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Author: Shin-Horng Chen, Meng-Chun Liu

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International R&D Deployment and Locational Advantage
A Case Study of Taiwan

Meng-chun Liu and Shin-Horng Chen

3.1 Introduction

Recent decades have witnessed the upsurge of East Asia as a major manufacturing base within the developing world, initially as a result of the catching-up of Asian newly industrialized countries (NICs) and, more recently, as a result of the emergence of newly developing economies within the region, mainland China in particular. This has much to do with both indigenous innovation and the relocation of the value chain activities of multinational corporations (MNCs). Lall (2003) elaborates on these two points, arguing that the performance of economies such as Taiwan and Korea may be attributed more to the former, while other less-advanced economies within the region may be gaining more momentum from the latter.

There has, however, been a growing trend for countries in East Asia to seek to attract the R&D facilities of MNCs. On the one hand, not all foreign direct investment (FDI) has equal value because many of the MNCs' subsidiaries are as footloose as branch plants, which can of course lead to the so-called branch plant syndrome (Firn 1975). By contrast, the MNCs' subsidiaries with strong R&D mandates as well as strategic geographical or product range responsibilities tend to adhere more to the host economy and are hence considered to be highly desirable in terms of their effects on local wealth generation. There is, on the other hand, a matching trend within the process of globalization, which has MNCs consolidating the R&D activities of their subsidiaries on a global scale (Petrella 1989; OECD

Meng-chun Liu is deputy director of the International Division of the Chung-Hua Institution for Economic Research. Shin-Horng Chen is director of the International Division of the Chung-Hua Institution for Economic Research.

1997; Patel and Pavitt 1998; Guellec et al. 2001; Kaufmann and Tödtling 2001).

More importantly, the outreach of the MNCs' R&D activities was initially geared to the developed countries, but this has more recently focused on the developing world (Reddy 2000). In particular, countries such as India (Reddy 2000) and China (Xue and Wang 2001; Chen, Shih, and Kao 2002; Walsh 2003) have been documented as less advanced but nevertheless high-profile host countries for MNCs' offshore R&D facilities. The literature on R&D internationalization has proliferated over the past decade, focusing mainly on issues such as the current trends (OECD 1997; Patel and Pavitt 1998; Cantwell and Santangelo 1999; Gerybadze and Reger 1999; Voelker and Stead 1999; Patel and Pavitt 2000; Kumar 2001; Guellec, van Pottelsberghe de la Potterie 2001), organizational evolution (Zedtwitz 2002; Zedtwitz and Gassmann 2002) and the MNCs' motives (De Meyer 1993; Paoli and Guercini 1997; Cantwell and Santangelo 1999; Gerybadze and Reger 1999; Zander 1999). More recent research has addressed the locational aspect of the MNCs' R&D facilities, especially within a host country (Cantwell and Mudambi 2000; Cantwell and Iammarino 2000; Frost and Zhou 2000). However, the relevant literature remains largely based on the experiences of the developed countries.

Furthermore, less attention has been paid to research issues concerning the deepening of foreign corporate R&D activities in host countries, especially for those that are less advanced. Foreign corporate R&D deepening has been recognized as a means for host countries to anchor foreign-owned firms (Kearns and Ruane 2001). This is particularly important for a less-advanced country aiming to enhance the commitment of MNCs to its domestic economy even as its comparative advantage shifts. Moreover, the deepening of foreign corporate R&D in the domestic regions is useful in terms of capitalizing on the agglomeration effect of corporate R&D activities (Carrincazeaux, Lung, and Rallet 2001). Nonetheless, the substantial body of the site-selection literature has focused mainly on the geography of new R&D facilities and investment by MNCs while completely disregarding the fact that this may involve a cumulative process of expansion, contraction, and adaptation of firms' existing facilities in host-country locations (Frost and Zhou 2000).

Set against the preceding background, this paper aims to contribute to the current understanding of R&D internationalization by exploring factors underlying R&D activities in less-advanced economies, with Taiwan standing out as a prime example. The authors are aware that countries such as China and India have drawn considerable attention with regard to this issue (for example, Reddy 2000; Xue and Wang 2001; Chen, Shih, and Kao 2002; Walsh 2003), but on the one hand, little systematic evidence has yet been produced on this issue, while on the other hand, their unique attributes, such as huge market potential, may undermine the applicability of

the experiences of these two countries to other less-advanced economies. By contrast, Taiwan, like the majority of the less-advanced economies, has a small domestic market; hence our empirical analyses will focus on the industrial and/or microaspect of the issues concerned. In particular, our studies aim to identify industrial conditions in a less-advanced country that may lead to the deepening of the offshore R&D activities of MNCs. While the determinants of foreign R&D have been explored within the current research using aggregate macro-level country-specific data, the role played by industrial conditions in a less-advanced host country remains largely unexplored to date.

Our empirical work draws on the Statistics on Overseas Chinese and Foreign Investment, a Taiwanese government database concerning foreign corporations' business operation activities in Taiwan, which enables us to utilize the aggregate industrial-level and time series data to examine the issues concerned. The paper is organized as follows. The next section begins with an examination of the literature on R&D internationalization in order to highlight factors that may be considered as locational advantages for a less-advanced host country in attracting MNCs' offshore R&D. We borrow the concept of locational advantage from Dunning's well-known eclectic paradigm and emphasize the significance of first-tier supplier advantage in a Taiwanese context. In the third section, we take advantage of an official database to reveal the patterns of foreign corporate R&D in Taiwan, followed in the subsequent section by a description of the research strategy employed in the paper, in terms of the model specifications and data source. The empirical results are presented and discussed in the penultimate section, followed in the final section by some general conclusions drawn from this study.

3.2 Locational Advantage of R&D Internationalization

In the studies on R&D globalization, the bottom line appears to be that although not yet truly globalized, R&D is undergoing a process of globalization (Howells 1992) and that its progress varies across sectors and economies (Casson and Singh 1993; Dunning 1994). Although more recent literature (OECD 1997; Patel and Pavitt, 1998; Guellec, van Pottelsberghe de la Potterie 2001; Cantwell and Santangelo 1999; Gerybadze and Reger 1999) has also confirmed that this is an escalating trend, despite this trend, the globalization of R&D has largely been considered as a developed country-centric phenomenon.

Reddy (2000), among others, has revealed a rising trend in terms of the R&D operations of MNCs in the developing world. The factors underlying this trend, as highlighted by Reddy, can be summarized as follows. In specific terms, MNCs are themselves facing an increasing need to monitor and learn the new global trends and, hence, to engage in multisourcing of tech-

nology inputs, partly because of rising R&D costs, the increasing demand for R&D personnel, and a shortage of R&D personnel in the industrialized countries. Conversely, some, if not a great many, of the less-advanced economies are able to provide an abundant supply of R&D personnel or skills, especially with regard to the so-called noncore R&D areas. This match of supply and demand has been facilitated by factors such as improved information and communication technologies, the flexibility of new technologies that allows delinking of manufacturing and R&D, and the comparative advantages of the less-advanced host countries.

