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R&D Activities of Foreign and National Establishments in Turkish Manufacturing

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Technical progress is the major source of productivity growth in the long run. Research and development (R&D), resulting in new knowledge, new processes, and new goods, is a major source of technical progress according to the R&D-based endogenous growth theory (Romer 1990). Multinational corporations (MNCs), most of them based in developed countries, play a major role in global R&D and in the international transfer of technology. Foreign direct investment (FDI), most of it undertaken by MNCs, is a major vehicle of technology transfer to developing countries (Moran 1998, 2001, chapter 11 of this volume). FDI can be a major vehicle of technology transfer to and diffusion in developing countries via positive externalities through four channels (Organization for Economic Cooperation and Development, or OECD, 2002a, 98; Blomström and Kokko 1998, 11–15):

- Horizontal linkages: National firms may adopt foreign technologies or upgrade their own technologies under greater competition from foreign firms in the same industry.
- Vertical (backward and forward) linkages: Foreign firms may transfer technology to national firms that are their suppliers or customers in different industries.
- Labor mobility: Employees of foreign firms may transfer their knowledge to national firms when changing employers or starting their own firms.

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- R&D internationalization: R&D activities of foreign firms may help strengthen host country capability for R&D directly or indirectly by stimulating the R&D activities of national firms.

I concentrate on the fourth channel in terms of a panel data–based investigation of the R&D activities of foreign-owned ("foreign") and nationally owned ("national") establishments in Turkish manufacturing. I focus not only on whether foreign and national establishments differ in the levels and compositions of their R&D activities but also whether sectoral FDI concentration has a spillover effect on the R&D activities of national establishments.

Background and Literature Review

MNCs play a critical role in global R&D and in the international transfer of technology. They own, produce, and control most of the world's advanced technology, since they are responsible for a significant part of global R&D. In fact, the desire to acquire modern technology may have become the most important reason why most countries try to attract FDI as the flows of technology to MNC affiliates dominate all types of formal technology transactions between countries (Blomström, Kokko, and Zejan 1992; Blomström and Kokko 1998, 2003; Kokko and Blomström 1995). Moreover, these inflows of new technology to MNC affiliates create the potential for technology spillovers to the host country (Blomström and Kokko 1993, 1998, 2003; Kokko and Blomström 1995).

In its recent *World Investment Reports* the United Nations Conference on Trade and Development (UNCTAD 2002, 18) has emphasized the importance of R&D by foreign affiliates in host countries:

> Another important aspect of international production is innovative activity by foreign affiliates. The presence of research and development (R&D) can signify that affiliates are engaging in complex and high value functions. R&D can contribute to capacity-building in host countries and provide spillover benefits to local researchers.

Also,

> The specific advantages of R&D by foreign affiliates must also be remembered. Affiliates can gain from the access they have to R&D in the parent firm's networks. Local firms can capture spillover benefits from R&D in foreign affiliates by learning from their research methods, hiring their trained employees and collaborating with them on specific projects or as suppliers (UNCTAD 2003a, 106).

Foreign affiliates of MNCs undertake R&D primarily to adapt their parents' processes or products to local markets' requirements (Kumar 2001; Fors and Zejan 1996).

Most MNCs concentrate their R&D in their home countries or other developed countries (UNCTAD 2002, 18–20). US MNCs conducted 87 per-

cent of their R&D at home in 1998 (although foreign affiliates accounted for about one-third of their global sales). Japanese MNCs conducted 97 percent of their R&D at home in 1995 (although foreign affiliates accounted for about one-quarter of their global sales). MNCs' concentration of R&D in their home country may be due to three reasons: (1) effective control and economies of scale in the R&D activity; (2) agglomeration economies from clustering of R&D personnel and activities; and (3) stronger intellectual property protection in developed countries than in developing countries (OECD 2002a, 103).

According to UNCTAD (UNCTAD 2002, 19, table I.10), foreign affiliates' share of R&D in total R&D of host countries is lower than their share in production but with wide variations. Innovative corporate activity as measured by patents is still predominantly located close to the firm's headquarters (OECD 1999). In 1994, the R&D carried out by foreign subsidiaries represented only 11 percent of the total R&D of 12 major OECD countries. In general, the R&D intensity of domestic firms was higher than that of foreign subsidiaries. According to the OECD (OECD 2002b, 307, annex table 18), in 1995, R&D expenditures by foreign affiliates in Turkey accounted for 32.8 percent of total business R&D, the second highest percentage among the OECD countries after Ireland, which accounted for 64.6 percent (see also UNCTAD 2002, 19, table I.10). During 1986–99, R&D expenditures by foreign affiliates increased both in real terms and as a share of business in many of the OECD countries, including Canada, France, Ireland, Japan, Sweden, the United Kingdom, and the United States. In Ireland and Hungary, foreign affiliates accounted for more than two-thirds of business R&D in 2000. In 2001, R&D conducted abroad and by foreign affiliates accounted, on average, for about 12 percent of the total industrial R&D expenditures in the OECD countries (OECD 2003).

Compared with the substantial research on the globalization of R&D by MNCs among developed countries (Zander 1998; Branstetter 2000, 2001; Serapio and Dalton 1999; Florida 1997; Kumar 2001; Cantwell and Janne 1999; Zander 1997, 1999; Meyer-Krahmer and Reger 1999; Gerybadze and Reger 1999; Niosi and Godin 1999; Asakawa 2001; Granstrand 1999; Fisch 2003; Zedtwitz and Gassman 2002; Cantwell and Iammarino 2003), there is relatively little empirical research on the R&D activities of MNCs in developing countries (Blomström and Kokko 1998, 14–15). Chuang and Lin (1999) find that in Taiwanese manufacturing, R&D and FDI are substitutes, after they correct for selection bias. They conclude that since foreign firms can receive technological support from their parent company, they have little incentive to conduct R&D themselves. Kearns and Ruane (2001) show, on the basis of a plant-level analysis of different R&D activity measures and after controlling for plant and sector characteristics, that R&D-active MNC plants (with majority foreign ownership) in Ireland had a higher probability of survival and created higher-quantity and better-quality jobs during 1986–96 than non-R&D active MNC plants.

