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MULTINATIONAL FIRMS, TECHNOLOGY DIFFUSION AND TRADE

Wilfred J. Ethier

James R. Markusen

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ABSTRACT

Empirical evidence indicates a close association between multinational firms and knowledge capital, a "public good" within the firm. We model a firm which wishes to exploit its knowledge capital abroad, but whose workers learn all the knowledge necessary for production and can defect and produce the good themselves. The home firm must then choose between costly exporting and the possible dissipation of its knowledge capital by producing abroad. The paper examines the choice between exporting, licensing, and acquiring a subsidiary in this environment. We analyze the cost and technology parameters that support the alternative modes of serving the foreign market, and we describe the international equilibrium that jointly determines the pattern of specialization and the market mode.

Wilfred J. Ethier
Department of Economics
University of Pennsylvania
Philadelphia, PA 19104-6297

James R. Markusen
Department of Economics
University of Colorado
Boulder, CO 80309-0256
and NBER

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I. Introduction

THIS PAPER ADDRESSES the nexus of increasing returns to scale, international trade, growth and technological competition and dissemination.[1] Much recent literature has endogenized the rate of growth, technological change and the pattern of specialization. We instead endogenize market structure and link it to the international dissemination of knowledge.

Multinational enterprises (MNEs) are closely linked to knowledge-based capital,[2] whose services are easily transported between distant locations (managers and engineers visiting plants) relative to the services of physical capital. Knowledge-based capital often facilitates multi-plant production (blueprints or chemical formulae are costlessly supplied to additional plants). It is not surprising then to find an association between MNEs and the production of high-tech, R&D intensive goods. This association is central to this paper. Also central is the choice of mode under which the firm services a foreign market. We consider three choices: (1) exporting, (2) licensing a foreign firm, and (3) establishing a subsidiary (i.e., becoming a true MNE). The theory of the MNE is, or should be, first of all a theory of endogenous firm organization and endogenous market structure.

We model home firms that continually compete to introduce new products. A successful home firm has a proprietary advantage in its new product for just two periods and must decide how to exploit this advantage abroad. The firm chooses between exporting the good embodying the knowledge and exporting the knowledge itself to a subsidiary or licensee. Foreign production gives the foreign producer the knowledge needed for future production. We assume the complete absence of protection for "intellectual property" (knowledge capital) in the foreign country. The MNE must then choose between costly exporting and the possible dissipation of its proprietary asset. We address these points in a dynamic model in which home firms continually introduce new products. We analyze what underlying characteristics of the technology and market support alternative modes of serving that market.

We assume that a licensing contract is product specific whereas a subsidiary arrangement is firm specific. Thus a license does not embody any future commitments to future products of the home firm. Subject to incentive compatibility constraints on both the home firm and the subsidiary, the MNE contract gives the subsidiary rights to all future products as long as neither the home firm nor the subsidiary repudiates the agreement.[3] For this commitment to be valuable the subsidiary must earn positive rents from each product. Conversely, if the home firm and the licensee find no value in an (incentive compatible) commitment to future products, the home firm may be extracting all rents on each product.

We show that there are five distinct equilibrium outcomes possible for a given product: (1) the home firm exporting in both periods, (2) a two-period license with a foreign producer, (3) a subsidiary arrangement, (4) exporting in the first period followed by a one period license in the second, or (5) two successive one-period licenses with distinct foreign firms. Other potential arrangements are inconsistent with equilibrium. In situations where (1), (2) or (3) are chosen, all rents are extracted from the foreign market. Contract (3) involves sharing of rents between the home firm and the subsidiary while the home firm captures all rents in (1) and (2). With (4) and (5) some rents are dissipated but the licensee(s) earn no rents. The home firm is better off dissipating some rents than sharing the maximum rents with a subsidiary.

Results suggest how the type of equilibrium relates to the importance of pure-public-good knowledge capital (intellectual property) relative to the fixed cost of foreign production, the discount rate, the transfer costs to exporting, the foreign wage relative to the home wage, and the number of home firms competing to introduce new goods. The latter two variables are endogenous to our model, so we use their relation to the equilibrium type to solve for the full international equilibrium. This is then used to describe the influence of home and foreign market size on the pattern of international specialization, equilibrium market mode, relative wages and equilibrium intensity of research.

II. The Basic Model

Assume two countries, H and F, each exogenously endowed with a single factor of production, labor, immobile between countries. Firms in H use labor to conduct research and to produce goods; firms in F are assumed unable to conduct research and only produce goods.

A. New Products

Firms in H that conduct research enter a two-period race to develop a new product, with ρ units of H labor per period necessary for research; the firm with the best results wins, capturing for itself the ability to produce the next generation of new goods. *Ex ante* each project is equally likely to succeed, so if N firms try, the probability of success is $1/N$ for each.[4] The winner acquires exclusive knowledge of how to produce the new product plus a plant in H to manufacture that product at constant marginal cost. The product will remain new for two periods and then become old upon the appearance of the next generation new product. We assume that the firm must supply the H market from its plant located there, and that it can prevent anyone else from producing the product in H for the two-period duration of its newness. The firm can supply the F market either by exporting from its plant in H or by local production in F. The latter might be done by the H firm itself employing labor in F at a subsidiary, or by a firm in F licensed by the home firm.

Knowledge of how to produce a new product disseminates gradually. In the first period, only the H firm that developed the product knows how. Anyone involved in producing the good in the first period can produce it in the second. Thus first-period franchisees or subsidiary employees can now produce it themselves. After the second period, knowledge becomes common: any firm in either H or F can produce it, and it ceases to be new.

As long as the product remains new, production in either location involves a per-period fixed labor cost G plus a constant marginal cost of one unit of labor. Since the firm must supply H from its home plant, the fixed cost there is not relevant to exports, but exporting does involve an additional constant transfer cost t per unit, in terms of H labor.

Our model posits that the services of the knowledge-based capital resulting from the firm's research project can be costlessly supplied to foreign producers, and so G reflects additional input needed for production of a good that, because of its newness, may require unusual facilities or a monitoring effort independent of the length of the production run. These inputs will no longer be required when production becomes standardized, that is, when the good becomes old. Higher values of G indicate that the public-good aspect of knowledge is less important (i.e., knowledge is a less-pure public good).

We assume externalities to research. The externality influences all firms equally, so it does not affect the probability of success for any firm. We therefore assume that the externalities simply lower the fixed costs associated with the new good that is developed. That is, G is decreasing in N (and at a decreasing rate): $G = G(N)$ with $G' < 0$ and $G'' > 0$.

B. The Market for New Goods in F

Now consider demand conditions in F. Assume F has a large number L of identical consumers, each receiving the per capita income I. In particular, each individual has the following utility function.

$$u = Y - \frac{Y^2}{2} + \sum_{t=1}^{\infty} c^{-t} Y_t \tag{1}$$

Here $c > 1$ is the value placed on newness and Y_t consumption of the good that was new t generations ago[5]. The budget constraint is

$$I \geq pY + \sum_{t=1}^{\infty} wY_t \tag{2}$$

where p and w are the prices of new and old goods respectively. The market for old goods is competitive and they will be produced in F in any equilibrium that we will examine. Thus w will equal the wage in F. Taking first-order conditions of (1) subject to (2) gives the following.

$$Y_t = 0, \quad t > 1; \quad Y_1 = \frac{I}{w} - \frac{p}{w} + \frac{1}{c}\left[\frac{p}{w}\right]^2; \quad Y = 1 - \frac{p}{cw} . \tag{3}$$

Thus only new goods and the newest generation of old goods are actually demanded and so produced in equilibrium. Since there are a total of L consumers in F, the total demand for new goods is given by $y = LY$. This gives the following inverse demand function.

$$\frac{p}{w} = c - by, \quad \text{where } b = \frac{c}{L} . \tag{4}$$

The H firm may supply the F market as a monopolist directly from production in H or indirectly from production in F by a licensee or subsidiary. In either case, revenue and marginal revenue for a monopoly firm are given by

$$py = (cy - by^2)w, \quad MR = (c - 2by)w . \tag{5}$$

Setting marginal revenue equal to marginal cost w determines y, p and therefore profits if F is supplied by production in F itself. Monopoly rents R are given by

$$R = \left[\frac{(c-1)^2}{4b} - G\right] w . \tag{6}$$

If F is supplied by production in H, the marginal cost is instead $1 + t$ but the fixed cost G need not be incurred. We normalize the wage in H to unity: H labor is the numerâire and w the ratio of F wages to H wages. Since F will produce old goods in any equilibrium, $w \leq 1$. Then the monopoly rent becomes E.

$$E = w\frac{(c - m)^2}{4b} \tag{7}$$

Here $m = (1+t)/w$; $m > 1$ can be thought of as the marginal cost of serving F by exports relative to the cost of producing in F.

