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Licensing versus direct investment: implications for economic growth

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Abstract

We develop a symmetric two country model of foreign direct investment (FDI) that captures the internalization decision and its implications for both the *rate* and *magnitude* of innovations. When mode choice (licensing versus FDI) is fixed, a subsidy to multinational production increases the rate but decreases the size of innovations. When mode can switch, the rate and size of innovations both increase, provided the subsidy is not too large. Although innovation size decreases for industries where firms already were choosing FDI, innovation size increases for industries where firms switch from licensing to FDI because multinationals choose larger innovations than licensors. © 2002 Elsevier Science B.V. All rights reserved.

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1. Introduction

For several decades, foreign direct investment (FDI) flows have been growing much faster than world trade, and worldwide sales of foreign affiliates of multinationals now exceed exports (UNCTAD, 1997). Part of this expansion in FDI can be attributed to the policy shift of many governments toward attracting FDI or restricting it less. Between 1991 and 1998, some 58 countries began to take

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a proactive approach toward attracting FDI, roughly doubling the number of such countries from 60 to 118 (Moran, 1998).

Despite the growing importance of FDI and the increased desire of many countries to attract FDI, the consequences of FDI for economic growth have received scant attention in the theoretical literature – a void noted by Grossman and Helpman (1995). Empirical evidence on the effects of FDI on growth does suggest that, on balance, FDI has a positive impact on growth: recent studies include Borensztein et al. (1998) and Balasubramanyam et al. (1996).

Almost all existing theories of FDI and licensing have been developed in either static or partial equilibrium models.¹ A few dynamic general equilibrium models do explore the effect of FDI on growth but these models have ignored the possibility of licensing.² This omission is significant: as Ethier (1986) notes, the study of FDI must be foremost a study of internalization – the decision to keep activities within the firm. Historically (and even today), some countries have not allowed foreign firms to choose their mode of supply, preferring technology licensing (or joint ventures) over fully owned subsidiaries of foreign firms.³ How do such policy interventions affect economic growth?

We build a symmetric two – country model of FDI that captures the internalization decision and its implications for both the rate and magnitude of innovation. We examine how policy interventions (taxes or subsidies to FDI) that alter the incentive to internalize production within the firm affect economic growth.⁴ To our knowledge, ours is the first work to analyze these issues in a setting where firms can choose between FDI and licensing.⁵ We find that the ability of firms to switch modes from licensing to FDI in response to policy changes is vital for ensuring that a subsidy to FDI leads to faster economic growth.⁶

Markusen (1995) provides several stylized facts about FDI that are central to our model. First, FDI is mostly horizontal, where multinationals create local

¹See Markusen (1984, 1989); Ethier (1986); Horstmann and Markusen (1987, 1992, 1996); Saggi (1996, 1999); Markusen and Venables (1998); Wright (1993) and Vishwasrao (1994).

²See Wang and Blomström (1992); Helpman (1993); Walz (1997); Glass and Saggi (1998, 1999), and Petit and Sanna-Randaccio (2000). The main exception is Ethier and Markusen (1996) but their focus is on mode choice rather than innovation.

³Licensing can also be interpreted as a joint venture between a local firm and a foreign firm. The crucial distinction is that, unlike FDI, arms length arrangements such as licensing force foreign firms to share rents with local firms.

⁴In our model, a subsidy to FDI can also be interpreted as a decline in the cost disadvantage suffered by multinationals due to some other factors such as improvements in communications technology that facilitate coordination across countries.

⁵Horstmann and Markusen (1992) consider shifts in the mode firms choose of serving markets abroad, but in a setting without growth. Aghion and Howitt (1990) determine the innovation magnitude, but in a model without FDI or licensing.

⁶Our model also shares a feature similar to the inefficient entry in Horstmann and Markusen (1986): parameter changes that lead to more FDI do so by drawing in (from licensing) firms with higher production costs than existing multinationals.

production facilities within each country or region. Second, multinationals have substantial intangible assets and arise in industries with large R&D expenditures relative to sales – see also Brainard (1997) and Caves (1996). Third, multinationals suffer cost disadvantages relative to their local rivals due to operating in unfamiliar environments or logistical difficulties of coordination.

As Davies (1977) noted, foreign firms typically suffer a cost disadvantage relative to local firms due to lack of familiarity with local conditions. As a result, local firms will enjoy greater present value in a given project than foreign firms as long as they employ the same technology. If a foreign firm with a superior technology could appropriate the entire rent using technology licensing, it would always prefer licensing to FDI. However, empirical evidence indicates that, on average, licensors can appropriate less than half of the surplus associated with the license transaction (Caves, 1996; Caves et al., 1983). This aspect of technology licensing serves as an important assumption in our analysis.

Since our interest is in aggregate implications, we abstract from the details of why licensors are forced to share rents.⁷ We assume that the share of rents captured by licensees is the same in the two countries. If rent sharing is primarily due to information asymmetries, then roughly the same rent shares should apply everywhere. Legal systems and protection of intellectual property rights may also affect the share of rents that licensees retain – see Markusen (2001); Vishwasrao (1994) and Yang and Maskus (2001) for models that capture such effects.

Our model is based on the familiar ownership, location and internalization (OLI) paradigm where exports, licensing, or multinational production can arise as the chosen method of serving markets abroad. In our model, ownership advantage results from investments in innovation. There is a continuum of industries and firms may attempt to improve the product in any industry – they pick an innovation intensity and an innovation size as well as which industry to target with their innovation.

Once a firm is successful in innovation, it chooses its market *mode*: whether to serve the market abroad by establishing a local production subsidiary or by licensing its technology to a local firm (a location advantage such as transportation costs rules out exports). Our model uses two parameters to capture the tradeoff between incomplete extraction of rents as a licensor and greater costs as a multinational. An increase in the *share of profits retained by licensees* or a decrease in the *cost disadvantage suffered by multinationals* strengthen the incentives for internalization, thus making FDI more attractive relative to licensing.

While our primary interest is in understanding how adjustments in the market mode between licensing and multinational production contribute to changes in the speed and size of innovation, we begin with a base case where the mode and size

⁷See Gallini and Wright (1990); Rockett (1990); Horstmann and Markusen (1987, 1996) and Wright (1993) for models generating this outcome based on informational considerations.

of innovations are fixed. In this benchmark, a decrease in licensee profit retention or in the cost disadvantage of multinationals increases the rate of innovation.

