV. Measures of the Cost of Capital (CCAP)

The variable CCAP (followed by some number, e.g. CCAP3) refers to our empirical measure of the cost of capital for a debt-free firm. In terms of the model developed in section III, CCAP would measure the term $q(\rho+\delta)/p$, where q is the capital goods deflator, p the firm's output price, ρ the riskless rate of interest, and δ the depreciation rate. The only new variable introduced in this expression is the riskless rate of interest; this was proxied by the yield on a U.S. government ten-year bond. This basic form of the cost of capital was denoted by CCAP3.

An alternative form, following one of the options used by Jorgenson (1963), added a speculative element, the negative of the rate of change of capital goods prices. We used the rate of change of a U.S. capital goods deflator, constructed by weighting equally the structures deflator and the equipment deflator. This variable was denoted by CCAP4. In one case, for firm #3, an undeflated variant of CCAP4 proved superior to CCAP4 itself; this variable was denoted by CCAP2 and differed from CCAP4 only insofar as the ratio of prices, q/p, was set to 1.

None of the above measures takes any account of changes in the tax system over time. In order to test for the impact of variations in such things as the investment tax credit, allowable depreciation rates, and, of course, the corporate tax rate, a variable constructed by Hall (1986) was also tested. It added nothing and, in fact, produced somewhat inferior results to CCAP4.

V. Measures of Internal Funds Available for Fixed Investment (FUND)

Variables measuring internal funds available for fixed investment are an integral part of the so-called reduced form regressions. See equation (18) and the preceeding discussion for the justifcation of this variable. The idea was to get a measure of that part of the capital stock (or its change) that could be financed by internal funds; any financing over and above this figure would of course necessitate the flotation of additional debt. This divison of the financing of the capital stock between internal and external sources is, of course, equivalent to determining the firm's debt/assets ratio.

A number of alternative measures could be constructed depending on what alternative uses of internal funds were assumed to be determined **prior** to the decision to finance fixed investment; the best fitting variable, FUND4, assumed that both dividends and changes in current assets were predetermined as far as fixed investment was concerned.

Since the variable refers to the financing of a stock of capital, the theoretical variable starts with a measure of the portion of the lagged capital stock not financed by debt: the value of the firm's gross capital stock (both domestic and foreign) minus its outstanding long-term debt. Added to this is the flow of potential internal finance for **additions** to the capital stock; this equals a measure of cash flow (profits after tax plus depreciation) minus dividends minus the change in current assets. As noted above, the latter two variables were subtracted from cash flow on the assumption that they are predetermined with respect to fixed investment. The relaxation of this assumption would require two more equations in the model in order to determine all four variables simultaneously.

VI. Alternative Measures of the Debt/Assets Ratio (Φ)

The debt to total assets measure allowed various possibilities for defining the relevant numerator. Two alternatives were attempted: long-term debt and the sum of long-term debt, notes payable, and debt due within a year. The ratio using the latter definition produced results that were slightly superior in all regressions except those for firm #5.

APPENDIX C: EQUATIONS FOR INDIVIDUAL FIRMS

Firm #1

Inverted Marginal Conditions

$$I_d = \underset{}{103.79} + \underset{(5.7)}{13.00}\,Q_d - \underset{(0.2)}{0.015}\,K2_d(t-1) + \underset{(0.2)}{4145.14}\,CCAP4(t-1)$$

$$- \underset{(3.5)}{51280}\,(2\Phi-\Phi^2) - \underset{(1.4)}{81.78}\,(1-\delta)^{t-1} + \underset{(8.8)}{96.37}\,DV66$$

RSQ = .96; SER = 10.28; ρ = -0.52; DW = 1.88; Range = 61-79.

$$I_f = 8.72 + \underset{(0.06)}{0.62}\,Q_f + \underset{(0.3)}{0.06}\,K_f(t-1) + \underset{(1.7)}{281.99}\,CCAP3(t-1)$$

$$- \underset{(2.0)}{14070}\,(2\Phi-\Phi^2)(t-1) - \underset{(0.2)}{4.42}\,DV72$$

RSQ = .47; SER = 4.19; ρ = 0.76; DW = 1.24; Range = 61-78.