For our empirical work, we propose a concept framework for further analysis that is essentially based on Dunning's (1993) eclectic paradigm, with a strong flavor of the evolutionary approach to technology (Nelson and Winter 1982; Frost and Zhou 2000). According to Dunning (1993), where firms possess advantages of ownership and internalization and host countries enjoy locational advantages, international production may take place. In our view, Dunning's paradigm may be useful for analyzing the offshore R&D activities of MNCs if one interprets ownership, internalization, and locational advantages in the context of R&D, with these advantages being related mainly to the technological routines and trajectories of the firms and the host countries (Dosi 1982). In short, what a firm and an economy can do, or is about to do, is linked strongly to their routines and previous bases.

In our opinion, the ownership advantages of MNCs generally lie in their core technology and world-class brand names. Their core technologies allow them to set the agenda, at an international level, and influence the way in which technology will progress, while their world-class brand names enable them to gain direct access to customers and marketplaces, which in turn facilitate their initiation of concepts for product development and the means of further exploiting market potential elsewhere.

The internalization advantages of MNCs may include systems integration capabilities, product planning capabilities, market access advantages, and information and communication networks. In particular, with systems integration capabilities and information and communication networks at their disposal, they may be able to deploy core and noncore R&D across boundaries, while maintaining control over the profits generated during the whole process. Likewise, the possession of product planning capabilities and market access advantages means that MNCs have control over the two ends of the "smiling curve" and, hence, have the final say in the benefits derived from the entire value chain they face.

With regard to Taiwan as a location for offshore R&D by MNCs, we have to refer to the way in which economic development has evolved on the island, as it is well known as a typical example of the export-oriented industrialization paradigm. Although this goes hand in hand with the process of migration from labor-intensive sectors towards high-technology

and capital-intensive industries, Taiwan's major sectors are characterized by their vertical disintegration and the pursuit of "original equipment manufacturer" or "original design manufacturer" (OEM/ODM) contracts for brand marketers, without direct access to the final market. In terms of R&D, local firms may, in general, lack systems integration capabilities and the ability to take the initiative in product and technology development; however, some of the industrial players may be positioned as first-tier suppliers possessing innovation capabilities in certain areas and industrial segments, which could be considered as Taiwan's main locational advantage in offshore R&D. A notable example at issue is Intel, which has recently set up an R&D and innovation center in Taiwan dedicated to product innovation in wireless local area networks (WLANs) partly because Taiwan has been the major global supplier of WLAN sets. Other examples involving Sony and Hewlett Packard (HP) seem to follow the same logic. This is particularly feasible for a sector such as information technology (IT) because Taiwanese IT firms have evolved from pure manufacturers toward integrated service providers, giving rise to intensified interdependence between the network flagships and their Taiwanese subcontractors (Chen 2002). That said, even in an industry such as footwear, we can find the collocation of Nike's main offshore R&D center and its main supplier, Pao Cheng Industrial Corporation, in Taichung.

In order to elaborate on this point within an economy such as that of Taiwan, industrial clusters coevolve with the international industrial structure of the sectors concerned. In addition, whether these industrial clusters are sustainable depends heavily on the extent of localization that may involve at least two things: first, the presence of indigenous firms with substantial innovation capabilities and, second, the ability to "anchor" the network flagships. With regard to the latter, we mean more than the local operations or investments of the network flagships because they can be as footloose as branch plants, as compared to performance plants. Instead, we mean something like international linkages that are so enduring as to enable those indigenous firms to leverage for industrial upgrading.

Moreover, the trend toward globalization involves a process of increased disintegration, certainly of production, but even of innovative capabilities around the globe (Feenstra 1998), with the result that some, if not many, of the indigenous firms and/or industrial clusters in the less-advanced economies are nowadays able to shoulder important functions that used to be undertaken by their counterparts in the developed world. For one thing, outsourcing has become a widely adopted practice in quite a number of industries as a means of ensuring that brand marketers remain cost competitive. As a result, many network flagships have become hollowing-out corporations, focusing their operations on the two ends of the smiling curve, namely the R&D and marketing functions (Chen and Ku 2000; Kotabe 1996; Swamidass and Kotabe 1993; Venkatesan 1992), leading to a certain

degree of delinking of R&D and manufacturing for the sector concerned; typical examples at issue include Ericsson in the handset industry and IBM in the personal computer (PC) industry. Within this process, the brand marketers are increasingly linked up with other firms that may not even be in the same neighborhood.

In addition, in many cases, innovation involves technical systems that are inherently large, comprising a set of jointly-consumed interdependent products (Windrum 1999). Because of network effects and product compatibility, successful innovations for technical systems entail intensive interfaces between multiple actors with different knowledge and skills bases, termed as "innovation networks." By implication, not only does such an innovation often result from the collective efforts of interrelated firms, but it also demonstrates that the value chain does not need to be completely internalized within individual firms. Therefore, in many cases, industrial competition takes place between rival technological and production networks that contain a multiplicity of differentiated firms, rather than between vertically integrated oligopolists.

In a sense, the evolutionary approach to technology (Nelson and Winter 1982) is a constructive building block underlying the concept of international linkages. The essence of this approach, in short, is that what a firm or an economy can do, or is about to do, is linked strongly to their routines and previous bases. In technological terms, a firm can be considered as a producer, repository, and user of knowledge, producing or acquiring knowledge and putting it to the most efficient use. Each firm's competitive advantage lies in its stock of knowledge, and because firms possess idiosyncratic knowledge, they are likely to be heterogeneous. Product innovation involves an assortment of knowledge related to various stages of the value chain. Knowledge applied to manufacturing, marketing, and customer services is complementary to the knowledge used in product innovation. Vertical integration of the innovation function in the value chain is only justified, however, if internalization is the best way to acquire the relevant knowledge, and this is not often the case. Because product innovations address the needs of customers, the knowledge most valuable to product innovation is that obtained from interacting with customers, in other words, marketing. Therefore, product innovation combined with marketing may be the optimal mix of services offered by a firm, which may involve interactions between firms and their customers and suppliers.

Relevant studies on this issue highlight some additional motives for MNCs' offshore R&D. A substantial part of the literature jointly suggests that the locational decisions of MNCs' offshore R&D are generally determined by the following four major factors. First, MNCs need to be close to their clients for the purpose of offshore R&D. The host country's industrial advantages can therefore be regarded as a driving force to anchor the offshore R&D of MNCs. In this regard, the accumulated production ex-

periences and capabilities of a host country may serve as an important local condition in attracting MNCs' R&D facilities. For example, Fors and Zejan (1996) suggested that MNCs' offshore R&D is, to a large extent, found in locations where overseas production is taking place. Such expatriated R&D investment generally supports the local use of production technology and products, which are designed or created outside the home country.