Next, we examine how internalization advantage affects the size and speed of innovation when firms can choose their modes of serving markets abroad. We assume that industries inherently differ with respect to their multinational cost disadvantage because technologies in some industries are harder to adapt to different economic environments or to coordinate across geographically separated locations. As a consequence, some industries serve markets abroad through multinational production while others choose licensing. In this general model, a subsidy to multinational production causes *multinationals to reduce the magnitude of their innovations* by reducing their need to generate ownership advantage.

However, the subsidy also makes FDI more attractive relative to licensing thereby increasing the extent of FDI, the fraction of all industries that choose to serve markets abroad through multinational production. Since multinationals choose larger innovations than firms that license their technologies, *firms switching from licensing to FDI raise the magnitude of their innovations*. Provided the subsidy is not too large, the average innovation magnitude (across both multinationals and licensors) rises. Thus, host country policies that attract FDI through financial incentives *increase both the rate and average magnitude of innovations*, clearly increasing economic growth.

Mode switching also has the potential to alter the effect of licensee rent retention on economic growth. Policy, either directly or indirectly, can affect the allocation of rents between the licensor and the licensee. With mode fixed, an increase in the licensee's share of rents reduces the speed of innovations without altering their size, so economic growth necessarily declines. However, when some industries switch their mode from licensing to multinational production, the average innovation size increases due to multinationals choosing larger innovations than licensors. The larger size of innovations can dominate their less frequent occurrence, leading to an increase in economic growth.

Section 2 establishes the behavior of firms. Section 3 characterizes how the parameters central to the internalization decision influence the rate of innovation for the base case where innovation size and the mode of serving markets abroad are fixed. Section 4 examines the effect of internalization advantage on the magnitude as well as the rate of innovation when firms may switch market modes between FDI and licensing and contrasts these findings with the base case. Section 5 concludes. All proofs appear in Appendix A.

2. Dynamic OLI model

We build a dynamic OLI model based on the quality ladders model of innovation by Grossman and Helpman (1991a,b), but with two symmetric innovating countries. Assuming symmetric countries greatly simplifies our analysis

and may not be too far from reality for similarly developed countries. Our model formalizes the view that ownership, location and internalization advantages dictate whether firms serve markets abroad through export, FDI (establishing a production subsidiary abroad), or licensing their technology to local firms.

Ownership advantage refers to some aspect, such as a unique product design, that a firm does better than others.⁸ Location advantage refers to some aspect, such as tariffs or transportation costs, that makes producing in the same location as consumption preferable to producing in one place and shipping to wherever demand is located. Internalization advantage refers to some aspect, such as incomplete contracts, that makes keeping transactions within the firm preferable to arms-length transactions between firms.⁹

We are primarily interested in FDI and licensing, so we assume that tariffs or transportation costs are sufficiently high that FDI and licensing are the only relevant options remaining for serving markets abroad. Initially, we assume that an exogenous fraction η of all industries use multinational production to serve markets abroad, while the remaining $1 - \eta$ use licensing. We will refer to η as the *extent of FDI* and $1 - \eta$ as the *extent of licensing*. In this base case of exogenous internalization, we explore how parameters that affect the profitability of licensing and FDI alter the rate of innovation. Later, we will allow the extent of FDI η and the innovation magnitude λ to vary, but for now they are fixed.

2.1. Product market

A continuum of products $j \in [0,1]$ are each available in different quality levels. Assume consumers are willing to pay a premium λ for a one-quality-level improvement in a product, where λ is the innovation size or magnitude. Consumer preferences giving rise to these properties are the same as in Grossman and Helpman (1991a,b) – details are provided in Appendix A. Let E be aggregate expenditure, the amount consumers that spend on each product. Consumers live in either the domestic or the foreign country. Of the total spending, $E_D = f_D E$ is spent by domestic consumers and $E_F = f_F E$ is spent by foreign consumers, where the expenditure shares sum to one $f_D + f_F = 1$.

Normalize the unit labor requirement in production of any quality level of any product to one in each country. Let the labor requirement in innovation be given by a in both countries. Further, let L denote the total world labor supply so that each country's labor supply equals $L/2$. As a result, the countries have the same wage, and the expenditure shares both equal one-half $f_D = f_F = 1/2$. Altogether, these assumptions make the two countries exactly identical.

Also, normalize the common wage to one. Thus, the marginal cost of producing

⁸See Horstmann and Markusen (1989) and Markusen (1984).

⁹See Markusen (1995); Saggi (1996, 1999); Ethier and Markusen (1996) and Horstmann and Markusen (1996).

one unit of output (of any quality) is 1 in either country. Assuming Bertrand behavior, suppose in each industry, one firm can produce the highest quality level and another firm can produce the quality level one below.¹⁰ Firms maximize profits by engaging in limit pricing. Each firm that invented the highest quality level available of a product charges the highest price that keeps its rival (the firm able to produce the next highest quality level of that product) out of the market.

Thus, prices will be $p = \lambda$, a mark-up of the quality increment relative to marginal costs. A rival could sell the lower quality level at no less than its marginal cost of one and make non-negative profits. Consumers view the higher quality level sold at price λ to be equivalent to the lower quality level sold at a price of one, so λ is the limit price. With these prices, sales are $x = E\delta$, where define the inverse innovation magnitude as $\delta \equiv 1/\lambda$. A firm's instantaneous profit takes the form $\pi = (p - c)x$ (where c is marginal cost), which depends on how the market abroad is served.

Let $\zeta > 0$ be the cost disadvantage of multinationals operating abroad. A multinational has marginal cost $c^M = 1 + \zeta/2$ and thus earns instantaneous profits.

$$\pi^M = E \left[1 - \left(1 + \frac{\zeta}{2} \right) \delta \right] \quad (1)$$

The downside of FDI is the additional costs ζ of operating in an unfamiliar location.¹¹

While multinationals face a cost disadvantage, licensors do not capture the full rents created by an ownership advantage. Let $\theta > 0$ be the fraction of profits collected by licensees, with the remaining $1 - \theta$ collected by the licensor. A licensor has marginal cost $c^L = 1$ and thus earns instantaneous profits.

$$\pi^L = E(1 - \delta) \left(1 - \frac{\theta}{2} \right) \quad (2)$$

The two countries have the same θ and ζ to keep them symmetric. We do not permit θ to be a function of the innovation size λ because we will develop an alternative explanation of why larger innovations are kept within the firm; we will show that multinationals develop larger innovations than licensors.