Amsden et al. (2001) conclude, on the basis of firm-level interviews, that the type of R&D undertaken by MNCs in Singapore cannot be categorized as even applied research and that most R&D is tightly coupled with solving production problems. Their conclusion is not supported, however, by Sigurdson and Palonka, who show that Singapore has become, thanks to generous government grants and public R&D institutions, a major R&D center for many MNCs, especially in the information technology and pharmaceutical industries (Sigurdson and Palonka 2002, 21–24). On the other hand, Sigurdson and Palonka (2002, 11–14) conclude that FDI in Indonesia has been less effective in transferring technology, with almost all R&D conducted by government research institutes with little relevance for the needs of the industrial sector. They attribute the failure of FDI to contribute to Indonesia's technological development to the local firms' lack of absorptive capacity and ineffective government policies. Todo and Miyamoto, however, find that in Indonesian manufacturing the R&D activities of foreign firms improved the productivity of national firms, especially of those national firms that also carried out R&D. Their conclusion is that "in order to benefit more from diffusion of advanced knowledge from MNEs [multinational enterprises], governments of less developed countries are advised to encourage FDI associated with R&D activities and human resource development" (Todo and Miyamoto 2002, 27).

Costa and de Queiroz find that foreign industrial affiliates in Brazil had more complex and deeper technological capabilities than their national firms, reflecting their more effective R&D activities. They conclude that "even larger domestic firms are lagging behind their local foreign rivals in further technology development" (Costa and de Queiroz 2002, 1441). Liu and Chen, using industry-level panel data, find that R&D intensity of foreign firms in Taiwan is positively associated with export orientation, local sourcing of materials and capital goods, and sectoral availability of R&D personnel (Liu and Chen 2003). According to an unpublished study cited in UNCTAD (2003b, 106), in India "foreign affiliates reveal a lower R&D intensity than their local counterparts after taking account of extraneous factors." According to UNCTAD (2003c, 141–76), in the South African automotive industry, R&D intensity (R&D expenditures as percentage of sales) of exporting firms tended to be significantly higher (2.55 percent) than that of nonexporting firms (0.95 percent) and that "transfer of technology and other spillovers have been significant features associated with the investment in local subsidiaries by parent companies" (UNCTAD 2003c, 150). Javorcik and Saggi, on the basis of a partial equilibrium duopoly model of mode choice, predict that direct foreign investors with more advanced technologies would prefer full ownership to joint ventures relative to those with less advanced technologies (Javorcik and Saggi 2004). They test their prediction successfully with survey data from Eastern European transition economies and the former Soviet republics (Javorcik and Saggi 2004). The implication is that joint

ventures are likely to carry out more R&D than wholly owned ones in order to close the technology gap.

To summarize the literature review, the limited empirical evidence on the R&D activities of foreign firms in developing countries, although mixed, suggests that on the whole inward FDI stimulates host country R&D. Furthermore, in order for national firms to benefit from technology spillovers, including those from the R&D activities of foreign firms, they must also be R&D active.

As for host country intervention to promote foreign firms' R&D activities, among developed countries, Australia has applied an R&D requirement in terms of R&D expenditures (UNCTAD 2003b, 28). Among developing countries, India seems to be the only one to impose a mandatory R&D requirement in some circumstances (UNCTAD 2003b, 105–06). A few other developing countries such as Chile, Malaysia, and South Africa have imposed voluntary R&D requirements in return for FDI incentives (UNCTAD 2003b, 28). The tangible results have been, unsurprisingly, meager. In Malaysia, for example, although foreign affiliates have contributed significantly to the country's R&D activities, the R&D requirements have not played an important role (UNCTAD 2003b, 152–59). According to UNCTAD (2003b, 28):

> The main problem is that a firm is unlikely to set up R&D activities in the absence of local capabilities and technical skills to absorb, adapt and develop technology and know-how. Thus, in comparison with the availability and quality of appropriately skilled labour, the provision of fiscal or financial incentives is of limited relevance for R&D investments.

Turkey's R&D Trends and Policies

As a developing country Turkey lags behind developed countries in its R&D intensity (OECD 2002b, 32, figure 1.8). Gross domestic expenditure on R&D (GERD) as a proportion of gross domestic product (GDP) was 0.32 percent in 1990. It rose to 0.53 percent in 1991 but then dropped to 0.49 percent in 1992, 0.44 percent in 1993, and 0.36 percent in 1994. In 1995, it was up slightly to 0.38 percent. Between 1996 and 2000, the GERD-to-GDP ratio increased from 0.45 percent to 0.64 percent (Elci 2003, 19). These ratios are very small compared to other OECD countries. Moreover, universities conduct more than two-thirds of the R&D in Turkey, while the private business sector accounts for about only one-fifth of the total national R&D. In 1995, about two-thirds of all R&D was financed by the government, while the business enterprises accounted for the rest. Manufacturing industry constitutes the largest portion of the total business enterprise R&D expenditures. Its share declined, however, from 95 percent in 1990 to 92 percent in 1995.