Reduced Form

$$I_d = 45.36 + \underset{(6.8)}{14.79}\,Q_d - \underset{(2.2)}{20.08}\,Q_f - \underset{(1.4)}{0.06}\,K2_d(t-1) - \underset{(0.6)}{126.29}\,CCAP3(t-1)$$

$$+ \underset{(3.7)}{0.08}\,\Delta FUND4R1 - \underset{(1.1)}{52.85}\,(1-\delta)^{t-1} + \underset{(11.4)}{97.25}\,DV66$$

RSQ = .98; SER = 7.91; ρ = -0.60; DW = 2.09; Range = 61-79.

$$I_f = 25.59 - \underset{(7.8)}{32.23}\,Q_f(t-1) - \underset{(9.8)}{0.54}\,K_f(t-1) + \underset{(6.7)}{0.06}\,FUND4R - \underset{(3.7)}{14.80}\,DV72$$

RSQ = 0.95; SER = 4.38; ρ = -0.58; DW = 2.32; Range = 62-79.

Firm #2

Inverted Marginal Conditions

$$I_d = 686.69 + \underset{(2.6)}{12.17}\, Q_d - \underset{(0.04)}{0.002}\, K2_d(t-1) - \underset{(3.1)}{3160.61}\, CCAP3 - \underset{(2.3)}{28810}\, (2\Phi-\Phi^2)(t-1)$$

$$- \underset{(3.2)}{39060}\, (2\Phi-\Phi^2)(t-2) - \underset{(1.5)}{342.62}\, (1-\delta)^{t-1}$$

RSQ = .89; SER = 20.65; ρ = 0.68; DW = 1.59; Range = 60-79.

$$I_f = 22.91 + \underset{(1.9)}{29.91}\, Q_f(t) - \underset{(0.8)}{12.79}\, Q_f(t-1) - \underset{(0.7)}{0.11}\, K_f(t-1)$$

$$+ \underset{(0.5)}{300.62}\, CCAP3(t-1) - \underset{(1.9)}{24030}\, (2\Phi-\Phi^2)(t-2)$$

RSQ = .59; SER = 15.26; DW = 2.37; Range = 61-79.

Reduced Form

$$I_d = 635.08 + \underset{(6.9)}{38.84}\, Q_d(t-1) - \underset{(3.5)}{0.23}\, K_d(t-1) - \underset{(4.3)}{6760.32}\, CCAP3(t-1)$$

$$+ \underset{(2.0)}{0.09}\, FUND4R(t-2) + \underset{(2.2)}{0.14}\, FUND4R(t-3) - \underset{(2.9)}{73.13}\, DV72$$

RSQ = .96; SER = 25.37; DW = 1.57; Range = 62-79.

$$I_f = 220.49 - \underset{(1.9)}{11.96}\, Q_d(t-1) + \underset{(3.5)}{18.00}\, Q_d(t-2) + \underset{(2.2)}{26.55}\, Q_f + \underset{(0.7)}{10.39}\, Q_f(t-1)$$

$$- \underset{(4.1)}{0.76}\, K_f(t-1) - \underset{(3.1)}{2057.93}\, CCAP3(t-2)$$

$$+ \underset{(1.8)}{0.03}\, FUND4R(t-2) + \underset{(2.2)}{0.08}\, FUND4R(t-3)$$

RSQ = 0.82; SER = 11.68; DW = 2.40; Range = 62-79.

Firm #3

Inverted Marginal Conditions

$$I_d = \underset{}{113.50} - \underset{(0.07)}{0.63}\,\Delta Q_d(t-1) + \underset{(2.9)}{29.27}\,\Delta Q_d(t-2) + \underset{(2.5)}{18.20}\,\Delta Q_d(t-3)$$

$$- \underset{(1.8)}{2021.58}\,\Delta CCAP3(t-1) - \underset{(1.8)}{2277.15}\,\Delta CCAP3(t-2)$$

$$+ \underset{(3.0)}{0.11}\,K_d(t-1) + \underset{(5.0)}{179.69}\,DV74 - \underset{(2.8)}{120000}\,\Delta\Phi(t-3)$$

RSQ = .91; SER = 37.71; ρ = 0.56; DW = 1.87; Range = 62-79.

$$I_f = 86.49 + \underset{(3.9)}{30.01}\,Q_f(t-1) - \underset{(1.7)}{0.17}\,K_f(t-1) - \underset{(1.5)}{922.30}\,CCAP3(t-1) - \underset{(2.4)}{0.06}\,(2\Phi-\Phi^2)$$

RSQ = .96; SER = 39.97; ρ = -0.45; DW = 2.14; Range = 61-79.

Reduced Form

$$I_d = 7.60 + \underset{(3.6)}{48.17}\,Q_d - \underset{(1.8)}{16.14}\,Q_f - \underset{(3.3)}{0.27}\,K_d(t-1)$$

$$- \underset{(2.4)}{1091.47}\,CCAP2(t-1) + \underset{(3.4)}{0.16}\,FUND4R$$

RSQ = .93; SER = 42.06; DW = 1.98; Range = 61-79.

$$I_f = -180.70 + \underset{(3.3)}{20.26}\,Q_f(t-1) + \underset{(0.86)}{6.29}\,Q_d(t-1) - \underset{(3.6)}{0.22}\,K_f(t-1)$$

$$+ \underset{(3.5)}{0.11}\,FUND4R - \underset{(0.5)}{131.99}\,CCAP2(t-1) + \underset{(4.8)}{1.6E{+}6}\,SWITCH - \underset{(3.2)}{83.13}\,DV71$$

RSQ = 0.98; SER = 23.55; DW = 1.98 Range = 61-79.