If H takes on a local partner during the first period, that partner will be able to produce new goods on its own in the second period. So consider the profits of each of two identical firms, both located in F, in a Cournot-Nash equilibrium. Let R^* denote total duopoly profit.

$$\frac{R*}{2} = \left[\frac{(c-1)^2}{9b} - G\right] w \tag{8}$$

Comparing the monopoly profit to the duopoly profit of each firm and of the two firms together:

$$R - \frac{R*}{2} = \frac{5(c-1)^2}{36b} w \tag{9}$$

$$R - R* = \left[\frac{(c-1)^2}{36b} + G\right] w \ . \tag{10}$$

Finally, we derive the Cournot-Nash duopoly profit, for the two firms together (E^*) and for each individually, if the only difference between the two is that one produces in H and one produces in F. Let a denote H's share of E^*.

$$E* = \frac{w[(c - m) - (m - 1)]^2 + w[(c - 1) + (m - 1)]^2}{9b} - wG \tag{11}$$

$$aE* = \frac{w[(c - m) - (m - 1)]^2}{9b} \tag{12}$$

$$(1 - a)E* = \frac{w[(c - 1) + (m - 1)]^2}{9b} - wG \tag{13}$$

Home exports must at least cover their cost for (12) to describe equilibrium, and this requires that $c - m$ not be less than $m - 1$. This in turn means that $c - 1 \geq 2(m - 1)$, and utilizing this relation in a comparison of (6) and (13) reveals that $R \geq (1\text{-}a)E^*$. Also R exceeds R^* from (10), and $(1\text{-}a)E^* \geq R^*/2$ from (8) and (13). On the other hand, the model implies no necessary relation between E and R^*.

III. Choice of Supply Mode

We now consider the H firm's choice of how to supply the F market while its products remain new. First we describe the alternatives, then we consider when each might be chosen. Two features of our model are crucial in deciding which arrangements are feasible.

Only a single H firm can initially produce new goods, but many F firms compete with each other, so H can dictate the terms of any agreement.

H cannot prevent a first-period partner from producing new goods in competition with H in the second period. Nor can the F partner prevent H from exporting on its own or from taking on a new partner in the second period.

In this section w and N will be treated as exogenous parameters; they will then be endogenized in Section V.

A. Alternative Supply Arrangements

H might simply export during both periods, earning E in each for total discounted earnings of $E(1+d)$. Alternatively, H might export in the first period and license a firm in F during the second. The licensee during that second period could earn R, which H could extract as a license fee, since there are many potential partners in F. Thus H earns $E + dR$ over the two periods (the fact that the licensee learns about the product is of no consequence, since that knowledge becomes common after the second period).

Alternatively, H might license a firm in F for both periods, earning $Q_1 + dQ_2$, where (Q_1, Q_2) denotes the two-period negotiated royalty schedule. The license might instead extend only over the first period, during which H earns the fee Q. In the second period H would then have to compete with its former licensee, earning aE^* if it did so by exporting, or the fee Q^* if it instead licensed another foreign firm during the second period.

The final possibility is for H to become an MNE by establishing a foreign subsidiary. H would agree to pay its employees in F total compensation of C_1 and C_2 in the respective periods. Let the two-period payments received by the firm from the subsidiary be given by Q_1 and Q_2, with a present value of $Q_1 + dQ_2$. The subsidiary's employees then receive $C_1 + dC_2 = (R - Q_1) + d(R - Q_2)$.[6] The MNE would be a permanent arrangement, providing for the exploitation by its employees in F of any future new goods developed by H.

Table 1 lists the possible alternatives with their implied payoffs. The earnings entries record total two-period discounted earnings of the respective firms. F_1 refers to foreign participants in an arrangement during period 1, and perhaps in period 2 also; F_2 refers to a foreign participant only in the second period.

Table 1

Alternative Arrangements

ARRANGEMENT	H EARNINGS	F_1 EARNINGS	F_2 EARNINGS
Exporting	$E(1+d)$	0	0
Exporting, then Licensing	$E + dR$	0	0
Licensing, then Exporting	$Q + daE^*$	$R\text{-}Q + d(1\text{-}a)E^*$	0
Successive One-Period Licenses	$Q + dQ^*$	$R\text{-}Q + d(R^*/2)$	$d((R^*/2) - Q^*)$
Two-Period License	$Q_1 + dQ_2$	$R\text{-}Q_1 + d(R\text{-}Q_2)$	0
MNE	$R\text{-}C_1 + d(R\text{-}C_2)$	$C_2 + dC_2$	0

B. Exporting Equilibria

Different parameterizations support different outcomes, and this relationship between parameters and outcomes (market structures) is what interests us. We illustrate the results in Figure 1, a parameter space in two key variables: R, total rents available in the foreign market, and $(1\text{-}a)E^*$, the return to the foreign licensee/subsidiary from defecting in the second period. Recall that our assumptions imply that $R > (1\text{-}a)E^* > R^*/2$ and $R > R^*$, so the relevant region in Figure 1 is restricted to below the 45° line, above the $(1\text{-}a)E^* = R^*/2$ line, and to the right of the $R = R^*$ line. Point A denotes that point in the plane where $R = R^*$ and $(1\text{-}a)E^* = R^*/2$. (The origin (0,0) is off the figure to the left, on the 45°line). The case $R^* > 0$ is reflected in the figure by the fact that A is below the 45° line. The two other restrictions noted below the figure will be discussed in due course.

Suppose first that $R < E$. Then there exists no contract which some F would accept that can give H a payoff greater than or equal to $E(1+d)$. Thus we have exporting in both periods.