The Technology Development Foundation of Turkey (TTGV), founded in 1991 and funded by the World Bank, is a member of the Association for

Technology Implementation in Europe (TAFTIE). The TTGV provides R&D support to Turkish industry through soft loans—up to 50 percent of the proposed project budgets—with long repayment periods. All firms, regardless of size or years in existence, that submit R&D project proposals are eligible for R&D support. In fact, 73 percent of the firms supported by the TTGV to date have been small or medium-size enterprises (SMEs) (with fewer than 250 employees), and 51 percent have been less than 10 years old. Since 1995 the Scientific and Research Council of Turkey (TUBITAK), founded in 1963, has provided R&D grants through its Technology Monitoring and Evaluation Board (TIDEB), with SMEs accounting for 70 percent of the companies supported to date. Close to 80 percent of the companies applying for R&D support from either of these two sources have received it (Elci 2003, 28). There are also various other incentives, in the form of different state subsidies, for R&D besides those provided by the TTGV (Elci 2003, 29–31). A country's protection of intellectual property rights (IPR) affects both its appeal as a host country, especially for FDI in R&D facilities, and the transfer of state-of-the-art technology to MNCs' foreign subsidiaries (Mansfield 1994). IPR protection is important for R&D and for innovation through international trade, FDI, and licensing in major industrializing countries (Maskus 2000). Thus, unsurprisingly, inadequate IPR protection has often been mentioned as a major reason for Turkey's relative lack of appeal as a host country (Foreign Investment Advisory Service, or FIAS 2001a, 2001b; Erdilek 2003). For example, the US government has repeatedly complained about this, placing Turkey on the Special 301 Watch, or the Priority Watch List, and suspending its Generalized System of Preferences (GSP) trade privileges in the 1990s. Since the 1994 establishment of the Turkish Patent Institute, the 1995 Trade-Related Aspects of Intellectual Property Rights (TRIPS) Agreement of the World Trade Organization (WTO), and especially the country's 1996 Customs Union Agreement with the European Union (EU), which was aimed at achieving full EU membership, Turkey's IPR protection has increased significantly (Elci 2003).

Data

Establishment-level panel data used in this study come from two separate sources of the Turkish State Institute of Statistics (SIS) for 1993 to 1995, which I bridged by using common establishment codes. The first source of data is the Annual Manufacturing Industry Survey ("Manufacturing Survey"), and the second source of data is the Survey of Research and Development in Turkish Industry ("R&D Survey"). The Industrial Statistics Section of the SIS carries out the Annual Surveys of the Manufacturing Industry that cover all establishments regardless of size. The Science-Technology, Information Indicators and Analysis Division of the SIS carries out the Annual Surveys of Research and Development in Turkish Industry in compliance with the

standard OECD methodology (OECD 1994), referred to as the Frascati Manual. OECD annually publishes the aggregated Frascati Manual–based R&D statistics of Turkey and its other members in the *OECD Science, Technology and Industry Scoreboard* (OECD 2003).

Although the Manufacturing Survey also contains data on R&D expenditures, they are not as reliable as those in the R&D Survey. I use establishment and sectoral explanatory variables based on data from the Manufacturing Survey to analyze the establishment R&D activities from the R&D Survey. All the Turkish lira values for 1994 and 1995 are deflated by the four-digit sector-specific annual producer price deflators in the absence of deflators for the input-supplying sectors. The rather short three-year duration of the panel is because readily available and reliable foreign ownership data did not exist for the earlier years, and data for later years were not yet accessible.

The OECD methodology defines R&D[1] as "creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications" (OECD 1994, 13). The OECD methodology involves the measurement of two inputs: R&D expenditures (current and capital) and R&D personnel (in terms of full-time equivalence). The Frascati Manual divides R&D into three activities: basic research, applied research, and experimental development (OECD 1994, 50–51). The manual also distinguishes among three types of R&D personnel: researchers, technicians, and other supporting staff (OECD 1994, 67–68).

Two basic issues—censoring and selection bias—need to be addressed concerning the data (Baltagi 2001, chapter 11; Greene 2003, chapter 22). The censoring issue arises in the case of censored observations in R&D in the Manufacturing Survey. The Manufacturing Survey includes all establishments, most of which conduct no R&D according to the survey's single R&D question (which does not define R&D) about their R&D expenditures. So, the R&D-related dependent variables are censored from below at zero, requiring censored regression (tobit) estimations. The second issue, addressed below, arises in the form of possible sample selection bias in the R&D Survey, which includes only a handful of primarily large establishments that conduct R&D according to the precise and restrictive OECD definition.

During 1993–95, 14.40 percent of all establishments indicated having R&D in the Manufacturing Survey but only 1.39 percent indicated having R&D in the R&D Survey.[2] The lower percentage in the R&D Survey can be attributed to either the precise and restrictive OECD definition of R&D in that survey

1. OECD uses R&D as the acronym for research and experimental development whereas it typically stands for research and development.

2. The relevant statistical tables of this section, omitted due to space restrictions, are available from the author upon request.

or the possible sample selection bias in favor of larger establishments. For the three individual years, the data are quite similar, except that the percentages of establishments indicating R&D have increased slightly but steadily during 1993–95 according to both surveys. Although we do not see much difference in the responses to the two surveys across time, we do see a sharp difference across national and foreign establishments. In both surveys, the percentage of foreign establishments with R&D is significantly higher than that for national establishments. The difference is relatively much greater in the R&D Survey, with only 1.03 percent of the national but 13.24 percent of the foreign establishments indicating R&D programs.