Second, MNCs may undertake offshore R&D in order to access new foreign technologies for the development of new products and production processes. Due to the dynamics of technology, some R&D-oriented firms, those based in Asia and Europe, for example, have set up labs in the United States to take advantage of centers of excellence (Dambrine 1998; Voelker and Stead 1999). Fors and Zejan (1996) argue that MNCs tend to locate their R&D in the host regions that are relatively specialized, technologically, in the firms' own areas as a means of gaining access to foreign centers of excellence and taking advantage of localized knowledge spillovers. Similarly, Niosi (1999) indicated that learning is a critical element in the new trend of international R&D, which often entails locating closely to major innovation centers in order to broaden the scope of the parent's technological portfolio.

Third, it is regarded as becoming increasingly important for MNCs to relocate their R&D overseas in order to hire foreign R&D labor. Having examined locational choices for overseas R&D investment by MNCs based in the United States and Japan, Kumar (2001) argued that a country with an abundant R&D labor force will enjoy a locational advantage in attracting MNCs' R&D investment.

Fourth, the locational choice of MNCs' overseas R&D can be motivated by the ability to serve local markets. In an examination of determinants of foreign affiliates' R&D investment in sixteen Organization for Economic Cooperation and Development (OECD) countries, Gao (2000) highlighted the market size of host countries as a critical factor. Besides stressing the significance of foreign market size, Kumar (2001) summarized three locational advantages of host countries in driving foreign R&D investment; these were a large domestic market, an abundance of low-cost R&D manpower, and the overall scale of national technological effort. From an alternative perspective, Westney (1992) identified four research mandates for the offshore R&D of MNCs in terms of technology activity; these were technology transfer, product modification, new product development, and basic research. Each of these research mandates had its own types of linkages with the host economy. Foreign R&D sites can be similarly classified into two categories, namely, a home-base augmenting site and a home-base exploiting site (Kuemmerle 1997). A mandate for basic research, as in a home-base augmenting site, will require close linkages with local basic research centers, such as universities and research institu-

tions. In contrast, for a home-base exploiting site, a mandate for local product modification will require close linkages to consumers.

The foregoing studies have relied mainly upon case studies, questionnaire surveys, or aggregate country data to examine the determinants of locational choices for MNCs' offshore R&D, and most of these studies were based on the experiences of the advanced countries. In light of this, we are motivated to apply industry-level data to examine the determinants of MNCs' R&D activities overseas in a newly industrialized economy, such as that of Taiwan.

3.3 Foreign Corporations' R&D in Taiwan

Many of the East Asian economies, including Taiwan, have orchestrated programs to attract foreign-owned R&D units, jumping on the bandwagon of promoting their local economies as international innovation hubs. This gives rise to an important question concerning what factors may drive MNCs' offshore facilities to become engaged in R&D activities. In a sense, foreign affiliates engaging in R&D activities may involve an evolutionary process of upgrading their strategic mandates. Ferdows (1997) described the path of MNCs' foreign plants to higher strategic roles. Foreign affiliates that are upgrading their mandates may have started from a lowly position, which could even be an offshore factory with the purpose of accessing low-cost production resources, a server factory for the purpose of proximity to market, or an outpost factory for the purpose of collecting information. They may, in due course, be upgraded to a higher position, which may be a source factory for low-cost production, and that will result in them having greater authority over procurement or, perhaps, a contributor factory for the purpose not only of serving specific national or regional markets but also for product or process engineering and the development and choice of suppliers. Finally, foreign affiliates promote their mandates to the position of a leading factory for the purpose of creating new processes, products, and technologies for the entire firm. This upgrading process of foreign affiliates' mandates spotlights the importance of a few intangible benefits in technology sourcing, namely learning from foreign clients, local suppliers, competitors, and foreign research centers and attracting talent globally, as opposed to tangible assets, namely reducing direct and indirect costs, capital costs, taxes, logistical costs, and jumping tariff and nontariff barriers.

Although it is well-documented that FDI has played an important role in Taiwan's economic development, it is seldom realized that, to some degree, some of the MNCs in Taiwan have also invested in R&D. From the data set provided by the Investment Commission at the Ministry of Economic Affairs (MOEA), we can calculate that Taiwan's estimated average R&D intensity for foreign-owned subsidiaries, over the periods 1987–

1991, 1992–1996, and 1997–2000, was 1.22 percent, 1.48 percent and 2.49 percent, respectively; this perhaps indicates that Taiwan's mandate has significantly improved in terms of MNCs' regional or global innovation networks. The last figure becomes more significant if we take into account the fact that Taiwan's total R&D expenditure accounted for just 2.30 percent of the island's gross domestic product (GDP) in 2002 (see table 3.1).

Having said that, it would be misleading to play down the significance of Taiwan's domestic R&D capacity. Besides its R&D intensity being as high as 2.30 percent in 2002, in terms of the U.S. patents granted, Taiwan ranks fourth in the world in 2001, with electrical and electronic machinery, equipment, and supplies as a product field outnumbering all other fields and registering an increase from 2,013 to 7,644 over the second half of the 1990s. This may imply that Taiwan's IT sector has moved from foreign technology to indigenous innovation (Wu, Lin, and Lin 2002). It is such an innovation capacity that enables Taiwan to leverage international R&D networks.

As table 3.2 shows, the survey for the whole period from 1987 to 2000 reveals that the electrical and electronic machinery industry registers the

Table 3.1 **R&D intensity of foreign corporations and capital inflow in Taiwan's manufacturing sector**

	1987–1991	1992–1996	1997–2000
R&D intensity ratio (%)	1.22	1.48	2.49
Capital inflow (US$1,000)	5,737,184	5,026,103	7,593,008

Source: Investment Commission, MOEA, Republic of China (ROC), *Statistics on Overseas Chinese and Foreign Investment.*

Table 3.2 **R&D intensities and capital inflow of foreign corporations at industry level, 1987–2000**

Manufacturing industry	R&D intensity	Capital inflow distribution
Electrical and electronic machinery	2.72	47.72
Primary metal and metal products	2.47	9.73
Machinery	1.47	11.23
Leather and related products	1.18	0.97
Pulp, paper, and allied products	0.97	0.61
Chemicals and chemical products	0.87	16.20
Rubber and plastic products	0.46	2.49
Textile and apparel	0.32	2.46
Food and beverages	0.26	5.92
Nonmetallic mineral products	0.24	2.23
Lumber, wood products, and furniture	0.17	0.43
Mean/Total	1.80	100.0

Source: Investment Commission, MOEA, ROC, *Statistics on Overseas Chinese and Foreign Investment.*

highest R&D intensity of foreign corporations, followed by the primary metal and metal products and machinery industries. By contrast, both the food and beverages and lumber, wood products, and furniture industries are the industries with the lowest R&D intensity of foreign corporations in Taiwan. Not surprisingly, these industries with high foreign R&D activities tend to fall in the category of the so-called high-tech industries, while the traditional industries registered a relatively lower level of foreign R&D intensity.