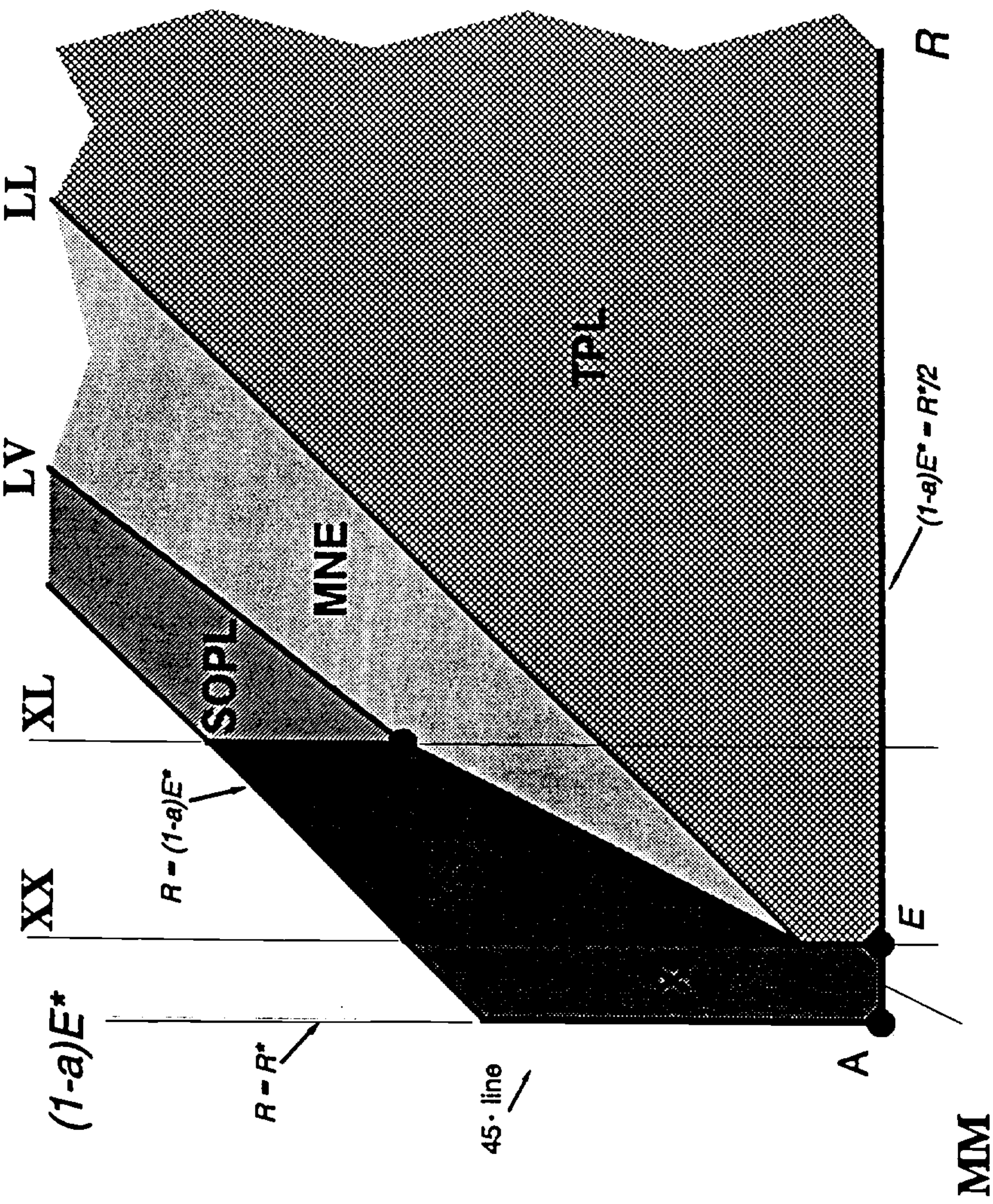

Figure 1

Possible Equilibria if $[(1-d+2D)/2D]R^* > E > R^* > 0$

XX is the locus 1 where $R = E$. Thus to the left of XX, exporting is chosen for both periods. To the right of XX H will never choose to export in both periods, because if it exports in period one a license will dominate exporting in period two. We summarize.

Proposition 1: *If $R < E$, exporting in both periods is the equilibrium. If $R > E$, exporting takes place in at most one period.*

C. Two-Period Licenses in Equilibrium

Consider next the two-period licensing option, and reason backwards, assuming first that H would respect the contract and asking whether F would. F would prefer a duopoly rather than to go-it-alone if and only if $(1-a)E^* > 0$. Consider this case first and evaluate whether F would violate a two-period license. Consider the fee schedule

$$Q_1 = R + (1-a)E*d, \qquad Q_2 = R - (1-a)E* \ . \tag{14}$$

This schedule gives F no incentive to violate or to go-it-alone. H will not defect either if $Q_2 > R^*/2$, the maximum Q^* that H could extract from a second licensee. Thus

$$R - (1-a)E* > \frac{R*}{2} \tag{15}$$

supports a two period license (TPL) if H offers it. Note from (14) that H's total return is $Q_1 + Q_2d = R(1+d)$, so H captures all rents. Thus under (14), (15), and $(1-a)E^* > 0$, TPL is the equilibrium. Locus LL in Figure 1 gives (15) with equality. This locus is parallel to the 45° line. Points (to the right of XX) below LL give TPL as the equilibrium. Note finally that points above LL cannot support a two period licensing contract. There is no second-period license fee that would not cause either H or F to violate.

The above argument applies when $(1-a)E^* > 0$, as in Figure 1, but the conclusion does not depend on this. Suppose that $0 > (1-a)E^* > R^*/2$. The fee schedule (14) will not work here, because it would induce F to walk away in the second period. Here a feasible schedule is

$$Q_1 = Q_2 = R \ . \tag{16}$$

F has no incentive to reject or to violate in the second period. H collects all rents so that this contract is preferred to exporting or to an MNE. But might H violate in the second period? If F responds by going-it-alone, ($R^*/2 < 0$), then H earns R from the second licensee, so that H is no better off than honoring contract (16). If F responds by playing duopoly ($R^*/2 > 0$), H will violate only if $R^*/2 > R$, which contradicts (9). The fee schedule (16) thus supports TPL as the equilibrium the right of XX when $(1-a)E^*$ and R^* are negative. Note finally that as R^* and $R^*/2$ approach zero, the LL locus shifts left and approaches the 45° line. Thus with $0 \geq (1-a)E^* > R^*/2$, TPL is indeed the only relevant contract.

Proposition 2: *A two-period licensing contract (TPL) is the equilibrium to the right of XX and below LL in Figure 1. Above LL, a two-period license can not be supported.*

The restriction $R > E$ is a market-size restriction since a branch plant, whether owned by the firm or by a licensee, is a high fixed cost choice while exporting is a high variable cost choice. Then $(R - E)$ grows with the size of the market. Similarly, R^* grows with the size of the market.

D. A License Followed by Exporting

To the right of XX and above LL, a single-period license followed by exporting cannot be an equilibrium. To see this, note that if H were to export in the second period, H would have to compete with its former partner, since $(1-a)E^* > 0$. If instead H were to issue a new second period license,[7] that would generate a duopoly since $R^*/2 > 0$. In this case, H earns Q^*. The maximum Q^* that H can extract from a second licensee is $R^*/2$. Thus H would prefer a second license to licensing followed by exporting if and only if

$$\frac{R*}{2} > aE* \ . \tag{17}$$

But the restriction that we are above LL implies that

$$\frac{R*}{2} > R - (1-a)E* \ \geq E* \ - (1-a)E* \ - aE* \tag{18}$$

if $R \geq E^*$. Referring back to equations (6) and (11), we can show that this inequality must hold. The maximum value of E^* occurs when the home firm cannot compete in this duopoly, so that the defecting licensee earns $(1\text{-}a)E^* = E^* - R$. But this maximum value satisfies (18).

Proposition 3: *A one-period license followed by exporting can never occur in equilibrium.*

Any equilibrium featuring a one-period license in the first production period will also feature another license in the second period. We accordingly refer to this arrangement as successive one-period licenses (SOPL). Table A2 in the Appendix lists and describes the loci in Figure 1.

E. MNE Equilibria

Consider next the choice between a subsidiary (MNE) and successive one-period licenses (SOPL). For MNE to be feasible, F's two-period earnings must be great enough to induce F to accept (19), F's second-period earnings must be great enough so that F does not defect (20), and the second-period fee must be great enough that H does not defect (21):

$$(R - Q_1) + d(R - Q_2) \geq 0 \tag{19}$$

$$(R - Q_2) + \frac{V}{d} \geq (1-a)E* \tag{20}$$

$$Q_2 \geq \frac{R*}{2} . \tag{21}$$

V denotes the present value to F of the MNE arrangement beyond the current two periods. In the future, the arrangement will be of value only when H succeeds in bringing out new products, which happens with probability $1/N$. V is accordingly given by

$$V = \frac{d^2}{(1-d)N}\left[R - \frac{(Q_1 + dQ_2)}{1+d}\right] = \frac{d^2}{(1-d^2)N}\Big((1+d)R - (Q_1 + Q_2 d)\Big) . \tag{22}$$

Note first that any earnings schedule (Q_1, Q_2) satisfying (19), (20), and (21) for which (19) is met with equality implies that $V = 0$. This means that the (Q_1, Q_2) could be implemented as a TPL, but this is impossible above LL. Thus any feasible schedule must imply a strict inequality in (19).