The major difference in the responses to the two surveys is due to establishment size, which is measured by total revenue. According to the Manufacturing Survey, establishments in all five total revenue quintiles have R&D, but the R&D propensity increases significantly with total revenue. According to the R&D Survey, however, almost all the establishments with R&D programs are in the largest total revenue quintile, which raises the issue of possible sample selection bias. According to the SIS, the R&D Survey is administered to all establishments with R&D departments and to all R&D centers in the country.[3] It covers all state economic enterprises, which are all large, and all large private companies ranked in terms of their sales and value added. It also covers, however, SMEs that either conduct R&D under the aegis of technology centers and/or have applied to various government agencies such as TTGV and TUBITAK for R&D support (SIS 1997, VIII). Therefore, it appears that no clear-cut sample selection bias exists in the R&D Survey, and that it reflects largely the strong association between R&D propensity and establishment size. Nevertheless, I estimated the Heckman selection model (heckit) by the full information maximum-likelihood estimator, which is preferable to the two-step efficient estimator, for all the random-effects tobit regressions to show that, on the whole, no conclusive econometric evidence exists for sample selectivity.[4] The Marmara region, which is Turkey's most industrialized region, accounted for slightly more than half of all the establishments in the Manufacturing Survey.[5] Its dominance among the seven regions was even greater in terms of foreign establishments; it accounted for two-thirds of all foreign establishments. The dominance of the Marmara

3. Unfortunately, the SIS did not provide information on the response rates to its surveys.

4. Using the Heckman selection model, developed for cross-section data, to test and correct for sample selection bias in panel data is problematic, since there are two selectivity bias correction terms in panel data instead of one as in cross-section data (Baltagi 2001, 220). The Heckman selection model estimation results are available from the author upon request.

5. The seven regions of Turkey are Marmara, Aegean, Mediterranean, central Anatolia, Black Sea, eastern Anatolia, and southeastern Anatolia.

region was even greater in the R&D Survey. The R&D Survey contains no observations from the least developed Eastern Anatolia and Southeastern Anatolia regions.

Foreign establishments accounted for 28.54 percent of the observations in the R&D Survey, as opposed to 3.00 percent of the observations in the Manufacturing Survey. Although foreign establishments accounted for 22.18 percent of the total revenue in the Manufacturing Survey, their share of the total R&D expenditure was 55.43 percent in the R&D Survey. Although they accounted for 10.99 percent of the total employment in the Manufacturing Survey, their share of the total R&D employment was 47.02 percent in the R&D Survey. The average R&D expenditure/total revenue ratio of foreign establishments, 0.8670 percent, was much greater than that of national establishments, 0.1987 percent.[6] The overall average R&D expenditure/total revenue ratio of 0.3470 percent in manufacturing is quite close to the economywide ratios mentioned earlier.

When we examine the distribution of foreign establishments by total revenue quintiles and ownership percentage groups, we observe that foreign establishments, regardless of percentage of ownership, tend to be of larger size than national establishments. Their share in the total revenue quintiles increases from the smallest to the largest across all five ownership percentage groups. The largest total revenue quintile contains the majority of foreign establishments across each of the five ownership percentage groups and accounts for more than two-thirds of all the foreign establishments. Although the highest foreign ownership percentage group has the largest share (more than one-third) of foreign establishments, the distribution of foreign establishments across the five ownership percentage groups does not follow a definite pattern.

Research Questions

I tried to answer the following research questions on the basis of the data from the Manufacturing and R&D Surveys:

- Do the compositions of R&D activities in terms of three types of R&D expenditure and three types of R&D personnel differ between national and foreign establishments?
- How significant are foreign ownership by establishment and foreign ownership concentration by sector for the probability that an establishment will have R&D activity?

6. In an earlier study, my estimate of this ratio for foreign firms was 0.7 percent (Erdilek 1982, 80).

- How significant are foreign ownership by establishment and foreign ownership concentration by sector in explaining 13 different R&D activity indicators?[7]

Methodology, Model, and Hypotheses

First, I used two-sample t-tests with unequal variances as well as Hotelling's T-squared generalized means test to find out whether foreign and national establishments differ statistically in their R&D propensities as well as their compositions of R&D expenditures and personnel. Then, I estimated random-effects logit regression, random-effects tobit regression, and ordered logit regression models in which I controlled for establishment characteristics such as private versus public ownership, size, vertical (backward) integration, and regional location, as well as for sector characteristics in terms of international competitiveness and industrial concentration. I was limited by the data in my choice of explanatory variables. I could not control for some important establishment characteristics such as years of existence, entry and exit, capital intensity, exports, and imports since I had no data.[8]

In the random-effects logit regressions, the dependent variable is a dummy variable, indicating the absence (= 0) or presence (= 1) of (either aggregate or one of three specific types of) R&D activity. In the random-effects tobit regressions, which have the same explanatory variables as the random-effects logit regressions, the continuous dependent variable is one of the 13 different R&D activity measures. In the ordered logit regressions,

7. The 13 R&D activity indicators are: (1) total R&D expenditure to total revenue ratio; (2) total R&D full-time equivalent (FTE) employment to the total employment ratio; (3) total R&D FTE personnel salary to total employee compensation ratio; (4) average R&D FTE salary; (5) percentage of basic research in total R&D expenditure; (6) percentage of applied research in total R&D expenditure; (7) percentage of experimental development in total R&D expenditure; (8) percentage of researchers in total R&D FTE employment; (9) percentage of technicians in total R&D FTE employment; (10) percentage of other supporting staff in total R&D FTE employment; (11) percentage of researchers' FTE salary in total R&D FTE personnel salary; (12) percentage of technicians' FTE salary in total R&D FTE personnel salary; and (13) percentage of other supporting staff's FTE salary in total R&D FTE salary.