Firm #4

Inverted Marginal Conditions

$$I_d = 239.06 + \underset{(0.6)}{1.64}\, Q_d - \underset{(1.5)}{0.36}\, K2_d(t-1) - \underset{(1.0)}{48.28}\, CCAP4(t-1)$$

$$- \underset{(1.1)}{99350}\, \Phi + \underset{(1.9)}{78500}\, \Phi^2 - \underset{(0.8)}{153.17}\, (1-\delta)^{(t-1)}$$

RSQ = .70; SER = 12.10; ρ = 0.68; DW = 2.21; Range = 60-75.

$$I_f = 10.46 + \underset{(3.6)}{9.50}\, Q_f(t-1) - \underset{(0.6)}{0.07}\, K_f(t-1) - \underset{(0.15)}{4.68}\, CCAP4(t-1) - \underset{(3.2)}{17040}\, \Phi(t-2)$$

RSQ = .91; SER = 5.14; ρ = -0.83; DW = 2.58; Range = 60-75.

Reduced Form

$$I_d = 29.95 + \underset{(1.9)}{6.20}\, Q_d + \underset{(2.6)}{11.32}\, Q_f(t-1) - \underset{(4.3)}{0.47}\, K_d(t-1)$$

$$+ \underset{(2.0)}{0.15}\, FUND4R(t-1) - \underset{(3.0)}{30.93}\, DV75$$

RSQ = .77; SER = 9.39; DW = 1.55 Range = 62-75.

$$I_f = 42.99 + \underset{(2.7)}{5.94}\, Q_f(t-1) - \underset{(2.8)}{3.01}\, Q_d(t-1) - \underset{(1.5)}{0.14}\, K_f(t-1) - \underset{(2.8)}{297.99}\, CCAP3(t-1)$$

$$+ \underset{(4.3)}{0.08}\, FUND4R1(t-1)$$

RSQ = 0.94; SER = 3.81; ρ = -0.78; DW = 3.21; Range = 62-75.

Firm #5

Inverted Marginal Conditions

$$I_d = 700.60 + \underset{(9.4)}{6.5}\, Q_d - \underset{(2.2)}{0.15}\, K_d(t-1) + \underset{(1.5)}{371947}\, CCAP(t-1)$$

$$-\underset{(5.4)}{1.1E{+}6}\, (2\Phi-\Phi^2) + \underset{(4.9)}{606.7}\, DV65$$

RSQ = .95; SER = 118.27; ρ = -0.50; DW = 2.16; Range = 60-79.

$$I_f = 770.26 + \underset{(5.2)}{16.95}\, Q_f(t-1) - \underset{(2.1)}{0.18}\, K_f(t-1) - \underset{(3.0)}{4345.1}\, CCAP(t-1)$$

$$-\underset{(4.2)}{714192}\, (2\Phi-\Phi^2)(t-2)$$

RSQ = .71; SER = 58.77; DW = 2.14; Range = 60-79.

Reduced Form

$$I_d = -314.34 + \underset{(2.4)}{2.66}\, \Delta Q_d + \underset{(0.5)}{0.89}\, \Delta Q_d(t-1) - \underset{(1.6)}{16.68}\, \Delta Q_f(t-1)$$

$$-\underset{(0.2)}{0.026}\, K2_d(t-1) + \underset{(1.6)}{8012.62}\, CCAP1(t-1) + \underset{(5.0)}{0.14}\, \Delta FUND4R$$

$$+\underset{(8.5)}{0.18}\, \Delta FUND4R(t-1) + \underset{(5.8)}{0.11}\, \Delta FUND4R(t-2) - \underset{(1.0)}{814.10}\, (1-\delta)^{(t-1)}$$

RSQ = .94; SER = 115.06; DW = 2.19; Range = 61-79.

$$I_f = 445.17 + \underset{(2.45)}{18.31}\, Q_f(t-1) - \underset{(1.89)}{2.47}\, Q_d(t-1) - \underset{(0.4)}{0.07}\, K_f(t-1) - \underset{(2.8)}{6373.03}\, CCAP3(t-1)$$

$$+\underset{(2.17)}{0.04}\, FUND4R$$

RSQ = 0.54; SER = 85.0; DW = 1.74; Range = 61-79.