2.2. Ownership advantage through innovation

Firms must have some ownership advantage to offset the difficulty of serving foreign markets. Ownership advantage here takes the form of the unique knowledge of how to produce a higher quality level of a product relative to any other firm.

Innovation resembles a lottery: costs are born up front with an uncertain payoff.

¹⁰A description of the innovation process yielding these properties follows in Section 2.2.

¹¹A subsidy to multinational production is a reduction in multinational cost disadvantage.

The innovation process is the same as in Grossman and Helpman (1991a,b). Assume innovation races occur simultaneously for all products, with all firms able to attempt to invent the quality level above the current highest quality level.¹² Further assume undertaking innovation intensity ι^k for a time interval dt requires $a\iota^k dt$ units of labor and leads to success with probability $\iota^k dt$, where $k \in \{M,L\}$ denotes industries whose market mode is multinational production or licensing. Since price competition yields no profits when firms have the same technology, no quality level is ever invented twice.

Each non-producing firm chooses its intensity of innovation to maximize its expected value, given the innovation intensities of other firms.¹³ To generate finite rates of innovation, expected gains must not exceed their cost, with equality when innovation occurs with positive intensity

$$v^k \leq a, \iota^k > 0 \Leftrightarrow v^k = a, \tag{3}$$

where v^k is the value a firm gains from successful innovation if it serves the market abroad using mode k . This reward to innovation is the discounted stream of profits from production. We focus on equilibria with positive innovation intensities for both modes: innovation targets industries that serve markets abroad through multinational production as well as those that use licensing.

All producing firms are exposed to further innovation that ultimately ends the stream of profits earned from an innovation. Firms that successfully innovate earn the reward

$$v^k = \frac{\pi^k}{\rho + \iota^k}, \tag{4}$$

where π^k denotes instantaneous profits defined in Eqs. (1) and (2), ρ the discount rate, and ι^k the innovation intensity targeting industries that engage in market mode k .

The aggregate (or average) rate of innovation ι is the extent of FDI η times the innovation intensity targeting industries that engage in multinational production ι^M plus the extent of licensing $1 - \eta$ times the innovation intensity targeting industries that engage in licensing ι^L .

$$\iota \equiv \eta \iota^M + (1 - \eta) \iota^L \tag{5}$$

Once we characterize the labor constraints, we can describe the general equilibrium in the next section.

¹²See also Segerstrom (1991); Segerstrom et al. (1990); and Taylor (1993).

¹³Innovation is done by followers – see Grossman and Helpman (1991b).

3. Rate of innovation for the base case

Initially, we assume that the innovation magnitude λ and the extent of FDI η are exogenous.¹⁴ To hold mode fixed, we assume that the fraction η of industries engage in multinational production, while the others engage in licensing. We determine the equilibrium aggregate expenditure E and rate of innovation ι , as well the composition of innovation between targeting industries that conduct FDI and those that conduct licensing.

3.1. Labor constraint

By the assumed symmetry, each country performs half of the world's innovation, does half of the world's spending and provides half of the world's labor force. Each country's labor constraint is therefore equivalent to the world labor constraint. In the world, $a\iota = a[\eta\iota^M + (1 - \eta)\iota^L]$ units of labor are needed for innovation, and $x = E\delta$ units of labor are needed for production. The world labor constraint requires world labor demand for innovation and production to equal the world labor supply.

$$a[\eta\iota^M + (1 - \eta)\iota^L] + E\delta = L \quad (6)$$

The labor constraints, together with innovation conditions for multinationals and licensors derived next, provide the three key equations in our model, which will determine the variables ι^M , ι^L , and E .

3.2. Innovation conditions

In industries that conduct FDI, the valuation condition for firms is given by Eq. (3). Substituting the producing firm valuation Eq. (4) and multinational profits Eq. (1) into Eq. (3) yields the valuation condition for multinationals.

$$E \left[1 - \left(1 + \frac{\zeta}{2} \right) \delta \right] = a(\rho + \iota^M) \quad (7)$$

Decreases in multinational cost disadvantage ζ increase profits and thus the reward to innovation.

Substituting the producing firm valuation Eq. (4) and licensor profits Eq. (2) into Eq. (3) yields the valuation condition for licensors.

$$E \left(1 - \frac{\theta}{2} \right) (1 - \delta) = a(\rho + \iota^L) \quad (8)$$

¹⁴The proof of Proposition 1 allows the exogenous innovation magnitude for multinationals to exceed that for licensors, for later use.

Decreases in licensee profit retention θ also increase profits and thus the reward to innovation.

3.3. Solution

The system of equations is the labor constraint Eq. (6), the innovation condition for FDI Eq. (7), and the innovation condition for licensing Eq. (8). The system determines the equilibrium level of aggregate expenditure

$$E = (L + a\rho) \left[\frac{2}{2 - \theta(1 - \eta)(1 - \delta) - \eta\delta\zeta} \right], \quad (9)$$

the equilibrium innovation intensity targeting the products of multinationals

$$\iota^M = \frac{LN - (L + a\rho)[2\delta + (1 - \eta)\zeta\delta\theta(1 - \delta)]}{aN}, \quad (10)$$

and the equilibrium innovation intensity targeting the products of licensors

$$\iota^L = \frac{LN + (L + a\rho)[2\delta + \eta(\theta(1 - \delta) - \zeta\delta)]}{aN}, \quad (11)$$

where $N \equiv 2 - \theta(1 - \eta)(1 - \delta) - \eta\delta\zeta$.

Using the innovation intensities Eqs. (10) and (11), we find the equilibrium rate of innovation Eq. (5) to be

$$\iota = \frac{LN - 2(L + a\rho)\delta}{aN} \quad (12)$$

If we set the multinational cost disadvantage to be zero $\zeta = 0$ and licensee's rent share to zero $\theta = 0$, the equilibrium of the model replicates the aggregate expenditure and rate of innovation of the closed economy quality ladders model by Grossman and Helpman (1991a). In the absence of any friction between them, the two countries are just like one country split in half.

3.4. Comparative statics

Our first result reports the impact of various parameters that alter the profitability of licensors and multinationals. Reducing the multinational cost disadvantage ζ or reducing licensee profit retention θ increases the reward to innovation and hence leads to faster innovations. The composition of innovation between targeting licensors and targeting multinationals responds to the relative incentives for innovation: the first change favors innovation targeting multinationals while the latter favors innovation targeting licensors. Aggregate expenditure falls to free up labor from production to be used for innovation.