8. As Gordon Hanson commented, the basic assumption in using the random-effects logit and random-effects tobit estimations is that the unobserved establishment-level heterogeneity is uncorrelated with the observed establishment characteristics (Greene 2003, 689–94; Baltagi 2001, 206–14). If this assumption is violated, the random-effects coefficient estimates will be inconsistent. Unfortunately, the Hausman-Taylor instrumental variable estimation method for error components that deals with this potential problem in continuous dependent variable models is not applicable to the binary choice or limited dependent variable models I used.

which have the same explanatory variables as the random-effects tobit regressions, the dependent variable is one of the 13 different R&D activity measures each grouped into 6 categories. I estimate the following regression equation:

$$\begin{aligned} \text{R\&DActivity}_{ijt} = {} & \text{Constant} + \beta_1 \text{EstablishmentFDIShareGroup}_{ijt} \\ & + \beta_2 \text{SectorFDIShare}_{jt} + \beta_3 \text{RevenueGroup}_{ilt}(\text{Revenue}_{ijt}) \\ & + \beta_4 \text{EstablishmentPrivateOwnership}_{ijt} \\ & + \beta_5 \text{VerticalIntegration}_{ijt} + \beta_6 \text{ComparativeAdvantage}_{jt} \\ & + \beta_7 \text{HerfindahlIndex}_{jt} + \beta_8 \text{Year}_t + \beta_9 \text{Region}_{kt} + \mu_{ijt} \end{aligned}$$

where i = establishment, j = sector, k = region, l = revenue group, t = time, and

$$\text{SectorFDIShare}_{jt} = \frac{\Sigma_j \text{EstablishmentFDIShare}_{ijt} * \text{Employment}_{ijt}}{\Sigma_i \text{Employment}_{ijt}}$$

EstablishmentFDIShareGroup represents six dummy variables indicating the percentage of foreign ownership: 1 (= 0 percent foreign ownership), 2 (= 1–20 percent), 3 (= 21–40 percent), 4 (= 41–60 percent), 5 (= 61–80 percent), and 6 (= 81–100 percent). In the regressions run with only national establishments these variables are omitted, and in the regressions run with foreign establishments only the last five are used. Establishments with 0 percent foreign ownership are identified as national establishments. SectorFDIShare, the sectoral employment-weighted FDI concentration, is computed as foreign ownership percentage, averaged across all establishments in a sector, weighted by each establishment's share in that sector's employment. This variable is used as a proxy for spillover effects. RevenueGroup represents the dummy variables for the five establishment revenue groups, with equal number of observations, according to rising revenue levels. EstablishmentPrivateOwnership is a dummy variable indicating the absence (= 0) or presence (= 1) of private ownership. Establishments with 0 percent private ownership are identified as public (state-owned) establishments. VerticalIntegration is the establishment value added to output ratio, measuring backward (upstream) integration, i.e., the extent of intermediate manufacturing in the value chain. ComparativeAdvantage in each sector is measured by net exports divided by the sum of exports and imports in that sector. HerfindahlIndex represents Herfindahl sectoral concentration in terms of establishment revenues. Year and Region are dummy variables for the three years and the seven regions, respectively.

From the regression results, I expect, as my ad hoc hypotheses:

- Foreign establishments have a higher R&D propensity based on the analysis of my data from the SIS surveys.

- Establishments with higher percentage of foreign ownership have higher R&D propensity based on the empirical FDI literature.[9]
- National establishments in sectors with higher FDI concentration have higher R&D propensity—a positive spillover effect—because of either labor mobility or competitive pressures from foreign establishments.
- Establishments with larger revenues have higher R&D propensity based on the empirical industrial organization literature.[10]
- Public establishments have higher R&D propensity since they are, on the average, larger than private establishments and benefit more directly from state R&D incentives.
- Establishments with greater (backward) vertical integration have higher R&D propensity, since a longer value chain, extended to intermediate manufacturing, as opposed to mere assembly, increases either the need or the scope for R&D.
- Establishments in sectors with higher relative net exports have lower R&D propensity, since Turkish manufacturing's comparative advantage lies in labor-intensive sectors with lower skills and technologies.[11]
- Establishments in sectors with higher Herfindahl indices have higher R&D propensity, since higher concentration reflects less domestic competition and higher profitability, which can result in higher net revenues to finance R&D.[12]

9. Moran (1998, 126) concludes, on the basis of empirical evidence, that "the greater the activity of wholly owned subsidiaries in a given economy the more likely the prospects for spillovers and externalities to domestic firms," although he does not refer to R&D activities specifically. Moran (2001, and chapter 11 of this volume) reiterates the importance of full foreign ownership for the subsidiary's use of the state-of-the-art technologies. Javorcik and Spatareanu, too, conclude, based on empirical results for Romania, that wholly owned foreign firms receive more technology transfer than partially owned ones (Javorcik and Spatareanu 2003). Blomström and Sjöholm (1999) hypothesize that the greater the parent control, based on increasing percentage of ownership, the greater the incentive to transfer more sophisticated technologies to foreign affiliates. According to their empirical results for Indonesia, based on cross-section data for 1991, however, the degree of foreign ownership does not affect either the level of labor productivity in foreign establishments or the spillovers to national establishments, only foreign ownership matters (Blomström and Sjöholm 1999).

10. The empirical literature consensus is that the elasticity of R&D with respect to firm size is close to unity (Gustavsson and Poldahl 2003).

11. Among developed countries, comparative advantage and R&D are usually positively correlated, but for developing countries such as Turkey the correlation could be negative, especially in cases of import-substitution industrialization.

12. The effect of industrial concentration on R&D, both theoretically and empirically, has been controversial, however, since Schumpeter postulated a negative relationship between competition and innovation 70 years ago (Gustavsson and Poldahl 2003).

- Establishments located in the more developed regions, such as Marmara, Aegean, and Mediterranean, have a higher R&D propensity, reflecting their better infrastructure and the greater availability of highly skilled labor.