To solve for the optimal MNE contract, note that H is indifferent to a repatriation schedule change $\Delta Q_1 = -(d)\Delta Q_2 > 0$, and from (22) this leaves V unchanged as well. But it increases the left-hand side of (20), allowing H to raise fees overall. The implication is that H optimizes in a MNE agreement by setting the lowest level of Q_2 consistent with (21), so $Q_2 = R^*/2$. Intuitively, keeping Q_2 as low as possible minimizes F's incentive to defect in the second period, and so allows H to keep a larger share of the rents.

To delineate the area in Figure 1 where such a schedule is optimal, substitute (21) and (22) into (20) and impose equality. The latter becomes

$$(R - \frac{R*}{2}) + \frac{d}{(1-d^2)N}\Big((1+d)R - (Q_1 + dQ_2)\Big) = (1-a)E* . \tag{23}$$

Rearrange (23) to obtain explicitly the discounted repatriation schedule ($Q_1 + dQ_2$), and then set this equal to the return from successive one-period licenses, SOPL. In the latter case, the maximum first-period fee is ($R + dR^*/2$) and the discounted second-period fee (dQ^*) is $dR^*/2$.

Thus the fees from SOPL will be $(R + dR^*)$. Setting the MNE fees from (23) equal to the SOPL fees,

$$(Q_1 + dQ_2) = \frac{(1-d^2)N}{d}\left[R - \frac{R*}{2} - (1-a)E*\right] + (1+d)R = R + dR* \ . \tag{24}$$

Rearrange this equation as follows.

$$(1-a)E* = (R - \frac{R*}{2}) + \frac{d^2}{(1-d^2)N}(R - R*) \ . \tag{25}$$

Equation (25) gives the LV locus in Figure 1. Above LV, SOPL is preferred to MNE, while below LV MNE is preferred to SOPL. Note that LV is steeper than LL and that LV has an intercept on $R = E$ that lies above the intercept of LL, provided that $E > R^*$. This latter case is shown in Figure 1. Note also that on LV, F earns positive two-period rents in the amount $d(R - R^*)$, so that (19) is automatically satisfied with a strict inequality.

Now turn to the choice between an MNE contract and XSPL. Earnings from XSPL will equal $E + dQ_2 = E + dR$ since H can extract all rents in the second period. Earnings from the MNE continues to be given by the left-hand side of (24). Setting these two equal, we have

$$\frac{(1-d^2)N}{d}\left[R - \frac{R*}{2} - (1-a)E*\right] + (1+d)R = E + dR \ . \tag{26}$$

Rearranging,

$$(1-a)E* = (R - \frac{R*}{2}) + \frac{d}{(1-d^2)N}(R - E) \ . \tag{27}$$

Equation (27) is expressed in Figure 1 as locus MM. Note that $(Q_1 + dQ_2) = (E + dR)$ implies that F captures rents $(R - E)$ and so (19) is again satisfied. XSPL is preferred to MNE above MM and MNE is preferred to XSPL below MM. Note that MM and LL have the same intercept on $R = E$, and that MM is steeper than either LL or LV. Thus the relationships among MM, LV, and LL must be as shown in Figure 1, provided that $E > R^*$.

Proposition 4: *MNE is the equilibrium in Figure 1 above LL and below MM and LV.*

F. One-Period Licenses in Equilibrium

Now consider the region above LL, and above either MM or LV in Figure 1. In this region, a two-period license cannot be an equilibrium (we are above LL) and MNE cannot be an equilibrium (we are above MM or LV). Thus the equilibrium must be either XSPL or SOPL. For SOPL to be an equilibrium, Q_1 must be small enough to induce F to accept the first-period contract and Q^* must be small enough to attract a second period licensee.

$$Q_1 \leq R + \frac{R*}{2}d \tag{28}$$

$$Q*d \leq \frac{R*}{2}d \;. \tag{29}$$

H will prefer SOPL to XSPL if and only if the sum of the right hand sides of (28) and (29) exceeds $E + dR$.

$$dR* \;+ (1-d)R > E \;. \tag{30}$$

The locus of points in which (30) holds with equality is given by XL in Figure 1. Since $R > R^*$ from (6) and (8), XL must lie to the right of XX, provided once again that $E > R^*$. LV, MM, and XL intersect as they logically must (i.e., the intersection of MM and LV implies that H is indifferent between MNE and XSPL, and also indifferent between MNE and SOPL, so H is necessarily indifferent also between XSPL and SOPL: a point on XL).

Proposition 5: *In the region of Figure 1 above LL, and above* either *MM or LV, XSPL or X is the equilibrium to the left of XL and SOPL is the equilibrium to the right of XL.*

For all of the cases mentioned in Proposition 5 to be feasible possibilities, it is necessary that the common intersection of LV, MM and XL lie in the feasible zone below the 45° line, as is depicted in Figure 1. Now MM intersects the 45° line when $R = R - R^*/2 + (D/d)(R - E)$, or $R = (d/D)(R^*/2) + E$. This intersection will in turn be to the right of XL if

$$\frac{d}{D}\frac{R*}{2} + E > \frac{1}{1-d}E - \frac{d}{1-d}R* \tag{31}$$

or if

$$\left[\frac{1-d}{2D} + 1\right] R* > E . \tag{32}$$

This latter condition ensures that the common intersection of LV, MM and XL lies below the 45° line, so that the possibilities are as shown in Figure 1.

We now have a complete picture of one possible case in Figure 1, which shows the full range of possible outcomes. Figure 1 reflects constraint (32) and also, as we noted earlier, the constraint $E > R^*$. It is easy to find parameterizations of the model that satisfy these constraints. However, it also easy to see how the figure changes when these constraints fail. For completeness, we record these changes in Table 2 below.

Table 2

Alternative Possibilities

$E > [(1\text{-}d+2D)/2D]R^*$	MM, LV and XL intersect above the 45° line, so SOPL ceases to be possible; the other four feasible zones remain.
$[(1\text{-}d+2D)/2D]R^* > E > R^*$	Figure 1 applies as shown.
$R^* > E$	XL is to the left of XX and $R < R^*$ on XX; since our model requires $R \geq R^*$, X and XSPL cease to be possible: exporting can never occur in equilibrium.

IV. The Influence of Basic Parameters

The previous section offered a reduced-form analysis in the sense that alternative equilibria were related to potential outcomes such as E, R, E^* and R^* rather to the basic parameters of the model presented in section II. This was to make a complex situation a little more transparent (our model has a lot of basic parameters) and also to add some robustness by making clear that our arguments apply to any model generating such potential outcomes. This section, though, takes a step back to offer some general observations about how the results shown in Figure 1 and Table 2 relate to some of the more important basic parameters.

First consider the role of G. Since we hold the foreign market size constant, we can interpret increases in G as either decreases in the importance of knowledge capital relative to physical capital or costly-to-transfer technology, or as decreases in foreign market size.

Consider a *reduction* in G (e.g., an *increase* in the importance of knowledge capital relative to physical capital). Equations (6) and (13) imply that *reductions* in G *raise* R and $(1-a)E^*$ equal amounts: they correspond to movements up and to the right parallel to the 45° line in Figure 1. Thus if the initial arrangement is exporting, it eventually changes to XSPL or to TPL. Similarly, the equation for XL indicates that XSPL may switch to SOPL. Reviewing the equations for LL and LV along with equations (9), (10), and (13), we see that a decrease in G increases the left-hand sides of LL and LV and the right-hand sides are either constant (LL) or falling (LV). Thus a TPL tends to switch to an MNE and an MNE tends to switch to SOPL.