It should be noted that the Pearson correlation ratio shown in table 3.2 reaches a level of 0.724, pointing to a high and positive correlation between foreign corporate R&D intensity and the distribution of capital inflow within the manufacturing industry. Similarly, data on OECD members reveals a positive correlation between the share, on an international scale, of foreign affiliates' manufacturing turnover and that of manufacturing R&D (Guellec and Pattinson 2002). This may mean, on the one hand, that the former is a necessary condition for the latter, while on the other hand, in a Taiwanese context, this may suggest that an industry characterized by higher foreign R&D investment has become a major FDI target in recent decades. Those industries with high R&D intensity, such as Taiwanese IT firms in the electrical and electronic machinery and machinery sectors, have evolved from pure manufacturers toward integrated service providers and that these are indeed Taiwan's primary export industries.

3.4 Research Strategy

We draw on an official data bank for our empirical work and employ a regression technique to explore the factors determining the R&D intensity of foreign affiliates in Taiwan. This section discusses the research strategy and the key features of the empirical studies.

3.4.1 The Model

The principal aim of our empirical enquiry is to explore features that characterize foreign affiliates with a higher R&D intensity. The dependent variable is therefore denoted as Rdr, the R&D intensity of foreign corporations at industry level. Rdr_i is measured as the logarithm of the ratio of foreign corporations' total R&D expenditure performed to total sales in industry *i*. In this way, the total R&D expenditure of foreign subsidiaries is normalized by their sales to control for the size effect. In terms of explanatory variables, the study follows Varsakelis (2001) to incorporate the local procurement ratio in both materials (LOCMR) and capital goods (RAT1), along with export orientation (EXR), into the regression equation of foreign corporations' R&D intensity (RDR). We also examine the impact of R&D labor force (LRDP) and local industrial R&D capabilities (IRDR)

on foreign corporate R&D activities. The definitions and measurements of the explanatory variables in the empirical model are described as follows:

KLR

Capital labor ratio (KLR) is measured by the ratio of the book value of fixed capital stock to total labor expenditure. We attempt to examine whether KLR has a statistically significant coefficient in the R&D intensity equation. This variable characterizes the attributes of the production technologies employed by foreign affiliates. Ramstetter (1999) compared foreign multinationals and indigenous firms in Asian manufacturing industries and found that MNCs generally adopt relatively high capital-intensive production technologies, which may suggest MNCs' endowments of firm-specific assets. However, a high KLR may, to some extent, indicate the homogeneity of products. An industry with high KLR provides high homogenous products with lower product differentiation. For this reason, we presume that a foreign firm associated with high capital intensity has a low incentive to undertake R&D investment in the host countries.

LOCMR

LOCMR is a local content ratio, measured by the share of the value of local materials to the value of purchased materials. The variable is designed to examine the locational advantage of a host country in terms of industrial capability. As argued by Reddy (2000), one of the main factors determining R&D investment by MNCs in the less-advanced economies is the capability of local industry to produce advanced manufactured products. This will be helpful for MNCs to exploit their innovation assets and enhance their market competitiveness. The LOCMR may reflect the local dependency of foreign affiliates, in terms of supply chains, underlining the industrial capabilities of the host countries. Thus, the coefficient of the variable is presumed to be statistically significant and positive in the model.

In addition, LOCMRS, a square term of LOCMR, is used in this model to take into account a possible nonlinear influence on RDR. That is, the increasing marginal R&D investment to foreign affiliates' local content can be confirmed when the possible coefficient for LOCMRS in this model is positive. By contrast, there is a decreasing marginal R&D investment in foreign affiliates' local content if the possible coefficient for LOCMRS is negative.

RAT1

This is the local capital investment ratio, measured by the ratio of local capital purchased to sales, by controlling the size effect. Similar to LOCMR, in this paper RAT1 is intended to examine whether the indus-

trial capability of a host country can be a locational advantage in leveraging R&D investment by foreign affiliates. A host countries' effective industrial infrastructure, in terms of vertical industrial linkage, may attract foreign affiliates to undertake R&D activities in order to effectively interact with the local suppliers of capital goods for innovation. In addition, this research compares the effects of RAT1 with RAT2, which is the imported capital investment content, measured by the ratio of imported capital purchased to sales, on foreign corporate R&D intensity. We presume that the coefficient of RAT1 is positive in equation (1) and higher than that of RAT2.

EXPR

Export propensity (EXPR) is measured by the logarithm of the ratio of exports to sales. It is well documented that the market size of a host country plays an important role as a locational advantage in attracting foreign R&D to serve the local market and/or customize products for the local market. However, in some cases, foreign affiliates may function simply as an export outpost for their parent companies (Kumar 2001). This may be particularly true for an economy such as Taiwan, given its small market size. It is therefore possible that the R&D operations of MNCs' subsidiaries in Taiwan may be capitalizing on Taiwan's locational advantage in order to serve the international market. Thus, we presume that the coefficient of EXPR in the equation is statistically positive and significant.

It can, in fact, be argued that there exists a significant linkage between foreign corporations' decisions on local procurement and their product markets in terms of exports and imports. In the case of tariff-jumping FDI, foreign affiliates tend to utilize imported material and components in the production of goods to serve the host-country markets. In particular, Chen and Wang (1994) revealed that the United States's and Japanese MNCs in Taiwan producing electronic goods for export were inclined to utilize imports of materials and components; hence, there was a significantly negative relationship between MNCs' local content and their export orientation. Accordingly, this study aims to determine the interactive effect on MNCs' R&D investment from their foreign affiliates' local content and product exports; this is done by including a cross term, combining EXPR with LOCMR in the model. We consider that MNCs' affiliates with a high mandate may play the role of nexus, linking the host country's industries to their global production. Furthermore, foreign affiliates with a greater R&D commitment for new process technologies and products in the host countries may shoulder a higher strategic role in terms of local sourcing.

LRDP

Local industrial R&D capabilities (LRDP) is measured by the logarithm of numbers of R&D employees for each industry. This variable is a proxy

Table 3.3 Definitions of variables used in the statistical analysis

Variable	Definition	Impact on RDR
RDR	R&D intensity of foreign subsidiaries	
KL	Capital to labor ratio	+
RAT2	Imported capital content ratio	+
RAT1	Local capital content ratio	+
EXPR	Export ratio	+
LOCMR	Local material content ratio	+
EXPR*LOCMR	Cross term of EXPER and LOCMR	?
LRDP	Availability of R&D labor force	+

for the availability of R&D labor in the local industries. As shown in many studies, sourcing available R&D labor may motivate MNCs to relocate their R&D operations abroad (Kumar 2001). Thus, we presume that the coefficient of LRDP in the R&D intensity equation to be positive.

In order to examine the determinants of foreign corporate R&D intensity, industry-specific attributes are also taken into consideration in this study, with a summary of the variable definitions being provided in table 3.3. It should be noted, however, that this model does not consider certain omitted variables, including Taiwanese corporations' R&D investment and coordination costs of cross-border R&D, which are emphasized in many studies, such as Cantwell and Iammarino (2000) and Fischer and Behrman (1979). Taking the attribute of pooling data into account, we need to specify the fixed effects and random effects models. In addition, in the estimation of the regression models, we consider the influence of ten manufacturing industries but exclude the leather sector because of too many missing observations.