Empirical Results

Before investigating the significance of foreign ownership by establishment and foreign ownership concentration by sector for the probability that an establishment will have R&D activity in the Manufacturing and the R&D Survey through random-effects logit, I ran Hotelling's T-squared generalized means test as well as a two-sample t-test with unequal variances to show that foreign establishments had indeed statistically significant higher R&D propensity according to both surveys.[13]

Moreover, before investigating the significance of foreign ownership by establishment and foreign ownership concentration by sector for the various R&D expenditure- and R&D employment-based variables through random-effects tobit, I ran Hotelling's T-squared generalized means test as well as a two-sample t-test with unequal variances to show foreign ownership indeed mattered. Foreign establishments had statistically significant higher average percentages in all three types of R&D activity, although the rankings were the same for both groups. As expected, basic research accounted for the lowest and experimental development accounted for the highest average percentage. However, foreign establishments had statistically significant lower average percentages of basic research and applied research R&D expenditure and higher average percentages of experimental development R&D expenditure. On the average, foreign and national establishments differed in the composition of their R&D personnel, but the difference was not highly significant. The rankings of the three types of R&D personnel were the same for both groups. As expected, researchers accounted for the highest and other supporting staff accounted for the lowest average percentage. On the average, foreign and national establishments also differed in the composition of their R&D personnel total compensation—the difference was statistically more significant than their R&D personnel composition. The rankings of the three types of R&D personnel total compensation were the same for both groups. As expected, researchers accounted for the highest and the other supporting staff accounted for the lowest average percentage.

In summary, although foreign establishments devoted a lower percentage of their R&D expenditure to basic research and applied research, they had higher average percentages of researchers and technicians in their R&D

13. The relevant statistical tables, omitted due to space restrictions, are available from the author upon request.

personnel and paid higher proportions of their total R&D compensation to researchers and technicians than national establishments. Therefore, it is unsurprising that foreign establishments had statistically significant higher average R&D salary than national establishments.

Finally, foreign establishments had statistically significant higher R&D performance indices, in terms of R&D intensity (ratio of R&D expenditure to total revenue), R&D employment intensity (ratio of R&D employment to total employment), and R&D salary intensity (ratio of R&D employee compensation to total employee compensation) than national establishments.

I conclude, therefore, that foreign establishments in Turkish manufacturing during 1993–95 were on the average more active in R&D activities than national establishments. The question that remains is whether this difference was a result of their foreign status per se or some other explanatory variables such as their average larger size. The regression results presented below will attempt to answer that question.

In all the regressions, I specify three models. The first model includes both national and foreign establishments, the second model includes only national establishments, and the third model includes only foreign establishments. Although the panel has 30,948 observations, all the regressions are based on 30,573 observations for which data exist for all the explanatory variables.[14]

Random-Effects Logit Regression Results

Random-Effects Logit Regression Results for R&D Activity in the Manufacturing Survey

Table 5.1 presents the random-effects logit regression results for the Manufacturing Survey–based R&D activity indicator. Foreign ownership is positively and significantly associated with the presence of R&D activity when all establishments are included, but this association does not get stronger with increasing percentage of foreign ownership. The minority foreign ownership group 3, with 21–40 percent, has the strongest association in terms of the odds ratio. Increasing percentage of foreign ownership is not, however, significantly associated with the presence of R&D activity when only foreign establishments are included. Sectoral FDI concentration is positively and significantly associated with the presence of R&D activity—i.e., there is a spillover effect from foreign establishments to national establishments. There is no spillover effect when only foreign establishments are

14. The tables containing the summary statistics for the regression variables as well as the tables containing the pairwise correlation coefficients for the explanatory variables, omitted due to space restrictions, are available from the author upon request.

Table 5.1 Random-effects logit results for R&D activity in the Manufacturing Survey

Variable	Model (1): All establishments	Model (2): National establishments	Model (3): Foreign establishments
Constant	–5.5639841 (22.63)**	–5.5414014 (22.67)**	–1.5728112 (0.79)
Foreign ownership group 2 (1–20 percent)	0.8740066 2.3964935 (2.48)*	n.a.	n.a.
Foreign ownership group 3 (21–40 percent)	1.6089281 4.9974518 (4.03)**	n.a.	n.a.
Foreign ownership group 4 (41–60 percent)	1.3060664 3.6916238 (4.52)**	n.a.	n.a.
Foreign ownership group 5 (61–80 percent)	1.3857398 3.9977822 (2.85)**	n.a.	n.a.
Foreign ownership group 6 (81–100 percent)	0.8814141 2.4143113 (3.34)**	n.a.	n.a.
Foreign ownership share group 2 (21–40 percent)	n.a.	n.a.	0.2188673 1.2446661 (0.28)
Foreign ownership share group 3 (41–60 percent)	n.a.	n.a.	–0.2261132 0.7976278 (0.28)
Foreign ownership share group 4 (61–80 percent)	n.a.	n.a.	–0.4606459 0.6308760 (0.44)
Foreign ownership share group 5 (81–100 percent)	n.a.	n.a.	–0.8185475 0.4410719 (1.01)
Employment-weighted sector FDI share	0.0175988 1.0177545 (4.10)**	0.0169249 1.0170690 (3.79)**	0.0352433 1.0358717 (1.88)
Total revenue group 2	0.4638451 1.5901766 (4.52)**	0.4661498 1.5938458 (4.57)**	–0.6777123 0.5077773 (0.33)
Total revenue group 3	1.0268003 2.7921176 (9.89)**	1.0302789 2.8018471 (9.98)**	–0.1032099 0.9019376 (0.06)
Total revenue group 4	1.4869114 4.4234121 (14.13)**	1.4893397 4.4341666 (14.19)**	0.2148765 1.2397088 (0.12)

(table continues next page)

Table 5.1 Random-effects logit results for R&D activity in the Manufacturing Survey *(continued)*

Variable	Model (1): All establishments	Model (2): National establishments	Model (3): Foreign establishments
Total revenue group 5	2.4534530 11.6284303 (22.49)**	2.4213921 11.2615257 (22.26)**	1.4429452 4.2331449 (0.81)
Observations	30,573	29,654	919
Groups	12,871	12,568	376
Wald chi^2	975.23	793.56	45.00
Prob > chi^2	0.0000	0.0000	0.0004
Log likelihood	–10,589.074	–10,109.273	–471.51463
Rho	.5938589	.5843096	.7613425
Likelihood-ratio test of rho = 0:			
$chibar^2$ (01)	2,007.52	1,811.50	170.54
Prob ≥ $chibar^2$	0.000	0.000	0.000

$chibar^2$ = The likelihood ratio test statistic of rho.
Wald chi^2 = The Wald hypothesis test statistic for the model.