There are two basic implications of a fall in G. First, it improves the attractiveness of producing in F relative to exporting (reflected in the results that X or XSPL switches to producing in F in both periods, or at least one period in the case of the initial X). This is brought out most forcefully by the possibility that, because it raises R^* but not E, a fall in G might switch us into the regime $R^* > E$ which, as is recorded in Table 2, precludes exporting completely. But secondly, a fall in G increases the gains to H and F from defecting in the second period. This shows up in our result that TPL can switch to an MNE or an MNE can switch to SOPL. In summary, a fall in G (increase in the relative importance of knowledge capital) increases the likelihood of producing in one or both periods in F and, given two-period production in F, moves the contract from a license to a rent-sharing MNE to a succession of one-period licenses. The latter occurs at a value of G that is so low that defection is inevitable. Thus as the importance of knowledge capital increases, H first begins to share rents and then inevitably finds it preferable to dissipate some rent and capture all of the smaller "pie".

An even more limited role may be played by N, the number of firms competing in H to develop new products. The primary effect of a rise in N on Figure 1 is to flatten MM and LV and to shift them downwards, so that both approach LL in the limit. This expands the XSPL and SOPL regions at the expense of the MNE region: the commitment of the H firm to supply future products becomes less valuable as research competition intensifies because the firm can expect to develop fewer new products successfully. The regions corresponding to exporting and to two-period licenses are not affected directly by changes in N. But in addition to these direct effects, a rise in N produces indirect consequences due to its externality of decreasing G. If this externality is significant, the consequences of a fall in G that were just described must be added to the direct effects of the rise in N.

Now consider the role of t, the tariff/transportation cost per unit of exports. Refer again to Figure 1, and note that increases in t do not affect LL and LV. Increases in t move us vertically upwards, from (6) and (13). Thus for very small t, we are in the TPL region, for medium levels of t we move into the MNE region, and for still larger t SOPL become the equilibria, if we are to the right of XL. Increases in t also lower E, from (7), so they shift XX and XL to the left, thereby making exporting less likely and causing XSPL to correspond to smaller values of R.

High transfer costs render exporting unattractive, but they also make it difficult to sustain a two period agreement since they make it easier for F to defect ($(1-a)E^*$ increases with t). At a certain level of t, a two-period license can no longer be supported but the subsidiary can be, due to the present value of future rents to subsidiary employees. But for still larger t, rents from violating outweigh future rents from respecting, so only SOPL can be sustained. The effects of high transfer costs on XSPL are ambiguous: they make exporting unattractive, but with defection more likely, waiting for the second period to find a foreign partner may be the best that H can do. Geometrically, increases in t shift MM up, thereby reducing the size of the XSPL region (as it moves to the left). But they also cause us to move vertically up, so the effect on the likelihood of being in the XSPL region is unclear.

Consider next the role of d. High values indicate low discounting ($d \leq 1$). With reference again to Figure 1, note that $(1-a)E^*$ and R do not depend on d, and neither do LL and XX. Thus in the exporting or two-period licensing regions, d is irrelevant. Consider the MNE region. A decrease in d shifts LV and MM down and we eventually jump to XSPL or SOPL: increases in time preference reduce the value of future products to F and thus increase the incentive to defect. They also make H less willing to wait until the second period to extract rent: XL shifts to the left, expanding the SOPL region at the expense of the XSPL region.

Finally, consider w, the wage in F relative to that in H. From (7) and (8), an increase in w raises R^* in proportion and raises E proportionally more. MM falls and XL shifts right. Thus an increase in w makes exporting in one or both periods more likely. From (6) and (13) an increase in w also raises R in proportion and $(1-a)E^*$ in lesser proportion, thereby causing movements to below LL or LV from positions on or slightly above either. Thus, if we are initially in SOPL, there is a tendency to move from SOPL to MNE to TPL as w rises: relatively higher production costs in F make exporting from H a more potent second-period threat and second-period defection less of a threat.

Table 3

Circumstances Leading to Alternative Equilibria

	G	d	t	w	N
X	H	-	L	H	[L] -
XSPL	H, M	L	?	H	[M] H
SOPL	L	L	H	L	[H] H
MNE	M, L	H	M	L, M	[M] L
TPL	H, M	-	L	M	[L,M] -

In Table 3, H, M or L indicates whether high, medium or low parameter values make the respective arrangement the most likely outcome.[8] Bracketed terms in the N column apply if external effects are important (and therefore involve significant changes in G) and the unbracketed terms when externalities are limited.

V. International Equilibrium

Of the parameters in Table 3, two are endogenous: w and N. We examine this international equilibrium. It should surprise no one that it can assume many forms, depending on exogenous parameters. We do not attempt to be exhaustive but instead treat in some detail the case $R^* > E$. This necessarily holds for sufficiently small w because $E = 0$ if $wc < 1 + t$ while $R^* > 0$ even for an arbitrarily small (but positive) w, if the term in brackets in (8) is positive. As w rises, E rises relative to R^* and will eventually overtake it, but not within the relevant interval $0 \leq w \leq 1/(1+t)$ if G is sufficiently small and/or t sufficiently large. This is clear from (7) and (8). We assume this. Thus only TPL, MNE and SOPL are possibilities.

A. Equilibrium

Consider first the TPL case. Assume that preferences in H are identical to those in F, so that $b^h = c/L^H$, where L^H denotes the labor force in H. Recall that the successful H firm conducts research for two periods and then exploits its advantage during the next two periods. Thus $\pi(N, w)$, the payoff to a successful research project, discounted to the commencement of that project, is given by the following, with a TPL.

$$\pi(N,w) = d^2(1+d)\left\{\left[\frac{(c-1)^2}{4b} - G(N)\right]w + \left[\frac{(c-1)^2}{4b^h} - G(N)\right]\right\} \tag{33}$$

The labor devoted to research incurs a present-value cost of $(1+d)\rho$, where d denotes the discount factor. Thus free entry into research implies that N must satisfy

$$\frac{\pi(N,w)}{N} = (1+d)\rho \ . \tag{34}$$

In view of (33) this can be written as follows.

$$\phi(N,w) = \left[\left(\frac{c-1}{2}\right)^2\left(\frac{w}{b}+\frac{1}{b^h}\right) - G(N)(w+1)\right]d^2 - \rho N = 0 \tag{35}$$

Assume for simplicity that the externality G' is insignificant and can be ignored – we will describe in a footnote how things would change were this not so. The respective partial derivatives of the above equilibrium condition are then

$$\phi_N = -\rho\ ; \quad \phi_w = d^2\left[\frac{(c-1)^2}{4b} - G\right] > 0\ . \tag{36}$$

The condition $\phi = 0$ is depicted in Figure 2. Old goods are produced in F. If they are also produced in H, competition requires that the relative wage satisfy $w(1+t) = 1$, assuming that t units of F labor are required to move each old good from F to H. Let N^o solve (34) if $w = 1/(1+t)$, so that $N = N^o$ if any old goods are produced in H.

If instead of TPL we are in MNE or SOPL, the appropriately lower-valued term must be substituted into the expression for π. This reduces ϕ_w but leaves ϕ_N unchanged, so the graph of $\phi = 0$ becomes flatter. As we saw in the previous section, lower values of w make first MNE and then SOPL more likely. Figure 2 accordingly represents a case[9] where the equilibrium is TPL above w_{LL}, MNE between w_{LV} and w_{LL} and SOPL below w_{LV}. Let L^H denote the supply of H labor and $y^H(w)$ the supply of new goods to the H market:

$$y^H(w) = \frac{c}{2b^h} - \frac{1}{2b^h w}\ . \tag{37}$$

Then $\lambda(N, w)$, that part of the H labor force not used for new goods, is given by

$$\lambda(N,w) = L^H - G - \frac{c}{2b^h} + \frac{1}{2b^h w} - \rho N - y_1^H\ . \tag{38}$$

Let N^1 solve $\lambda(N, 1/[1+t]) = 0$. The partial derivatives of $\lambda(N, w)$ are as follows.