The intuition for why an increase in ζ lowers innovation targeting multinationals but increases innovation targeting licensors comes from the general equilibrium

nature of our model. An increase in ζ makes multinationals less attractive candidates as innovation targets so that resources shift into innovation targeting licensors. Alternatively, for both licensing and FDI to occur in equilibrium both licensors and multinationals must earn the same rate of return: if multinationals become less profitable, they must face a lower risk of being innovated over relative to licensors. Of course, innovators face reduced profitability overall when either mode becomes less desirable (due to an increase in θ or ζ) so that the aggregate rate of innovation must fall.

Proposition 1. (Fixed mode and innovation size) *A decrease in the cost disadvantage of multinationals ζ increases the aggregate rate of innovation and the innovation intensity targeting multinationals, while decreasing the innovation intensity targeting licensors and aggregate expenditure. Similarly, an increase in the share of profits retained by licensees θ decreases the aggregate rate of innovation, increases aggregate expenditure, and also shifts innovation toward targeting multinationals and away from targeting licensors.*

Empirical evidence supports this result. A survey by Mansfield et al. (1979) found that large US companies drew 29 to 34% of the returns from their R&D projects from foreign markets. Furthermore, the firms indicated that if they were to collect no returns from abroad, they would reduce their R&D anywhere from 16 to 26%, and if they were forced to use other methods than foreign subsidiaries, they would reduce their R&D anywhere from 12 to 15%.

4. Endogenous mode and innovation size

Now we allow the multinational cost disadvantage ζ to vary across industries and examine how the extent of FDI as well as the magnitude of innovations chosen by multinationals responds to incentives to FDI. Then we describe how the innovation conditions and resource constraint can accommodate this general case and show that the effects on the rate of innovation resemble those for the base case.

4.1. Mode choice

Now suppose the continuum of industries differ in the degree of cost disadvantage suffered by multinationals. Industries may differ in the difficulties of coordinating decisions over considerable distances; also, the technology involved in some industries may be less perfectly adaptable to different economic environments. For simplicity, assume the multinational cost disadvantage is uniformly distributed $\zeta(j) \in [\underline{\zeta}, \bar{\zeta}]$.

A firm serves the market abroad through multinational production rather than licensing if its profits as a multinational Eq. (1) exceed those as a licensor Eq. (2).

This condition holds if licensee profit retention is larger than the reduction in profits due to the multinational cost disadvantage.

$$\theta > \tilde{\theta} \equiv \frac{\zeta}{\lambda - 1} \Leftrightarrow \zeta < \tilde{\zeta} \equiv \theta(\lambda - 1) \tag{13}$$

The measure of industries conducting FDI is the *extent of FDI*

$$\eta = \frac{\tilde{\zeta} - \underline{\zeta}}{\zeta - \underline{\zeta}}, \tag{14}$$

with the remaining $1 - \eta$ conducting licensing.¹⁵ We focus on parameters such that $0 < \eta < 1$ so that both FDI and licensing occur (for different industries): $\underline{\zeta} < \tilde{\zeta} < \bar{\zeta}$.

Fig. 1 depicts the maximum licensee profit retention $\tilde{\theta}$ that leads to licensing for a range of multinational cost disadvantages ζ , given the innovation magnitude λ . The boundary (13) is an upward-sloping line through the origin with slope $1/(\lambda - 1)$: above the line, FDI arises and below it licensing. Drawing a horizontal line to represent a given level of licensee profit retention θ , the intersection with the boundary line (13) indicates the threshold $\tilde{\zeta}$ for that value of θ . Industries with a low value of multinational cost disadvantage $\zeta \leq \tilde{\zeta}$ choose multinational production, while those with high values $\zeta > \tilde{\zeta}$ choose licensing.

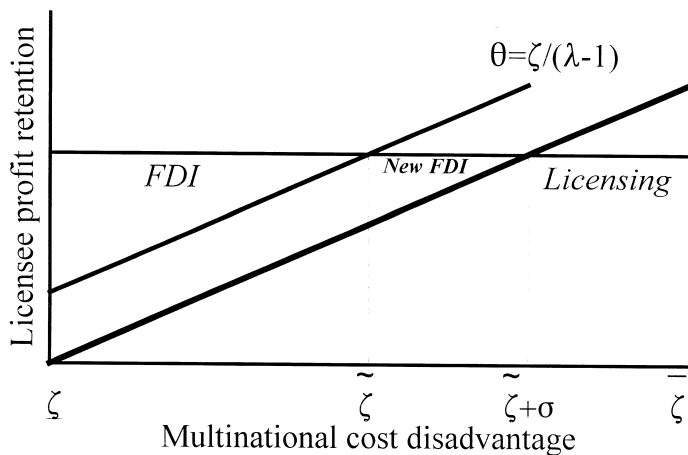


Fig. 1. Licensing versus direct investment decision.

¹⁵If FDI dominates licensing based on the innovation size chosen under licensing, then FDI will also dominate for any larger λ . Hence the expression for η is a lower bound when λ can be chosen.

4.2. Innovation size for multinationals versus licensors

Following the technique of Aghion and Howitt (1990) and Grossman and Helpman (1991a), suppose the resource requirement in innovation $a(\lambda)$ depends on the magnitude of the innovation attempted. We assume that the resource requirement in innovation increases with the size of the quality improvement $a'(\lambda) > 0$ at an increasing rate $a''(\lambda) > 0$.

The optimal quality increment equates the increase in the value of the innovation with the increase in the cost of the innovation.

$$v'(\lambda) = a'(\lambda) \quad (15)$$

Multiply each side of Eq. (15) by λ and, using the equilibrium condition (3), divide each side by v and a , respectively.

$$\frac{\lambda v'(\lambda)}{v(\lambda)} = \frac{\lambda a'(\lambda)}{a(\lambda)} \quad (16)$$

The left-hand side is the elasticity of the reward to innovation with respect to the magnitude of the innovation attempted, which depends on how a firm serves the market abroad. The right-hand side is the elasticity of the resource requirement in innovation with respect to the magnitude of the innovation attempted.