Based on the preceding discussion, the study derives a set of regressions for industry *i*, with the equation being:

$$(1) \quad \mathrm{Rdr}_{it} = a_0 + a_1\mathrm{EXPR}_{it} + a_2\mathrm{LOCMR}_{it} + a_3\mathrm{EXPR}^{*}_{it}\mathrm{LOCMR}_{it} + a_4\mathrm{RAT1}_{it} + a_5\mathrm{RAT2}_{it} + a_6\mathrm{KL} + a_7\mathrm{LRDP}_{it},$$

where LOCMR_{it} is the ratio of local material expenditure to total material expenditure in percentage terms; EXPR_{it} denotes the proportion of exports to total sales in percentage terms; $\mathrm{LOCMR}^{*}_{it}\mathrm{EXPR}_{it}$ refers to the cross term of LOCMR_{it} and EXPR_{it}; KLR_{it} is the ratio of capital stock to total labor costs; RAT1 and RAT2 denote respective local capital investment ratio and imported capital investment ratio; and LRDP_{it} denotes the total R&D labor force in industry *i* in year *t*. All the variables are taken in terms of the derivative of the natural logarithm in the empirical models, while other specific industry attributes are reflected in the fixed effects or random effects model.

Within the literature, equation (2) is known as the fixed effects model if

the intercept differs across individual groups (here the ten industries) and each individual intercept does not vary over time. Thus, equation (1) can be rewritten as

$$(2)\quad \mathrm{Rdr}_{it} = a_0 + a_1\mathrm{EXPR}_{it} + a_2\mathrm{LOCMR}_{it} + a_3\mathrm{EXPR}^{*}_{it}\mathrm{LOCMR}_{it} + a_4\mathrm{RAT1}_{it} + a_5\mathrm{RAT2}_{it} + a_6\mathrm{KL} + a_7\mathrm{LRDP}_{it} + \sum \lambda_i \mathrm{IND}_i + \varepsilon_{it}.$$

In other settings, we may view each individual specific constant term as randomly distributed across individual groups. It follows, therefore, that equation (1) can be reformulated as the following equation:

$$(3)\quad \mathrm{Rdr}_{it} = a_{0i} + a_1\mathrm{EXPR}_{it} + a_2\mathrm{LOCMR}_{it} + a_3\mathrm{EXPR}^{*}_{it}\mathrm{LOCMR}_{it} + a_4\mathrm{RAT1}_{it} + a_5\mathrm{RAT2}_{it} + a_6\mathrm{KL} + a_7\mathrm{LRDP}_{it} + \varepsilon_{it}$$

where a_{0i} is the intercept with random disturbance characterizing the ith observation and can be expressed as $a_{0i} = a_0 + u_i$, $i = 1, 2, \ldots, 10$, and u_i is a random error term with a mean value of zero and variance of σ_u^2.

3.4.2 The Data

The data were collected from two sources over a period of fourteen years. The industry-level data set used in this study is provided by the Investment Commission, MOEA, Taiwan, and contains information on production and R&D by foreign affiliates in the manufacturing sector. Industry-specific R&D data is taken from the National Science Council. After missing values were deleted, the available industrial data over the period 1987–2000 was pooled together to provide our sample. Table 3.4 presents a summary of the descriptive statistics of these variables from 137 available observations.

Table 3.4 Summary of statistics

Variable	Mean	Standard deviation	Minimum	Maximum	No. of observations
RDR	–5.409	1.451	–11.614	–0.938	137
EXPR	–1.404	0.860	–4.765	–0.007	137
LOCMR	–0.784	0.518	–4.184	–0.007	137
LOCMRS	0.882	1.912	0.000	17.507	137
LOCMR*EXPR	1.019	0.808	0.006	5.359	137
LRATIO	–5.134	0.862	–8.164	–3.549	137
KL	1.401	0.904	–5.888	4.031	137
RAT1	–3.504	1.256	–8.662	–0.566	137
RAT2	–4.200	1.348	–10.094	–0.946	134

Source: Calculated from Investment Commission, MOEA, ROC, *Statistics on Overseas Chinese and Foreign Investment.*

Note: All variables are taken in terms of natural logarithm.

Table 3.5 **Correlation analysis**

	EXPR	LOCMR	LOCMRS	LOIM	RAT1	RAT2	LRDP
LOCMR	–0.185						
LOCMRS	0.168	–0.930					
LOCMR*EXPR	–0.667	–0.401	0.251				
RAT1	0.194	0.035	–0.016	–0.209			
RAT2	0.134	0.112	–0.121	–0.149	0.351		
LRDP	0.115	0.063	–0.102	–0.186	0.247	0.142	
KL	–0.119	–0.038	0.015	0.090	0.170	0.065	0.140

Source: Calculated by the authors.

Table 3.5 presents the correlation coefficients for all the variables used in our empirical model, with the statistics showing that where the correlation coefficient is over 0.5, high correlations exist between EXPR*LOCMR and EXPR, and LOCMR and LOCMRS; however, all the other correlation coefficients are rather small, suggesting that no serious problem of multicollinearity exists within our empirical model.

3.5 Empirical Results

This section presents and discusses the empirical results, which are summarized in table 3.6. The general specification in columns (1) to (4) of table 3.6 include export dependence, local input content and their cross-terms, while columns (5) to (8) also take capital labor ratio into account. Based on the ordinary least squares (OLS) residuals, Lagrange multiplier test statistics for chi-square were undertaken for each regression equation; the statistics for each equation are significant at the 5 percent level. It is therefore necessary for us to apply the Hausman test to each equation in order to examine the statistical robustness of the fixed and random effects models. The chi-square values of equations (1), (2), (3), and (6) in table 3.6 are statistically significant, suggesting that these models favor the fixed effects model as opposed to the random effects model.[1] We go on to examine the effect of time trend, referred to as YEAR, on the R&D intensity of foreign affiliates in table 3.7. The coefficients of time trend on each equation are positive but insignificant; thus, the following discussion is based mainly on table 3.6. The overall results suggest that six of the explanatory variables, EXPR, LOCMR, LOCMRS, EXPR*LOCMR, RAT1, and LRDP are significant (all at the 5 percent level) in some, if not all, of the equations.

Foreign-owned subsidiaries with higher R&D intensity are found to be

1. After taking into account the effect of period on the regression models, we measure the Hausman chi-square static for each equation in table 3A.1, which suggests that these models favor the two-way random model as opposed to the two-way fixed model. Generally, in terms of empirical outcome, the differences between table 3.6 and table 3A.1 are only minor.