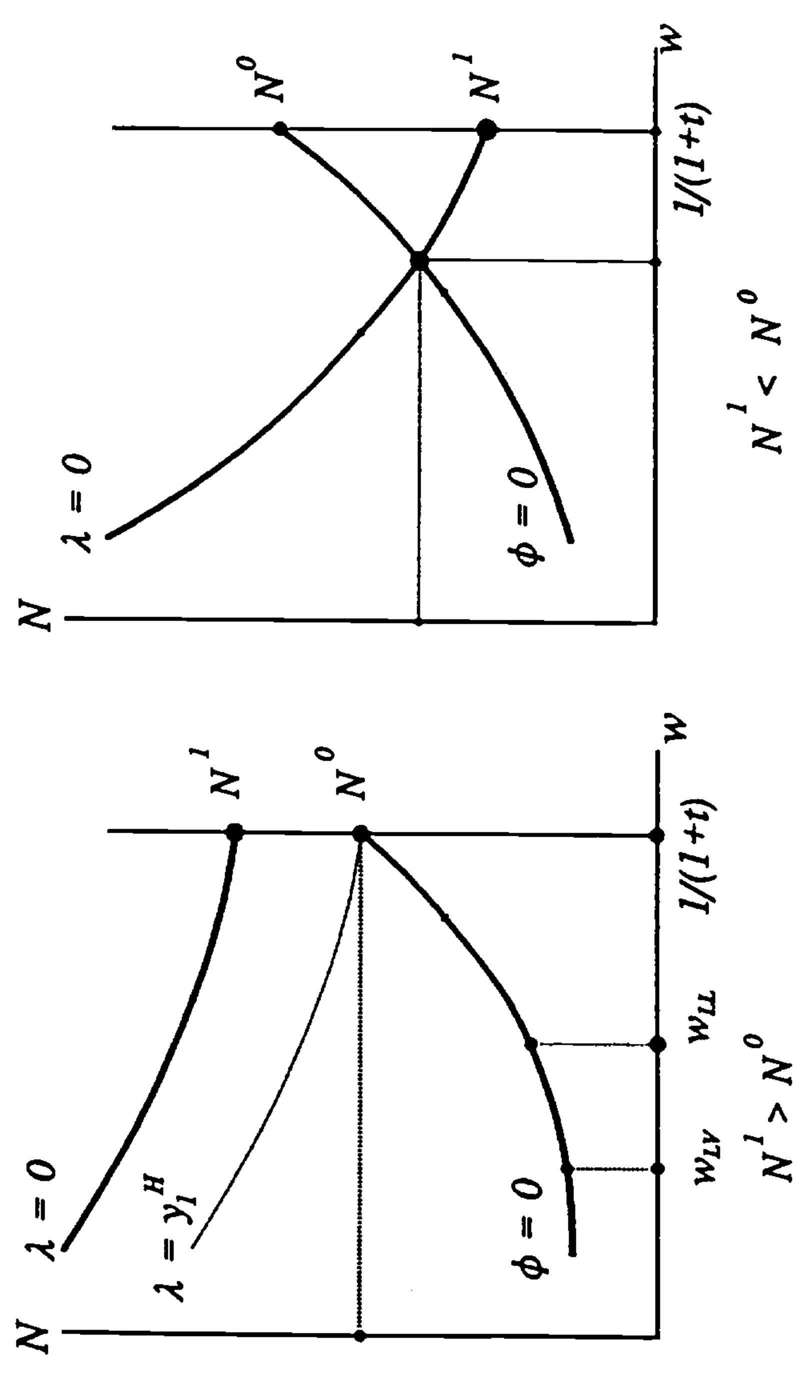

Figure 2

$$\lambda_N = -\rho \; ; \qquad \lambda_w = -\frac{1}{2b^h w^2} \; . \tag{39}$$

The condition $\lambda = 0$ is depicted in each panel of Figure 2. 'Isoquants' corresponding to positive production of old goods in H lie below and to the left of the $\lambda = 0$ contour. The figure shows equilibrium in the alternative cases where old goods are and are not produced in H:

$$\begin{aligned} &\text{If } \; N^0 \le N^1: \quad N = N^0; \;\; y_1^H = \lambda(N^0, \frac{1}{1+t}); \;\; w = \frac{1}{1+t} \\ &\text{If } \; N^0 > N^1: \quad y_1^H = 0 = \lambda(N, w); \;\; \frac{\pi(N, w)}{N} = \rho(1+d) \; . \end{aligned} \tag{40}$$

B. Country Size

Now that we have explicit expressions for ϕ and λ, it is straightforward to do comparative statics and directly relate various outcomes to particular values of the exogenous parameters such as t, c, d and ρ. For example, we can derive a specific condition for $N^1 > N^0$. We leave most such exercises to the determined reader, but will illustrate with a discussion of the effect of country size.

Foreign labor. Consider first the role played by L, the labor force in F. Variations in L vary the demands for both old and new goods in F, but under present assumptions these are met entirely by local production: nothing is exported from H. Thus such variations have no direct effect on the H labor market: our explicit expression for λ is independent of the parameter L.

Instead, a change in L impacts H by altering the profitability of selling new goods in F, influencing the incentive to undertake research in H. A rise in L directly lowers b in (35), shifting $\phi = 0$ up in Figure 2. As is clear from the figure, if $N^1 > N^0$, so old goods are initially produced in H, this causes no change in relative wages w but $N = N^0$ rises to the full extent of the shift in $\phi = 0$. As we move up onto successive λ contours, production of old goods in H falls: H labor is reallocated from old-good production to research. This is because the rise in L has increased the profitability of selling new goods in F, increasing the license fee received by the successful H researcher, causing all firms to intensify research. The higher license fees are paid with exports of old goods from F, replacing the lowered H production.[10] Note that the rise in L has increased specialization: H does more research and F exports more old goods.

If instead $N^1 < N^0$, either because this was the case initially or because the shift in $\phi = 0$ brings it about, equilibrium moves up along $\lambda = 0$, with w falling as N continues to rise, but by less than the full shift in $\phi = 0$. What's happening now is that, with no old goods produced in H, the labor for increased research can come only from lowering the production of new goods. The demand for researchers in H drives up H wages (thereby lowering w); this makes the sale of new goods in H less profitable, so production is cut back, releasing labor for research. But this also partially negates the increase in the value of winning the research race brought about by the increase in license fees, so the increase in N is moderated. The fall in w also makes the threat of second period exports from H less powerful, so if the fall is great enough it may no longer be possible to sustain TPL and equilibrium would shift to MNE or even to SOPL. While w is lowered by the upward shift in $\phi = 0$, the increase in L that causes this directly raises w_{LL}, since the latter two are positively related by the equation for the LL locus. Eventually w will fall below w_{LL}; whether this occurs within the relevant range depends of course on the parameterization.

Home Labor. A rise in L^H directly lowers b^h in (35), shifting $\phi = 0$ up analogously to a rise in L: the reward to selling new goods rises and induces additional research so N increases. Only now the higher profits from new goods are due to increased demand in H rather than from higher license fees in F. The shift in $\phi = 0$ is as follows.

$$\left[\frac{\partial N}{\partial L^H}\right]_{\phi=0} = \frac{cd^2}{\rho}\left[\frac{c-1}{2c}\right]^2 \qquad (41)$$

The $\lambda = 0$ locus is affected directly by the rise in L^H in two countervailing ways: the rise itself constitutes an increased labor supply, but the higher profitability from new goods generates an increased labor demand in order to increase new-good production. We have

$$\left(\frac{\partial N}{\partial L^H}\right)_{\lambda=0} = \frac{1 + \dfrac{1}{cw}}{2\rho} . \qquad (42)$$

The numerator of (42) is positive, so the effect on labor supply dominates that on labor demand. Thus the $\lambda = 0$ locus must also shift up in response to an increase in L^H.

If initially $N^t > N^0$ an increase in L^H produces basically the same results as an increase in L, except that the shift in the $\lambda = 0$ locus moderates (and may even reverse) the decline in the production of old goods in H. With $N^t < N^0$, the shift in $\lambda = 0$ magnifies the increase in N caused by the rise in L^H and moderates or reverses the fall in w.