Notes: Each cell lists the coefficient (*b*), the coefficient transformed to the odds ratio (i.e., e^b instead of *b*), and the absolute value of *z* statistics in parentheses (* = significance at 5 percent; ** = significance at 1 percent). The cells for the other explanatory variables are omitted due to space restrictions. Rho is the proportion of the total variance contributed by the panel-level variance component. If rho equals zero, then the panel estimator and the pooled estimator are not different. The likelihood-ratio test compares the panel estimator with the pooled estimator through the null hypothesis that they are not different.

included. Establishment size, measured by total revenue, is positively and significantly associated with the presence of R&D activity, when either all or only national establishments are included. Moreover, this association gets stronger with increasing total revenue. Private ownership is positively and significantly associated with the presence of R&D activity in the first two models.[15] It is dropped from the third model since all foreign establishments are private. Vertical integration is positively and significantly associated with the presence of R&D activity when either all or only national establishments are included. Comparative advantage is negatively and significantly associated with the presence of R&D activity in all three models. Herfindahl index is positively and significantly associated with the presence of R&D activity in only the first two models. The region dummy variables (relative to the Marmara region) are mostly negative but not all significant. The year dummy variables (relative to 1993) are positive in all three models but significant in only the first two. All three regressions

15. The regression coefficients for the rest of the explanatory variables, omitted from tables 5.1–5.6 due to space restrictions, are available from the author upon request.

are statistically significant in terms of the Wald chi-square statistic. This holds for all the other estimations reported below. In all three regressions, the proportion of the variance contributed by the panel-level variance is important according to the likelihood-ratio test, which compares the pooled estimator (logit) with the panel estimator. This holds for the second random-effects logit estimations as well as for most of the random-effects tobit estimations reported below.

Random-Effects Logit Regression Results for R&D Activity in the R&D Survey

Table 5.2 presents the random-effects logit regression results for the R&D Survey–based overall R&D activity (combined basic, applied, and experimental development activities) indicator. Foreign ownership is positively and significantly associated with the presence of R&D activity when all establishments are included, but this association does not automatically get stronger with increasing percentage of foreign ownership. Foreign ownership group 4, with 41 to 60 percent, has the strongest association in terms of the odds ratio (in contrast to the minority foreign ownership group 2, with 21 to 40 percent, according to the Manufacturing Survey–based results). Increasing percentage of foreign ownership, relative to the foreign establishments in the 1 to 20 percent foreign ownership group 2, is negative but for only two of the four foreign ownership share groups significantly associated with the presence of R&D activity when only foreign establishments are included. Sectoral FDI concentration is positively and significantly associated with the presence of R&D activity but does not indicate a spillover effect from foreign establishments to national establishments since it is insignificant when only national establishments are included. Establishment size, measured by total revenue, is positively and significantly associated with the presence of R&D activity in all three models. This confirms the result from the previous regression that large establishment size has a very strong association with the propensity to conduct R&D. Private ownership is negatively and significantly associated with the presence of R&D activity, contrary to the result obtained from the Manufacturing Survey–based regressions. Vertical integration is positively and significantly associated with the presence of R&D activity in the first two models. For only foreign establishments, however, vertical integration is negatively associated with R&D activity. Comparative advantage is negatively and significantly associated with the presence of R&D activity in the first two models. Herfindahl index is positively but not significantly associated with the presence of R&D activity in all three models. The year dummy variables are mostly positive but not significant in contrast to the results based on the Manufacturing Survey.

To sum up these two sets of random-effects logit regression results, although obtained from two different R&D databases, they are on the

Table 5.2 Random-effects logit results for R&D activity in the R&D Survey

Variable	Model (1): All establishments	Model (2): National establishments	Model (3): Foreign establishments
Constant	–26.7572766 (12.08)**	–56.3301782 (10.87)**	–8.1077674 (4.66)**
Foreign ownership group 2 (1–20 percent)	15.4792238 5.27888e+06 (7.90)**	n.a.	n.a.
Foreign ownership group 3 (21–40 percent)	13.7973853 9.82038e+05 (8.15)**	n.a.	n.a.
Foreign ownership group 4 (41–60 percent)	16.6917325 1.77471e+07 (10.67)**	n.a.	n.a.
Foreign ownership group 5 (61–80 percent)	14.2997731 1.62298e+06 (8.18)**	n.a.	n.a.
Foreign ownership group 6 (81–100 percent)	14.4534434 1.89256e+06 (9.49)**	n.a.	n.a.
Foreign ownership share group 2 (21–40 percent)	n.a.	n.a.	–0.8246977 0.4383675 (0.74)
Foreign ownership share group 3 (41–60 percent)	n.a.	n.a.	–5.0553583 0.0063751 (3.49)**
Foreign ownership share group 4 (61–80 percent)	n.a.	n.a.	–0.5208829 0.5939959 (0.37)
Foreign ownership share group 5 (81–100 percent)	n.a.	n.a.	–7.1678178 0.0007710 (4.31)**
Employment-weighted sector FDI share	0.0509063 1.0522243 (3.03)**	0.0254935 1.0258212 (1.27)	0.0883789 1.0924020 (2.46)*
Total revenue	0.0000031 1.0000031 (10.95)**	0.0000064 1.0000064 (11.96)**	0.0000015 1.0000015 (5.02)**
Observations	30,573	29,654	919
Groups	12,871	12,568	376
Wald chi^2	205.58	186.58	43.99
Prob > chi^2	0.0000	0.0000	0.0001
Log likelihood	–1,008.1027	–760.34778	–176.74422
Rho	.9887685	.997746	.9663656

(table continues next page)

Table 5.2 Random-effects logit results for R&D activity in the R&D Survey *(continued)*

Variables	Model (1): All establishments	Model (2): National establishments	Model (3): Foreign establishments
Likelihood-ratio test of rho = 0:			
chibar^2 (01)	1,529.12	1,354.02	224.99
Prob ≥ chibar^2	0.000	0.000	0.000

chibar^2 = The likelihood ratio test statistic of rho.
Wald chi^2 = The Wald hypothesis test statistic for the model.