Calculate $\partial v^M / \partial \lambda^M$ and similarly $\partial v^L / \partial \lambda^L$ and then multiply each by the quality increment divided by the reward to innovation λ/v^M or λ/v^L to find the condition for determining the quality increment for multinationals

$$\frac{1 + \zeta/2}{\lambda - 1 - \zeta/2} = \frac{\lambda a'(\lambda)}{a(\lambda)} \quad (17)$$

and for licensors

$$\frac{1}{\lambda - 1} = \frac{\lambda a'(\lambda)}{a(\lambda)}. \quad (18)$$

The condition for licensors is identical to the condition found by Grossman and Helpman (1991a) in their single country model.

The profits dissipated by the licensee act like a tax on profits earned in the foreign market: licensee profit retention does not distort the quality level chosen by a licensor.¹⁶ In contrast, for any $\zeta > 0$, the quality increment chosen by a multinational exceeds the quality increment chosen by a licensor: $\lambda^M > \lambda^L$. Multinationals choose larger innovations because larger innovations shrink the importance of their cost disadvantage and because they collect the entire increase in profits that results from an improvement in the quality of their products. If

¹⁶If θ were to increase in λ , the quality increment under licensing would be depressed: this property would reinforce our result that multinationals choose larger innovations than licensors. An increase in profit taxes abroad would act like an increase in θ .

licensing will occur, firms pick the innovation magnitude λ^L . If multinational production will occur, firms pick an innovation magnitude $\lambda^M(\zeta)$ that increases in the multinational cost disadvantage $\partial\lambda^M/\partial\zeta > 0$.

Fig. 2 illustrates the equilibrium quality increments chosen by multinationals and licensors. The upward-sloping curve **A** represents the increase in cost $\lambda a'/a$, while the downward sloping curves **L** and **M** represent the increase in reward $\lambda v'/v$ for licensors and multinationals. The **M** curve lies above the **L** curve provided $\zeta > 0$. Licensors choose quality increment λ^L while multinationals choose $\lambda^M > \lambda^L$. The larger the cost disadvantage faced by multinationals, the larger the magnitude of ownership advantage they create through innovation. When the multinational cost disadvantage is reduced (such as if multinational production is subsidized), the reward line shifts down to **M'** and multinationals decrease their quality increment to $\lambda^{M'} < \lambda^{M,17}$.

Proposition 2. *Multinationals choose larger innovations than licensors. A decrease in multinational cost disadvantage reduces the magnitude of innovations chosen by multinationals. An increase in the share of profits retained by licensees does not affect the magnitude of innovation chosen by licensors.*

The trait that multinationals invent larger improvements than licensors matches

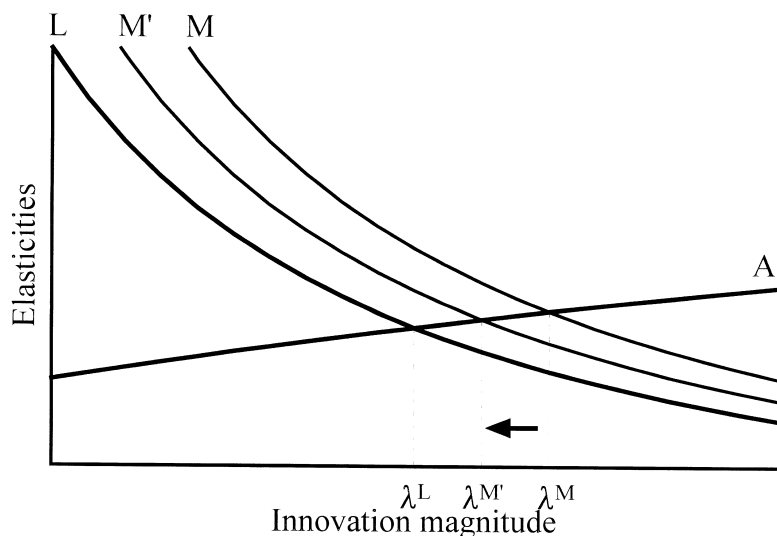


Fig. 2. Subsidy shrinks innovations when mode fixed.

¹⁷A reduction in the fixed costs of multinational production, or equivalently a lump-sum subsidy to FDI, would increase ϵ but not affect λ .

empirical evidence (see Mansfield and Romeo, 1980). We relate this property to the disadvantages faced by multinationals due to operating in unfamiliar economic environments and having to coordinate production over larger distances (see Markusen, 1995).

4.3. Composition effects with mode shifts

What happens if production by multinationals is subsidized so that the multinational cost disadvantage falls? Let $-\Delta\zeta(j) = \sigma$ so that the multinational cost disadvantage for each industry (net of any subsidy) falls by the amount of the subsidy to multinational production. Industries with multinational cost disadvantage in the range $(\tilde{\zeta}, \tilde{\zeta}']$ will switch from licensing to FDI, where $\tilde{\zeta}' \equiv \tilde{\zeta} + \sigma$, as the subsidy is sufficient to make FDI attractive relative to licensing. This switch from licensing to FDI is depicted in Fig. 1 by the segment labeled **New FDI** between the old boundary line and the new one. Thus the extent of FDI rises and the extent of licensing falls: $\partial\eta/\partial\sigma = \sigma/(\zeta - \underline{\zeta})$.

Industries that continue to license still pick the same innovation magnitude λ^L . Industries that continue with FDI reduce their chosen innovation magnitude $\lambda^{M'}(j) < \lambda^M(j)$: an industry with multinational cost disadvantage $\zeta(j)$ picks the innovation magnitude based on $\zeta'(j) \equiv \zeta(j) - \sigma$. But the industries that *newly serve* the market abroad through FDI (that originally licensed local firms) *increase* their innovation magnitude as the innovation magnitude for multinationals exceeds that for firms that license $\lambda^{M'}(j) > \lambda^L$. We additionally require $\tilde{\zeta} + \sigma \leq \bar{\zeta}$ so that there are enough industries that were licensing to switch to FDI. Table 1 captures the effects on innovation size.