Table 3.6 **Regression results of foreign affiliates' R&D intensity at industry level in the one-way model**

Variable	Fixed effect (1)	Fixed effect (2)	Fixed effect (3)	Random effect (4)	Random effect (5)	Fixed effect (6)	Random effect (7)	Random effect (8)
EXPR	1.336	0.941	1.014	0.915	1.021	1.318	0.889	0.927
	(3.898)**	(2.499)**	(2.785)**	(2.997)**	(2.989)**	(3.876)**	(2.436)**	(2.655)**
LOCMR	2.638	2.292	2.058	2.091	2.040	2.590	2.153	1.890
	(2.837)**	(2.347)**	(2.173)**	(2.313)**	(2.216)**	(2.807)**	(2.231)**	(2.029)**
LOCMRS	0.511	0.456	0.395	0.371	0.371	0.505	0.428	0.362
	(2.612)**	(2.230)**	(1.988)	(1.949)	(1.924)*	(2.603)**	(2.115)**	(1.850)*
EXPR*LOCMR	1.015	0.859	0.827	0.860	0.882	1.018	0.828	0.779
	(2.860)**	(2.375)**	(2.311)**	(2.584)**	(2.550)**	(2.895)**	(2.328)**	(2.229)**
RAT1		0.257	0.238	0.303	0.268		0.270	0.261
		(2.332)**	(2.324)**	(3.296)**	(2.755)**		(2.503)**	(2.624)**
RAT2		0.098					0.090	
		(1.200)					(1.102)	
LRDP				0.498	0.476			
				(4.248)**	(2.807)**			
KL					–0.231	–0.209	–0.173	–0.200
					(–2.016)**	(–1.763)	(–1.481)	(–1.732)
Constant				–6.137	–5.693		–2.221	–2.612
				(–6.216)**	(–4.376)**		(–2.501)**	(–3.333)**
LM test $\chi 2\,(1)$ =	115.15**	79.38**	82.42**	15.63**	10.23**	117.20**	66.82**	73.40**
Hausman test	$\chi 2(4) = 42.99$**	$\chi 2(6) = 58.16$**	$\chi 2(5) = 26.02$**	$\chi 2(6) = 9.18$	$\chi 2(7) = 3.43$	$\chi 2(5) = 66.17$**	$\chi 2(7) = 2.82$	$\chi 2(6) = 4.39$
Observations	137	134	137	137	137	137	134	137

**Significant at the 5 percent level.

Table 3.7 **Regression results of foreign affiliates' R&D intensity at industry level in the one-way model**

Variable	Fixed effect (1)	Fixed effect (2)	Fixed effect (3)	Random effect (4)	Random effect (5)	Fixed effect (6)	Random effect (7)	Random effect (8)
EXPR	1.364	0.995	1.060	0.933	1.066	1.358	0.971	1.000
	(3.856)***	(2.630)***	(2.879)***	(2.949)***	(3.016)***	(3.873)***	(2.621)***	(2.810)***
LOCMR	2.667	2.311	2.083	2.085	2.065	2.630	2.218	1.954
	(2.846)***	(2.372)***	(2.196)**	(2.280)**	(2.222)**	(2.831)***	(2.299)**	(2.092)**
LOCMRS	0.512	0.444	0.387	0.374	0.376	0.506	0.425	0.360
	(2.607)***	(2.173)**	(1.945)*	(1.940)*	(1.927)*	(2.600)***	(2.099)**	(1.839)*
EXPR*LOCMR	1.027	0.876	0.843	0.859	0.897	1.037	0.864	0.813
	(2.870)***	(2.426)***	(2.352)***	(2.541)***	(2.555)***	(2.922)***	(2.423)***	(2.316)**
RAT1		0.282	0.259	0.291	0.259		0.289	0.279
		(2.520)***	(2.461)***	(2.985)***	(2.526)***		(2.624)***	(2.715)***
RAT2		0.119					0.112	
		(1.430)					(1.350)	
LRDP				0.497	0.440			
				(3.708)***	(2.108)**			
KL					–0.230	–0.214	–0.185	–0.212
					(–1.989)**	(–1.793)*	(–1.584)	(–1.827)*
YEAR	0.009	0.032	0.022	–0.004	–0.004	0.012	0.035	0.027
	(0.342)	(1.241)	(0.885)	(–0.170)	(–0.170)	(0.495)	(1.368)	(1.076)
Constant				–6.118	–5.442		–2.172	–2.616
				(–5.705)***	(–3.500)***		(–2.092)***	(–3.116)***
LM test $\chi 2$ (1) =	114.86**	78.44**	79.54**	15.48**	10.24**	116.91**	62.82**	73.40**
Hausman test	$\chi 2(4) = 42.00$**	$\chi 2(6) = 40.95$**	$\chi 2(5) = 24.63$**	$\chi 2(6) = 7.97$	$\chi 2(7) = 1.84$	$\chi 2(5) = 59.75$**	$\chi 2(7) = 1.46$	$\chi 2(6) = 4.39$
Observations	137	134	137	137	137	137	134	137

**Significant at the 5 percent level.

characterized by a greater degree of localization in terms of their sourcing of both production materials and capital goods. To interpret this finding, we can refer to Westney's (1990) argument that if their ties with the local scientific and technical community are gaining strength (and probably, therefore, greater R&D intensity) MNCs' offshore R&D units are given higher hierarchical mandates. To put this another way, Reddy (2000) championed the concept of first-tier supplier advantage as a locational advantage for attracting MNCs' R&D units, which may imply that foreign-owned subsidiaries with a higher degree of localization may need to devote more effort to R&D in order to effectively interact with their local suppliers.

In addition, we find that where Taiwanese industrial sectors have a larger pool of R&D employees, their constituent foreign affiliates tend to be more R&D intensive. On the one hand, this seems to imply that the R&D efforts of foreign affiliates in Taiwan are driven by a local technology pool. On the other hand, assuming that a larger pool of R&D employees in a sector implies that its local firms are more technology aggressive, one can argue that indigenous R&D efforts serve as a complement to, rather than a substitute for, the R&D activities of foreign affiliates. In the following we categorize three main effects, namely the local industry capability effect, market linkage effect, and R&D labor resource effect, for further discussion.

3.5.1 Local Industrial Capability Effect

Columns (1) and (2) in table 3.6 includes the LOCMR and LOCMRS measures. The coefficient of LOCMR is positive and statistically significant, revealing that foreign affiliates in Taiwan using more local materials in their production have higher R&D investment. The significant and positive coefficient for LOCMRS reveals the increasing scale of foreign affiliates' R&D investments to their local procurement of materials and components.

Two aspects stand out from these empirical results. First, the results support our hypotheses, in the previous section, that a host country's excellence in production capabilities, in terms of the industry value chain, can be regarded as a locational advantage in leveraging foreign corporations to increase their R&D investment, even in a less-advanced host country. Therefore, MNCs may need to establish their offshore R&D centers close to their production partners for the purpose of time to market due to the severe global competition. Second, the extent of local sourcing in terms of both production materials and capital goods not only reflects the degree to which MNCs' offshore facilities are localized in the host country but also may prompt them to upgrade their local operations in R&D terms.

Consistent with this, we also compare the effects of RAT1 and RAT2 on foreign corporate R&D intensity. From columns (2) and (6) in table 3.6, the coefficients of RAT1 are not only statistically significant and positive but

also larger than those of RAT2, further demonstrating that local industrial infrastructure does matter in terms of driving foreign corporate R&D in a host country.