Comparison of (41) and (42) reveals that the locus $\lambda = 0$ shifts more than the $\phi = 0$ locus if and only if

$$\frac{1}{w} > \frac{d^2}{2}(c-1)^2 - c . \qquad (43)$$

Since the right hand side of this inequality is necessarily negative for all c in the interval $[1, 1 + (2/d^2)]$, this is a weak condition so the more interesting case occurs when it is satisfied: the labor-market equilibrium locus $\lambda = 0$ shifts more. Then if initially $N^t > N^0$ an increase in L^H causes the inequality to widen: w does not change and H continues to produce old goods. If initially $N^t < N^0$ we move up and to the right along the shifting $\phi = 0$ locus: research intensifies but the greater labor supply depresses wages in H. Since w_{LL} is invariant with respect to L^H (recall footnote 9) w will eventually rise above it if it is initially below, but, again, whether this occurs within the relevant range depends on the parameterization. Also, the initial inequality $N^t < N^0$ may ultimately be reversed. Thus H production of old goods is associated with a *large* home country, and the larger the home country the more likely is it that the equilibrium will feature TPL rather than MNE or SOPL. If instead (43) were violated and it were the $\phi = 0$ locus that shifted the more, these conclusions would be reversed.

The bottom line to this is that international diversification (that is, the production of old goods in H), relatively high F wages, and the TPL market mode are all associated with a large

H economy and a small F.[11] Intense research activity is associated with large sizes of both economies.

VI. Concluding Remarks

This paper draws on the empirical association between MNEs, knowledge-based assets, and advanced technology to analyze the choice of mode for serving a foreign market. The joint-input property of knowledge-based capital that supports MNE market structures in the first place also implies a risk of asset dissipation when the knowledge capital is transferred to a foreign firm. We assume that foreigners eventually learn to produce a good on their own, and learn faster if the good is actually produced in their country than if it is imported. We also assume that no contracts can enforce protection of intellectual property (knowledge capital), which may be a preferred assumption in the international context to complete enforceability.

A home firm with a new product must choose between costly exporting and the early loss of the value of its knowledge as a result of producing in the foreign country. When producing within the foreign country, the home firm must choose between a product-specific license of one or two periods and a subsidiary (becoming a MNE). The MNE structure is chosen when (1) knowledge capital is of medium or high importance relative to physical capital, (2) discounting is low so that commitments to future products are valuable, (3) exporting costs are medium, so that exporting is not chosen yet some disincentive is provided to subsidiary employees not to defect and face competition from exports, (4) the wage in F is low relative to H to encourage production in F, and (5) fewer H firms compete in product development, so that the subsidiary attaches a higher probability to successful new products.

In addition to exporting in both periods, a two-period license, and a subsidiary, the firm may resort to successive one-period licenses or to exporting followed by a one-period license when there exists no second-period license fee or share that would not lead one of the partners to defect. The firm thus chooses among five modes of serving the foreign market. We related each possible choice to the magnitudes of the five basic parameters. When exporting, a two-period license, or an MNE are chosen, all possible rents are extracted from the foreign market. The home firm retains all rents in the first two cases but shares them in the MNE mode. When successive one-period licenses or exporting followed by a one-period license are chosen, some rent is dissipated. The home firm finds the moral hazard problem severe enough so that it prefers to dissipate some rent rather than to give up the share necessary to induce a subsidiary/licensee not to defect.

Our analysis concludes with a description of general equilibrium in terms of basic parameters. This is used to examine the effects of country size on the pattern of specialization, the choice of market mode, equilibrium relative wages and the intensity of research. This paper has been confined to positive analysis, and we have made no attempt to describe the welfare implications of alternative equilibria or to analyze the consequences of policy measures. Instead we have developed a model that can be used for such purposes.

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Footnotes

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1. See Ethier (1979, 1982), Romer (1986, 1990) and Grossman and Helpman (1991).

2. See Caves and Murphy (1976), Wilson (1977), Mansfield and Romeo (1980), Caves (1982), Nicholas (1983), Davidson and McFertridge (1984), Markusen (1984), Beaudreau (1986) and Ethier (1986).

3. A subsidiary can be said to repudiate an MNE agreement if its employees quit to produce a similar product on their own.

4. Thus we take as exogenous the length of time a race lasts and the effort expended by each participant, and we also assume that research undertaken to develop one generation of new goods has no effect on the success of research devoted to a subsequent generation. We model the research process in this rudimentary way because we are less interested in the process itself than in the way its results are exploited.

5. Note that with this formulation the appearance of a new good causes the consumer to derive less satisfaction from old goods, rather than more from new goods. In effect, we rescale each individual's utility function whenever a new good comes on the scene. This will not be necessary for our basic results and we never add utilities across periods, but it will generate a convenient stationary property. Note also that new goods are subject to diminishing marginal utility but cease to be so once they become old. This is intended to represent a learning process by consumers.

6. Note that we use the same notation for the schedule of repatriated earnings by an MNE and for the license fee schedule. This is to conserve notation and to emphasize the parallelism

between the two alternative arrangements. For convenience, our notation is summarized in Table A1 in the Appendix.

7. H cannot issue a second license to its original partner in any equilibrium, because in our full-information model this would be equivalent to a TPL, which cannot be an equilibrium above LL.

8. The results on the roles of G and t are consistent with those of other theoretical papers such as Horstmann and Markusen (1987a, 1987b, 1991) and Ethier (1986), and also with empirical papers referenced in footnote 2.

9. w_{LL} is the value of w that satisfies the equation of the LL locus, and $(w_{LV}, \phi(w_{LV}))$ are the values of w and N that simultaneously solve the equation of the LV locus and $\phi = 0$. Thus w_{LL} depends on the parameters c, t, G and L, while w_{LV} depends on these same parameters and also on L^H, ρ and d. Implicit derivation of the equation for the LL locus reveals that $dw_{LL}/dL >$ 0. Of course not all permissable values of these parameters will result in solutions for w_{LL} and w_{LV} that lie in the relevant region $(0, 1/(1+t)]$, so not all three sections of the $\phi = 0$ locus need be relevant, but it is easy to find parameter values that ensure this.

10. We are describing a comparison of steady states, not the process of moving from one steady state to another.

11. Our analysis in this section has been based on the assumption that the externality G' is sufficiently small that it can be ignored. If this is not so, the externalities associated with an increase in N would lower the costs world-wide of producing new goods. In addition, the externality adds a positive term to both ϕ_N and λ_N. Should this be large enough to make both positive, the slopes of $\phi = 0$ and $\lambda = 0$ would both reverse, contours corresponding to positive H production of old goods would lie above $\lambda = 0$, and $N^0 > N^1$ would result in an equilibrium where H produces old goods. Furthermore, the positive terms added to ϕ_N and λ_N would be unequal, so, as the externalities G' become more pronounced, these expressions would not both change signs at the same time. This implies that there would be a range of externalities

that would cause $\phi = 0$ to be the more responsive to changes in L^H, so that a small home country-size would make TPL and home production of old goods more likely.

12. H might also offer an MNE arrangement after exporting in the first production period. But we ignore this because we are interested in equilibria that can emerge as steady state situations, and since a MNE is by assumption a permanent relation, such a transition could occur but once.

Appendix

This Appendix contains several aids to help the reader keep track of the argument in Section III, Choice of Supply Mode: a list of our notation, a description of the choice as a game between players in H and F (to give an overview of the argument), and a table describing the various loci.

Table A1: Notation

R	monopoly rent from a local plant
E	monopoly rent from exporting
R^*	total duopoly rent with two local plants
$R^*/2$	duopoly rent per firm with two local plants
E^*	total duopoly rent with exports and one local plant
$(1-a)E^*$	local plant's share of E^*
aE^*	exporter's share of E^*
w	wage in F relative to H
(Q_1, Q_2)	two-period license-fee or repatriation-of-earnings schedule
Q	one period license fee
Q^*	second period license fee from second licensee
d	discount factor ($d = (1+r)^{-1}$ if r is discount rate)
(C_1, C_2)	compensation paid by home firm in MNE contract
V	present value to F in future (beyond the first two periods) MNE contract.