Fig. 3 helps visualize that the average innovation magnitude must rise. The area under **ML** indicates the average innovation size chosen initially, and the area under **M'L** is that with the subsidy. Thus, comparing areas amounts to comparing the average innovation size. The shaded triangle indicates the degree that the average innovation size increases due to the subsidy. The innovation magnitude chosen over $[\underline{\zeta} + \sigma, \tilde{\zeta} + \sigma]$ with the subsidy matches that chosen over $[\underline{\zeta}, \tilde{\zeta}]$ in the absence of the subsidy. Provided $\sigma < \underline{\zeta}$ so that some multinational cost disadvantage remains net of the subsidy, the smallest innovation magnitude λ^M must still exceed the innovation magnitude under licensing λ^L . Thus, the degree that innovation magnitude for the range $[\underline{\zeta}, \underline{\zeta} + \sigma]$ exceeds the innovation magnitude

Table 1
Adjustment in innovation size

FDI	$[\underline{\zeta}, \tilde{\zeta}]$	$\Delta\lambda < 0$
Switch	$(\tilde{\zeta}, \tilde{\zeta}']$	$\Delta\lambda > 0$
License	$(\tilde{\zeta}', \bar{\zeta}]$	$\Delta\lambda = 0$

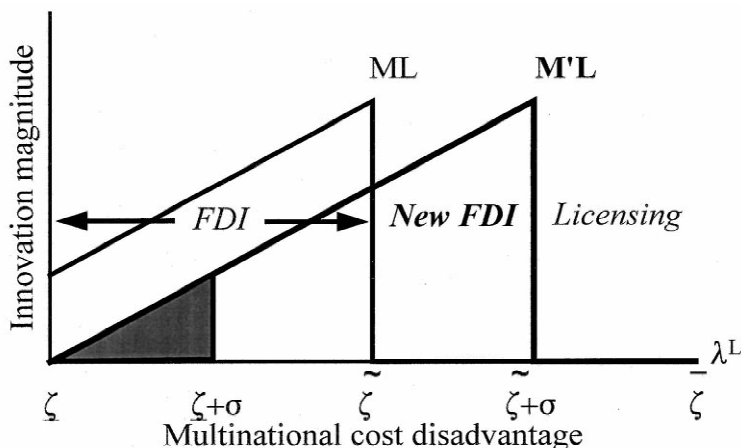


Fig. 3. Subsidy expands innovations when mode adjusts.

under licensing (the shaded area) is positive and represents the degree that the overall innovation magnitude increases due to the FDI subsidy.¹⁸

Proposition 3. *A subsidy to multinational production expands the extent of FDI and contracts the extent of licensing. Each industry conducting FDI shrinks its innovation magnitude, but some industries switch from licensing to FDI and these industries increase their innovation magnitude. The average innovation magnitude under FDI falls but the overall average innovation magnitude (under FDI and licensing) rises, provided the subsidy is not too large.*

Similar analysis can be performed for the case of an increase in licensee profit retention θ . An increase in θ increases the extent of FDI as the threshold $\tilde{\zeta}$ defined in Eq. (13) increases. Firms in industries that switch from licensing to FDI pick larger innovations than before. In fact, they have larger multinational cost disadvantages ζ than firms in industries that were already engaged in FDI; consequently, the firms that switch pick larger innovations than existing multinationals. Thus, the average innovation size for multinationals increases, as does the overall average innovation size. In this case, the increase in innovation size is generated entirely by firms that switch mode from licensing to multinational production.

Proposition 4. *An increase in the share of profits retained by licensees expands*

¹⁸In effect, we shift the innovation magnitude curve $M'L$ with the subsidy to the left by the amount of the subsidy to overlap the innovation magnitude curve ML without the subsidy, wrapping the range from $\underline{\zeta}$ to $\underline{\zeta} + \sigma$ around to the right.

the extent of FDI and contracts the extent of licensing. Industries that switch from licensing to FDI increase their innovation magnitude. The average innovation magnitude under FDI and the overall average innovation magnitude (under FDI and licensing) both rise.

When the mode (licensing versus FDI) is exogenous, subsidizing multinational production leads to smaller innovations and increasing licensee profit retention leaves innovation size unchanged. However, allowing firms to choose their mode of serving foreign markets drastically alters those conclusions: *any* force that increases internalization advantage (subsidies to multinational production or an increase in the licensee's share of profits) necessarily increases the average size of innovations. Yet allowing for the mode to shift does not alter the sign of our comparative static results for the speed of innovation.

4.4. Rate of innovation for the general case

Our key equations for determining the rate of innovation can be adapted to allow for differences in the magnitude of innovations across industry types. In the innovation valuation condition for multinationals (7), the inverse innovation magnitude $\delta^M(j) \equiv 1/\lambda^M(j)$ and the resource requirement in innovation $a^M(j)$ vary by industry j due to differences in the multinational cost disadvantage $\zeta^M(j)$ – based on the choice of the optimal innovation size discussed above. We then solve this innovation condition for the innovation intensity $\iota^M(j)$.

Define the average inverse of the innovation magnitude for multinationals as $\hat{\delta}^M \equiv \int_0^\eta \delta^M(j) dj/\eta$ and the average inverse of the innovation magnitude over all industries as the extent of FDI times the inverse magnitude for FDI plus the extent of licensing times the inverse magnitude for licensing $\hat{\delta} \equiv \eta \hat{\delta}^M + (1 - \eta)\delta^L$. In the world, production requires $x^M = E\hat{\delta}^M$ units of labor for each industry characterized by multinational production and $x^L = E\delta^L$ for each industry that licenses. World labor demand for production is then $x = \eta E\hat{\delta}^M + (1 - \eta)E\delta^L = E\hat{\delta}$. Similarly, for the labor demand in innovation, calculate the average for multinationals $\hat{a}\iota^M \equiv \int_0^\eta a^M(j)\iota^M(j) dj/\eta$ and for all industries $a\iota \equiv \eta\hat{a}\iota^M + (1 - \eta)\iota^L$. The world labor constraint Eq. (6) is essentially unchanged but stated in terms of averages over industries.

Then we are ready to solve the world labor constraint and the innovation valuation conditions for licensors Eq. (8) for aggregate expenditure E and the innovation intensity for licensors ι^L . The average innovation intensity targeting multinationals is $\hat{\iota}^M \equiv \int_0^\eta \iota^M(j) dj/\eta$ and the aggregate rate of innovation becomes $\iota \equiv \eta\hat{\iota}^M + (1 - \eta)\iota^L$. Economic growth, which was $g \equiv \iota \log \lambda$ in the base case, now becomes

$$g \equiv \int_0^\eta \iota^M(j) \log \lambda^M(j) dj + (1 - \eta)\iota^L \log \lambda^L. \quad (19)$$

Parameter changes can affect economic growth through effects on the innovation intensities $\iota^M(j)$ and ι^L , the innovation magnitudes $\lambda^M(j)$ and λ^L , or on the composition of them based on the extent of FDI η .