Firm #6

Inverted Marginal Conditions

$$I_d = 261.56 + \underset{(2.0)}{9.81}\, Q_d(t-1) - \underset{(1.7)}{0.16}\, K2_d(t-1) - \underset{(0.5)}{204.78}\, CCAP3(t-1)$$

$$- \underset{(2.0)}{23800}\, (2\Phi-\Phi^2) - \underset{(2.8)}{344.37}\, (1-\delta)^{t-1} - \underset{(3.8)}{55.76}\, DV64$$

RSQ = .87; SER = 13.12; DW = 1.53; Range = 62-79.

$$I_f = 4.41 + \underset{(1.6)}{17.62}\, Q_f(t-1) + \underset{(0.3)}{0.06}\, K_f(t-1) + \underset{(0.2)}{49.87}\, CCAP3(t-1) - \underset{(1.7)}{11170}\, (2\Phi-\Phi^2)$$

RSQ = .28; SER = 10.00; DW = 1.91; Range = 60-79.

Reduced Form

$$I_d = 258.74 + \underset{(3.3)}{15.77}\, Q_d(t-1) + \underset{(1.3)}{6.19}\, Q_d(t-2) - \underset{(1.8)}{34.47}\, Q_f(t-1) - \underset{(2.3)}{0.15}\, K2_d(t-1)$$

$$- \underset{(3.1)}{956.08}\, CCAP3(t-1) - \underset{(3.6)}{244.69}\, (1-\delta)^{t-1} - \underset{(3.1)}{45.24}\, DV64$$

RSQ = .91; SER = 13.09; DW = 2.23; Range = 61-79.

$$I_f = -10.98 + \underset{(2.4)}{22.68}\, Q_f - \underset{(0.06)}{0.15}\, Q_d(t-1) - \underset{(0.45)}{0.07}\, K2_f(t-1) - \underset{(2.1)}{251.96}\, CCAP3(t-1)$$

$$+ \underset{(1.5)}{0.02}\, FUND4R(t-1) + \underset{(0.2)}{6.06}\, (1-\delta)^{t-1} + \underset{(3.8)}{24.92}\, DV63 + \underset{(4.2)}{27.65}\, DV67$$

RSQ = 0.84; SER = 5.45; DW = 1.99; Range = 61-79.

Firm #7

Inverted Marginal Conditions

$$I_d = -144.86 + \underset{(1.9)}{6.0}\, Q_d - \underset{(1.6)}{5.31}\, Q_d(t-1) + \underset{(4.6)}{13.87}\, Q_d(t-2) + \underset{(0.5)}{0.03}\, K_d(t-1)$$

$$+ \underset{(2.4)}{715.21}\, CCAP3 - \underset{(1.8)}{22860}\, (2\Phi-\Phi^2)$$

RSQ = .95; SER = 10.04; DW = 1.91; Range = 60-75.

$$I_f = 33.92 + \underset{(2.0)}{4.35}\, Q_f + \underset{(3.0)}{6.86}\, Q_f(t-1) + \underset{(3.6)}{12.97}\, Q_f(t-2) - \underset{(4.5)}{0.67}\, K_f(t-1)$$

$$- \underset{(3.0)}{119.38}\, CCAP3 - \underset{(2.0)}{39.97}\, (2\Phi-\Phi^2)$$

RSQ = .87; SER = 2.67; DW = 2.16; Range = 61-75.

Reduced Form

$$I_d = 2.89 + \underset{(2.9)}{8.52}\, \Delta Q_d - \underset{(3.6)}{28.69}\, \Delta Q_f - \underset{(3.1)}{16.26}\, \Delta Q_f(t-1) + \underset{(3.3)}{0.16}\, K_d(t-1)$$

$$- \underset{(0.8)}{180.77}\, CCAP3(t-1) + \underset{(3.1)}{0.11}\, \Delta FUND4R$$

RSQ = 0.84; SER = 11.34; ρ = 0.60; DW = 1.74; Range = 62-75.

$$I_f = 36.44 + \underset{(3.3)}{16.21}\, Q_f(t-1) + \underset{(3.0)}{8.98}\, Q_f(t-2) - \underset{(2.2)}{1.76}\, Q_d(t-2) - \underset{(6.1)}{0.88}\, K2_f(t-1)$$

$$- \underset{(4.6)}{218.24}\, CCAP3(t-1) + \underset{(2.5)}{0.07}\, FUND4R(t-2) - \underset{(0.9)}{27.01}\, (1-\delta)^{t-1}$$

RSQ = .93; SER = 2.85; ρ = -0.72; DW = 2.80; Range = 62-75.

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