A Game-Tree Parable

Our model reqires that any feasible arrangement be incentive compatible. A convenient way to examine this is to describe the production of a new good as a two-period game between H and a potential partner in F and to look for subgame perfect equilibria. These will correspond to the feasible arrangements.

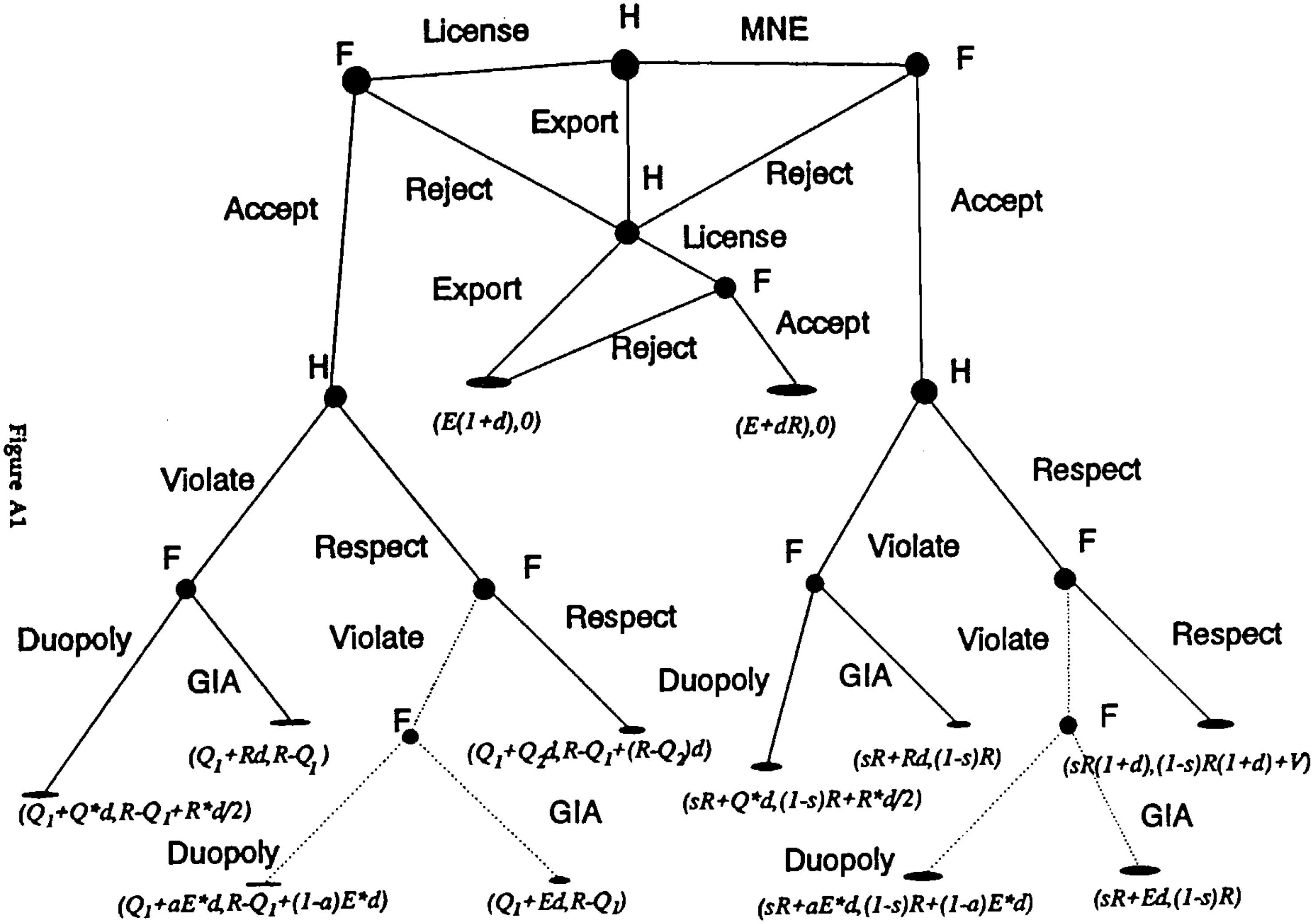
The game tree is shown in Figure A1. In the first play of the game, H chooses either to export directly (X), to offer a license (L), or to offer an MNE arrangement (M).

If exporting is chosen, or if all potential F reject a license or MNE arrangement offered instead, H must export in the first production period and choose whether to export again in the second period or to offer a license.[12] If H chooses X, or if it chooses L and all potential F reject this, H exports in both production periods. If H chooses L and some F accepts, H exports in the first period and licenses in the second.

If H chooses L or M in the first play, and if F accepts either the contract or the MNE arrangement, then H decides whether to honor or violate the contract at the beginning of the second period, where violating means that H negotiates a second license with a new licensee at the beginning of the second period. Suppose that H decides to respect the contract. F can in turn respect or violate. If F respects, the game ends. If F violates, he can either continue to produce against H as a duopolist, or go-it-alone (GIA) (not participate in producing this good).

Suppose instead that H violates. There is no meaning to F "respecting" in this case. F only has the choice of continuing to produce against the new licensee or going-it-alone.

A licensing contract which both players respect, if it emerges as an equilibrium of this game, corresponds to an incentive-compatible two-period license. Suppose instead that a license contract is agreed upon and that H respects it, but F violates. Assume for simplicity that H would not have time enough to negotiate a new license once the violation is revealed at the beginning of the second period, and must therefore resort to exporting. F will violate by continuing to produce, since it cannot do as well by leaving the industry. Such an equilibrium outcome corresponds to a first period license followed by exporting. If the initial agreement



License
H
MNE
F
F
Export
H
Reject
Reject
Accept
Accept
License
F
Export
Accept
Reject
H
H
(E(1+d),0)
(E+dR),0)
Violate
Respect
Respect
F
F
F
F
Violate
Duopoly
GIA
Violate
Respect
Duopoly
GIA
Violate
Respect
F
F
(Q1+Rd,R-Q1)
(Q1+Q2d,R-Q1+(R-Q2)d)
(sR+Rd,(1-s)R)
(sR(1+d),(1-s)R(1+d)+V)
(Q1+Q*d,R-Q1+R*d/2)
(sR+Q*d,(1-s)R+R*d/2)
GIA
GIA
Duopoly
Duopoly
(Q1+aE*d,R-Q1+(1-a)E*d)
(Q1+Ed,R-Q1)
(sR+aE*d,(1-s)R+(1-a)E*d)
(sR+Ed,(1-s)R)

Figure A1

was an MNE which F violates, the game proceeds exactly as just described: the second-period payoffs when H respects and F violates are exactly the same whether a license or a subsidiary was the initial contract.

Now suppose that a license contract is agreed upon, but H violates by issuing a second license. F will continue to produce, and such an equilibrium corresponds to successive one-period licenses.

If the initial agreement was an MNE and H violates, the game proceeds exactly as just described. The second-period payoffs when H violates and F also violates, either by continuing to produce or by going-it-alone, are the same regardless of whether the initial agreement was a license or an MNE.

Table A2: Loci

XX	$R = E$	To the left of XX, X must be the equilibrium. To the right of XX, XSPL dominates X.
LL	$(1-a)E^* = R - R^*/2$	Below LL (and right of XX) TPL is the equilibrium. Above LL TPL cannot be an equilibrium.
LV	$(1-a)E^* = (R - R^*/2) + D(R - R^*)$	[$D = d^2/((1-d^2)N)$] MNE dominates SOPL below LV and MM; SOPL dominates MNE above LV.
MM	$(1-a)E^* = (R - R^*/2) + (D/d)(R - E)$	[$D = d^2/((1-d^2)N)$] Above MM, X or XSPL dominates MNE; below MM, MNE dominates X or XSPL.
XL	$dR^* + (1-d)R = E$	SOPL dominates XSPL right of XL while XSPL dominates SOPL left of XL.