With the mode adjusting, a subsidy to multinational production, by reducing the effective cost disadvantage of multinationals, will necessarily increase economic growth by increasing both the size and the rate of innovations.¹⁹ The negative effect of licensee profit retention on the speed of innovations can be more than offset by innovations becoming larger due to the mode shift.²⁰

Proposition 5. *When firms can shift their mode of serving markets abroad, if multinational cost disadvantage falls (such as due to a subsidy to multinational production), innovations occur faster and are larger. If the licensee's share of profits rises, innovations occur slower but are larger.*

5. Conclusion

In this paper, we constructed a model that combines the dynamic aspects of endogenous innovation with the OLI paradigm to determine the impact of variations in internalization advantage on technological progress. Our model is consistent with a set of stylized facts emphasizing the significance of two-way FDI between similar developed countries in high-technology industries.

In our model, FDI occurs if profit retention by licensees is more destructive than the cost disadvantage of multinationals. A decrease in the profits retained by licensees or a decrease in the cost disadvantage of multinationals (such as due to a subsidy to multinational production) increases the aggregate rate of innovation.

A subsidy to multinational production acts like a reduction in multinational cost disadvantage and thus increases the extent of FDI relative to licensing. Multinationals choose larger innovations than licensors because ownership advantage helps to offset the additional costs of conducting operations within a firm across multiple countries. A subsidy to multinational production decreases the magnitude of innovations under FDI by lessening the net cost disadvantage of multinational production. Thus, when the mode of serving foreign markets is held fixed, a subsidy to multinational production leads to smaller innovations so economic growth need not increase.

¹⁹We confirm the effect of a subsidy for a numerical example: $L = 4$, $\rho = 1/30$, $\theta = 3/10$, $\zeta = 1/10$, $\bar{\zeta} = 1/2$, and $a = 1 + \lambda/2 + \lambda^2/4$. Increasing the subsidy from $\sigma = 0$ to $\sigma' = 1/10$ increases $\eta = 1/2$ to $\eta' = 3/4$, decreases E by 1.6%, decreases ι^L by 1.7%, increases ι^M by 0.87%, increases ι by 2%, decreases λ^M by 1.8% but increases λ by 0.48%. Economic growth increases by 2.4%.

²⁰Using the same parameters, we increase licensee profit retention from $\theta = 3/10$ to $\theta' = 2/5$ (with $\sigma = 0$), which also increases $\eta = 1/2$ to $\eta' = 3/4$. E increases 0.8%, ι^L decreases 5.4%, ι^M decreases 1.6%, ι decreases 0.8%, λ^M increases 1.7%, and λ increases 3.1%. Economic growth increases 3.3%!

Nevertheless, when firms can shift their mode, a subsidy to multinational production increases the average innovation magnitude over all industries, since innovations are larger under FDI than licensing and the extent of FDI rises in response to the subsidy. So when the mode is endogenous, a subsidy to multinational production leads to faster and larger innovations, and thus clearly faster economic growth.

Adjustment in mode also has key implications for the effects of licensee profit retention on economic growth. If mode were fixed, an increase in licensee profit retention makes innovations slower but has no effect on their size, so economic growth must necessarily decline. However, the shift in mode from licensing to multinational production leads to bigger innovations (since multinationals pick larger innovations than licensors). The impact of larger innovations can more than offset their reduced frequency, leading to the possibility of increased economic growth. We confirm through a numerical example that the size effect can indeed dominate the frequency effect, and thereby reverse the effect on economic growth compared to holding mode fixed.

While we pose our questions in terms of the choice between multinational production and licensing, our results apply more broadly to the decision whether to keep production within the firm. Any innovator might face a tradeoff between higher production costs if produce by itself or profit sharing if license production to a firm with better production abilities. The production cost disadvantage is apt to be less severe when operating abroad is not involved. Yet, some firms may be better suited for innovating than for producing, and thus license their technologies rather than produce in-house.

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Appendix A

A.1. Consumer's problem

Quality level m of product j provides quality $q_m(j) \equiv \lambda^m$. All products start at time $t = 0$ at quality level $m = 0$, so the base quality is $q_0(j) = \lambda^0 = 1$. All

consumers value quality: $\lambda > 1$. For quality level m to provide higher quality than the previous quality level $m - 1$, $q_m(j) > q_{m-1}(j) \rightarrow \lambda^m > \lambda^{m-1} \rightarrow \lambda > 1$. A representative consumer in country $i \in \{D, F\}$ has additively separable intertemporal preferences given by lifetime utility

$$U_i = \int_0^\infty e^{-\rho t} \log u_i(t) dt \tag{A.1}$$

where ρ is the common subjective discount factor. Instantaneous utility is

$$\log u_i(t) = \int_0^1 \log \sum_m \lambda^m x_{im}(j, t) dj \tag{A.2}$$

where λ^m is the assessment of quality level m and $x_{im}(j, t)$ is consumption of quality level m of product j at time t by consumers in country i .

The representative consumer maximizes lifetime utility subject to an intertemporal budget constraint. Since preferences are homothetic, aggregate demand is found by maximizing lifetime utility subject to the aggregate intertemporal budget constraint

$$\int_0^\infty e^{-R(t)} E_i(t) dt \leq A_i(0) + \int_0^\infty e^{-R(t)} Y_i(t) dt \tag{A.3}$$

where $R(t) = \int_0^t r(s) ds$ is the cumulative interest rate up to time t and $A_i(0) = f_i A(0)$ is the aggregate value of initial asset holdings. Individuals hold assets in the form of ownership in firms, but with a diversified portfolio, any capital losses appear as capital gains elsewhere so only initial asset holdings remain. Aggregate labor income is $Y_i(t) = L_i$, where L_i is the labor supply in country i . Aggregate spending is

$$E_i(t) = \int_0^1 \left[\sum_m p_m(j, t) x_{im}(j, t) \right] dj. \tag{A.4}$$

where $p_m(j, t)$ is the price of quality level m of product j at time t .

The representative consumer’s maximization problem can be broken into three stages: the allocation of lifetime wealth across time, the allocation of expenditure at each instant across products, and the allocation of expenditure at each instant for each product across available quality levels. In the final stage, the representative consumer allocates spending for each product at each instant to the quality level $\tilde{m}(j, t)$ offering the lowest quality-adjusted price, $p_m(j, t) / \lambda^m$. Settle indifference in favor of the higher quality level so the quality level selected is unique.