3.5.2 Market Linkage Effect

While much of the literature on R&D internationalization emphasizes the importance of market access for MNCs' offshore R&D, for an economy with small domestic market size, such as that of Taiwan, the market linkage effect may mean more to this issue and hence may be regarded as a location-specific advantage for such a host country in leveraging foreign R&D investment. For all specifications we find that those foreign-owned firms in Taiwan with a higher export propensity tend to be more R&D intensive. As an economy characterized by international competitiveness and export orientation, Taiwan may be able to act as a host for some MNCs in order to capitalize on its comparative advantages to serve the international market. Indeed, in a questionnaire survey undertaken for a separate study (Liu, Chen, and Lin 2002), R&D performers of foreign affiliates were asked to identify their highest-level R&D activities in Taiwan. The results showed that the level appeared to be, predominantly, the modification and development of products for the international market. Without denying the importance of market access to R&D internationalization, the evidence gleaned from that study suggests that given accumulated comparative advantage in production and the industrial value chain, host countries can still attract foreign R&D investment by playing the role of a hub for access to the international markets, even without large domestic market size.

It is interesting to note that the coefficient of the cross term EXPR∗LOCMR is positive at the 5 percent level of statistical significance, indicating that there exists an important interaction effect between foreign affiliates' export propensity and local content ratio in enhancing foreign affiliates' incentives to undertake local R&D. The coefficient of the cross term EXPR∗LOCMR is significantly positive, indicating that in Taiwan, foreign-owned firms with higher export propensity tend to be more R&D intensive in order to utilize more local materials and components. As is widely known, quite a substantial part of the manufacturing industry in Taiwan is internationally competitive and export oriented, with local players in many of the subsectors enjoying first-tier supplier status. By analogy, their MNC counterparts in Taiwan may have to act in the same way in order to exploit Taiwan's advantages. This may also indicate that as foreign affiliates in a host economy, such as that of Taiwan, begin to increase their R&D investment, there is a shift in their role, as they take on the role of nexus linking the local production capacity to their global production network.

The empirical results discussed previously are quite in line with the evolutionary process of foreign affiliates in upgrading their strategic roles

within their parents' global production networks as described by Ferdows (1997). In our view, foreign affiliates' R&D investment in the host countries may go hand in hand with their rising mandate within their parents' global networks. From the perspective of Ferdows (1997), foreign affiliates can enjoy greater authority over procurement, production planning, process change, outbound logistics, product customization, and redesign decisions, as their mandates are upgraded from an offshore factory, or a server factory, to a source or contributor factory. By analogy, foreign affiliates may increase their R&D investment and raise their local procurement and exports simultaneously. This empirical outcome is also consistent with Jarillo and Martinez (1990), who examined the different roles played by MNCs' subsidiaries in Spain. They found that subsidiaries tended to receive stronger mandates from their headquarters if they engaged in geographical localization in terms of R&D, purchasing, manufacturing, and marketing in the host countries, while also aggressively integrating themselves into their groups (headquarters plus other subsidiaries). Thus, it is reasonable to argue that foreign affiliates with a higher R&D intensity may reflect the upgrading of their mandates in the business groups in terms of their localization and integration strategies.

3.5.3 R&D Labor Resource Effect

Finally, turning to the explanatory variable, LRDP, the estimated parameter has the expected positive sign in the regression model and is significant at the 5 percent level in the random effects models. It therefore follows that the local R&D labor pool at industry level is positively and significantly related to the corresponding foreign affiliates' R&D intensity, confirming our hypothesis that MNCs tend to locate their overseas R&D investment to countries with abundant R&D resources. This result is also consistent with much of the research emphasizing the escalating importance of supply-side forces in driving R&D internationalization. By implication, it can be argued that a host country needs to demonstrate its technological strengths in certain industrial segments in order to attract offshore R&D by MNCs.

3.6 Conclusions

Within the overall process of globalization, international economic development has much to do with the relocation of the value chain of MNCs and indigenous innovation. These two factors are, however, interrelated. Given the footloose nature of MNCs' cross-border operations, it is deemed increasingly important for a host country to attract MNCs' facilities with strategic mandates, such as R&D. Therefore, R&D internationalization has become a trend that is no longer confined to the developed world, as the less-advanced economies are becoming increasingly involved in this

process. This gives rise to an important question as to what locational advantage a country may have and may be able to develop in order to attract MNCs' R&D activities.

In studying this issue, Taiwan appears to provide an interesting case. Although within this issue, such high-profile countries as China and India each have a large domestic market and a large pool of R&D labor, this is obviously not the case in Taiwan. In addition, Taiwan is not an economy characterized by technological leadership, which would be a distinct advantage in attracting technology-seeking FDI. However, despite these drawbacks, the Taiwanese case is more meaningful to many countries, including both developed and developing countries; indeed, this paper goes a step further than the previous research by exploring the issue at industry level, which appears to be more insightful.

Our empirical results show that in Taiwan, foreign affiliates with higher R&D intensity tend to be more export oriented and localized in terms of their sourcing of materials and capital goods. Of interest is the finding that such foreign affiliates also tend to be more R&D intensive. To interpret this finding, we can refer to Westney's (1990) argument that MNCs' offshore R&D units are given higher hierarchical mandates if their ties with the local scientific and technological community are gaining strength (and probably, therefore, greater R&D intensity). In fact, foreign affiliates tend to increase their R&D investment and have greater authority over material and component procurement, functioning as key suppliers and serving a specific regional market as they upgrade their strategic roles toward becoming a so-called leading factory.

Reddy (2000) championed the concept of first-tier supplier advantage as a locational advantage for attracting MNCs' R&D units, which may imply that foreign-owned subsidiaries with a higher degree of localization may need to devote more effort to R&D in order to effectively interact with their local suppliers. Moreover, we also find that foreign affiliates with a higher export propensity tend to be not only more R&D intensive but also that the effects of their export propensity has a positive interaction with the effects of the local sourcing of materials. This may have something to do with the heritage of Taiwan's economic development, which is widely known as being based upon export-oriented industrialization. In specific terms, some Taiwanese industries have successfully penetrated the international market, giving rise to a sound industrial infrastructure and capability. As a result, their foreign affiliate counterparts may be driven to invest more in R&D in order to capitalize on the Taiwanese comparative advantage, particularly if they are more reliant on local materials.

We are able to prove with statistical robustness that those sectors with a larger pool of R&D labor tend to attract more foreign affiliates' R&D activities. While some of our results are consistent with the previous findings, others may need to be interpreted in the context of the Taiwanese economy.

For example, the size of the local R&D labor force may reflect Taiwan's technological strengths in certain industrial sectors, which may in turn attract MNCs' to invest in R&D in Taiwan. This is in line with the so-called technology-related motive, namely, tapping into foreign science and technology resources.

Throughout the paper, there has been a focus on the concept of an evolutionary approach to technology in interpreting Taiwan's inward R&D internationalization. Without denying the possibility of leapfrogging development, we would like to emphasize the significance of a cumulative process of expansion to the efforts of less-advanced economies to anchor MNCs' offshore R&D. As Ernst (2000) puts it, an ideal location for knowledge-intensive activities is characterized by three conditions, attractive lead markets, a highly developed production structure, and excellent research environments, but not all of the criteria can be met at the same time by many locations in the less-advanced economies. The experiences of Taiwan seem to suggest that even without world-leading R&D centers of excellence, a less-advanced economy can still build up a competitive production base as a starting point to take part in global production networks, and, in due course, this accumulated production capability can become an incentive for foreign affiliates to invest in R&D.