In the second stage, the representative consumer then evenly spreads spending across the unit measure of all products, $E_i(j, t) = E_i(t)$, as the elasticity of substitution is constant at unity. Consumers demand $x_{\tilde{m}}(j, t) = E_i(t) / p_{\tilde{m}}(j, t)$ units of

quality level $\tilde{m}(j,t)$ of product j and no units of other quality levels of that product. Thus lifetime utility (A.1) becomes

$$U_i = \int_0^\infty e^{-\rho t} \left[\log E_i(t) + \int_0^1 [\tilde{m}(j,t) \log \lambda - \log p_{\tilde{m}}(j,t)] dj \right] dt \tag{A.5}$$

by substituting for instantaneous utility (and demand).

In the first stage, the representative consumer evenly spreads lifetime spending across time, $E_i(t) = E_i$, as the utility function is time separable and the aggregate price level does not vary across time $\log p_{\tilde{m}}(j,t) = \log p_{\tilde{m}}(j)$. Since aggregate spending is constant across time, the interest rate at each point in time reflects the discount rate $r(t) = \rho$, so $R(t) = \rho t$ in the intertemporal budget constraint.

A.2. Proof of Proposition 1

After taking the derivatives, we evaluate them at $\zeta = 0$ and $\theta = 0$ for simplicity (we permit $\delta^M < \delta^L$ for use in the more general case below). Let $\partial\sigma \equiv -\partial\zeta$ represent a reduction in multinational cost disadvantage due to a subsidy to multinational production. A decrease in multinational cost disadvantage (or increase in the subsidy to multinational production) increases the aggregate rate of innovation

$$\frac{\partial u}{\partial \sigma} = \frac{1}{2} \eta \delta^M \delta \left(\frac{L}{a} + \rho \right) > 0 \tag{A.6}$$

increases the innovation intensity targeting multinationals

$$\frac{\partial u^M}{\partial \sigma} = \frac{1}{2} \delta^M (1 - \eta + \eta \delta^M) \left(\frac{L}{a} + \rho \right) > 0 \tag{A.7}$$

decreases the innovation intensity targeting licensors

$$\frac{\partial u^L}{\partial \sigma} = -\frac{1}{2} \eta \delta^M (1 - \delta^L) \left(\frac{L}{a} + \rho \right) < 0 \tag{A.8}$$

and decreases aggregate expenditure.

$$\frac{\partial E}{\partial \sigma} = -\frac{1}{2} \eta \delta^M \left(\frac{L}{a} + \rho \right) < 0 \tag{A.9}$$

An increase in licensee profit retention decreases the aggregate rate of innovation

$$\frac{\partial u}{\partial \theta} = -\frac{1}{2} \delta (1 - \eta) (1 - \delta^L) \left(\frac{L}{a} + \rho \right) < 0 \tag{A.10}$$

increases the innovation intensity targeting multinationals

$$\frac{\partial \iota^M}{\partial \theta} = \frac{1}{2}(1 - \eta)(1 - \delta^L)(1 - \delta^M)\left(\frac{L}{a} + \rho\right) > 0 \tag{A.11}$$

decreases the innovation intensity targeting licensors

$$\frac{\partial \iota^L}{\partial \theta} = -\frac{1}{2}\delta(1 - \delta^L)\left(\frac{L}{a} + \rho\right) < 0 \tag{A.12}$$

and increases aggregate expenditure.

$$\frac{\partial E}{\partial \theta} = \frac{1}{2}(1 - \eta)(1 - \delta^L)\left(\frac{L}{a} + \rho\right) > 0 \tag{A.13}$$

A.3. Proof of Proposition 2

Define $M \equiv (1 + \zeta/2)/(\lambda - 1 - \zeta/2)$ and $A \equiv \lambda a' / a$. Note that

$$\begin{aligned} \frac{\partial M}{\partial \sigma} &= -\frac{\lambda/2}{(\lambda - 1 - \zeta/2)^2}, & \frac{\partial M}{\partial \lambda} &= -\frac{1 + \zeta/2}{(\lambda - 1 - \zeta/2)^2}, \\ \frac{\partial A}{\partial \lambda} &= \frac{a'}{a}\left(1 - \frac{\lambda a'}{a}\right) \end{aligned} \tag{A.14}$$

and $\partial A / \partial \zeta = 0$, when totally differentiating the condition (17), so a decrease in λ is required to restore the equality when σ increases (ζ decreases).

$$\frac{\partial \lambda}{\partial \sigma} = -\frac{1}{2}\left(\frac{\lambda a'}{a}\right)^2 (1 + \zeta/2)^2 < 0 \tag{A.15}$$

A.4. Proof of Proposition 3

The extent of FDI rises and industries that conduct FDI pick smaller innovations with an decrease in the multinational cost disadvantage, but the mode effect dominates so the average innovation size rises. A decrease in multinational cost disadvantage still unambiguously raises the rate of innovation

$$\frac{d\iota}{d\sigma} = \underbrace{\frac{\partial \iota}{\partial \sigma}}_+ + \underbrace{\frac{\partial \iota}{\partial \eta}}_+ \underbrace{\frac{\partial \eta}{\partial \sigma}}_+ + \underbrace{\frac{\partial \iota}{\partial \hat{\delta}^M}}_{-} \underbrace{\frac{\partial \hat{\delta}^M}{\partial \sigma}}_+ > 0 \tag{A.16}$$

where $\partial \iota / \partial \eta = (\delta^L - \delta^M)(L/a + \rho) > 0$ and $\partial \eta / \partial \sigma = \sigma / (\bar{\zeta} - \zeta)$.

A.5. Proof of Proposition 4

The negative effect of an increase in licensee profit retention on the rate of innovation is in part mitigated by the ability of firms to switch to FDI and the larger average innovation size.

$$\frac{d\iota}{d\theta} = \underbrace{\frac{\partial \iota}{\partial \theta}}_{-} + \underbrace{\frac{\partial \iota}{\partial \eta} \frac{\partial \eta}{\partial \theta}}_{+} + \underbrace{\frac{\partial \iota}{\partial \delta^M} \frac{\partial \delta^M}{\partial \theta}}_{+} < 0 \quad (\text{A.17})$$

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