Appendix

Table 3A.1 **Regression results of foreign affiliates' R&D intensity at industry level in the two-way effects model**

Variable	Random effect (1)	Random effect (2)	Random effect (3)	Random effect (4)	Random effect (5)	Random effect (6)	Random effect (7)	Random effect (8)
EXPR	1.299	0.938	0.974	1.014	1.058	1.287	1.041	0.034
	(3.708)**	(2.607)**	(2.780)**	(3.018)**	(3.012)**	(3.685)**	(2.725)**	(2.848)**
LOCMR	2.627	2.021	1.947	2.166	2.101	2.573	2.133	2.012
	(2.752)**	(2.097)**	(2.064)**	(2.316)**	(2.237)**	(2.705)**	(2.182)**	(2.120)**
LOCMRS	0.507	0.374	0.355	0.390	0.379	0.497	0.399	0.371
	(2.522)**	(1.835)*	(1.783)*	(1.979)**	(1.917)	(2.479)**	(1.931)**	(1.851)
EXPR*LOCMR	0.967	0.811	0.778	0.893	0.912	0.975	0.885	0.839
	(2.668)**	(2.293)**	(2.206)**	(2.559)**	(2.584)**	(2.703)**	(2.452)**	(2.351)**
RAT1		0.338	0.334	0.319	0.300		0.311	0.314
		(3.085)**	(3.226)**	(3.154)**	(2.930)**		(2.754)**	(2.973)**
RAT2		0.174				0.167		
	(1.980)**					(1.878)		
LRDP				0.484	0.481			
				(3.220)**	(2.693)**			
KL					–0.216	–0.184	–0.161	–0.190
					(–1.820)	(–1.489)	(–1.317)	(1.575)
Constant	–3.005	–1.822	–2.516	–5.839	–5.581	–2.807	–1.579	–2.261
	(–3.941)**	(–2.299)**	(–3.432)**	(–4.747)**	(–3.988)**	(–3.625)**	(–1.674)*	(–2.752)**
LM test $\chi 2$ (1) =	119.11**	79.78**	82.93**	16.16**	10.93**	121.32**	67.01**	73.73**
Hausman test	$\chi 2(4) = 4.57$	$\chi 2(6) = 6.15$	$\chi 2(5) = 5.08$	$\chi 2(6) = 4.43$	$\chi 2(7) = 4.13$	$\chi 2(5) = 4.39$	$\chi 2(7) = 4.17$	$\chi 2(6) = 4.32$
Observations	137	134	137	137	137	137	134	137

**Significant at the 5 percent level.

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Comment Thomas J. Prusa

This paper offers a new perspective on two important and related questions. First, why do firms engage in foreign direct investment (FDI)? And second, what exactly is transferred from parent to affiliate when FDI occurs? Liu and Chen persuasively argue that at least part of the answer to both questions is R&D.

In Dunning's electic paradigm the combination of firm-specific ownership and internalization advantages and host-country locational advantages are the necessary elements for FDI to occur. One unfortunate implication of the Dunning paradigm is that any given parent-affiliate relationship may be shorter lived than either party anticipated. After all, if a host country's locational advantage pulled in the parent company's investment, what happens when a new country with even more attractive locational attributes emerges? If the costs to terminating the relationship are not too large, the parent company will likely move foreign production to the new location. As the authors explain, the potential transitory nature of FDI-driven relationships can create additional risks and costs to the host country. A host government may pursue, therefore, policies that raise the cost to parent companies moving their affiliate production to the new low-cost location. But it must do so in a way that benefits the parent company. The authors explain that the costs to terminating a FDI relationship will be higher if the affiliate offers the parent firm more than simply low production costs. Thus, host countries whose foreign affiliates engage in R&D in addition to offering low-cost production will be a particularly attractive FDI location.

The paper is largely an attempt to examine whether there is a connection between affiliate R&D intensity and FDI with an eye toward the more intractable question of whether affiliate-based R&D activity can deepen the ties between the parent and affiliate. Taiwan serves as the case study for the inquiry. The authors begin by documenting a temporal connection between the R&D intensity and capital inflow (table 3.1). The authors then perform a series of fixed and random effect estimations to determine what exogenous factors explain R&D intensity. The factors can be thought of as either locational characteristics, such as the size of the local R&D labor force and the local capital content ratio, or firm/industry characteristics, such as the export ratio or the capital-to-labor ratio. In either case, one would think that if these factors were found to be significant influences, the host government could encourage nontransitory FDI by either investing in local resources or by encouraging FDI in particular industries.

Thomas J. Prusa is a professor of economics at Rutgers University, and a research associate of the National Bureau of Economic Research.

The findings are nicely exposited and very sensible. They find that within Taiwan, foreign affiliates with higher R&D intensity tend to be more export oriented, are localized within Taiwan in terms of their sourcing of materials and capital goods, and belong to sectors with a larger pool of R&D labor.

I do have a few minor comments on the current effort and also a couple of suggestions for future research. With respect to the current paper, I think the paper would have benefited from a more concerted effort to flush out exactly how the theory of FDI relates to the empirical question. Despite this comment the current discussion is excellent; in fact, the discussion of locational advantages and R&D is superb. My wish, however, is that the authors expounded more on the direction of causality. In particular, the discussion seems to indicate that both local R&D advantages can attract FDI and also that FDI deepening can encourage R&D. My sense is that this is two-way causality is correct. However, the econometric specifications really don't account for the potential connection.

I would have also liked to see the authors discuss whether R&D intensity has varied between local firms and foreign affiliates. It seems possible that the growth in R&D intensity is driven by the dynamism and innovation of local Taiwanese firms. This local innovation and creativity could have pulled-in FDI. While it seems hard to believe that local R&D has kept up with affiliate R&D, it would be helpful to document the differences.

I would also have liked to see a more detailed discussion of the industry-level differences and trends. The authors present evidence that R&D intensity and capital inflow vary considerably across industry. One industry, electrical and electronic machinery, stands out as a outlier in both dimensions. Are the results being driven by this one industry? This is unlikely, but it would bolster the findings if the authors gave a sense of the sensitivity of their results to one or two outliers.

With respect to future research, I have two suggestions. First, I think the dynamics are far more complicated than the current analysis suggests. In the current paper the authors control for dynamics by including a time trend. While it is highly reassuring that the results are largely unaffected when this trend is included, this is only the first pass. The issue needs more exploration. For instance, are the current parameter results largely a result of time series variation or cross-section variation? The authors might also consider allowing the individual parameters to vary across time, say by splitting the sample into "early" and "recent" time periods. Second, the regressions capture only contemporaneous effects. My sense is that in practice the connection between FDI and R&D intensity involves significant lags. That is, decisions and investments made years ago will impact current R&D.