Notes: Each cell lists the coefficient (*b*), the coefficient transformed to the odds ratio (i.e., e^b instead of *b*), and the absolute value of *z* statistics in parentheses (* = significance at 5 percent; ** = significance at 1 percent). The cells for the other explanatory variables are omitted due to space restrictions. Rho is the proportion of the total variance contributed by the panel-level variance component. If rho equals zero, then the panel estimator and the pooled estimator are not different. The likelihood-ratio test compares the panel estimator with the pooled estimator through the null hypothesis that they are not different.

whole quite similar. Foreign ownership has a positive and significant association with the presence of R&D activity among all establishments. The strength of this association, however, does not increase linearly with the percentage of foreign ownership. Among foreign establishments, on the other hand, no significant positive association exists between percentage of foreign ownership and R&D activity. In fact, the association is mostly negative, relative to the foreign establishments in the 1 to 20 percent foreign ownership group, although not always significant. As for sectoral FDI concentration, it is positively and significantly associated with the presence of R&D activity when all establishments are included. There is a strong spillover effect from foreign establishments to national establishments in the Manufacturing Survey but not in the R&D Survey. The only consistent difference between the two sets of results pertains to the role of private versus public ownership.

Random-Effects Tobit Regression Results[16]

Random-Effects Tobit Regression Results for R&D Intensity

According to table 5.3, foreign ownership is positively and significantly associated with an establishment's R&D intensity (the establishment ratio of total R&D expenditures to total revenue) only in the first model. This

16. Due to space restrictions, the detailed results for only 3 of the 13 R&D activity indicators are reported here. The detailed results for the other 10 R&D activity indicators are available from the author upon request.

Table 5.3 Random-effects tobit results for R&D intensity (total R&D expenditure to total revenue)

Variable	Model (1): All establishments	Model (2): National establishments	Model (3): Foreign establishments
Constant	–1.09843e–01 (16.02)**	–1.47246e–01 (13.78)**	–3.18070e–02 (7.72)**
Foreign ownership group 2 (1–20 percent)	3.93983e–02 (6.74)**	n.a.	n.a.
Foreign ownership group 3 (21–40 percent)	3.74816e–02 (4.21)**	n.a.	n.a.
Foreign ownership group 4 (41–60 percent)	4.59615e–02 (9.08)**	n.a.	n.a.
Foreign ownership group 5 (61–80 percent)	4.31465e–02 (3.86)**	n.a.	n.a.
Foreign ownership group 6 (81–100 percent)	3.36599e–02 (5.28)**	n.a.	n.a.
Foreign ownership share group 2 (21–40 percent)	n.a.	n.a.	–1.20165e–03 (0.37)
Foreign ownership share group 3 (41–60 percent)	n.a.	n.a.	–4.58608e–03 (1.46)
Foreign ownership share group 4 (61–80 percent)	n.a.	n.a.	–9.99723e–04 (0.23)
Foreign ownership share group 5 (81–100 percent)	n.a.	n.a.	–7.92196e–03 (2.56)*
Employment-weighted sector FDI share	5.17936e–04 (4.31)**	3.01457e–04 (1.76)	4.83735e–04 (4.89)**
Total output	6.81756e–09 (13.31)**	8.55314e–09 (12.69)**	3.22311e–09 (8.67)**
Observations	30,573	29,654	919
Groups	12,871	12,568	376
Wald chi^2	407.28	315.61	156.62
Prob > chi^2	0.0000	0.0000	0.0000
Log likelihood	180.20566	3.4251852	230.80861
Rho	.8144392	.8461469	.843226
Likelihood-ratio test of rho = 0: $chibar^2(01)$	1,062.98	891.26	218.75
Prob ≥ $chibar^2$	0.000	0.000	0.000

$chibar^2$ = The likelihood ratio test statistic of rho.
n.a. = not applicable
Wald chi^2 = The Wald hypothesis test statistic for the model.

Notes: The absolute value of *z* statistics is in parentheses (* = significance at 5 percent; ** = significance at 1 percent). The cells for the other explanatory variables are omitted due to space restrictions. Rho is the proportion of the total variance contributed by the panel-level variance component. If rho equals zero, then the panel estimator and the pooled estimator are not different. The likelihood-ratio test compares the panel estimator with the pooled estimator through the null hypothesis that they are not different.

association is strongest for the foreign ownership group 4, with 41 to 60 percent, confirming the result obtained from the logit regression based on the R&D Survey. In the third model, however, the association among all foreign establishments turns negative, and the highest foreign ownership percentage (81 to 100 percent) dummy variable becomes significantly negative. In other words, foreign establishments close to or with wholly foreign ownership seem to have markedly lower R&D intensity relative to other foreign establishments. This is robust across all the tobit regressions. Sectoral FDI concentration is positively and significantly associated with the presence of R&D activity but does not indicate a spillover effect from foreign establishments to national establishments since it is insignificant when only national establishments are included. This outcome confirms the result obtained from the logit regression based on the R&D Survey. Establishment size, measured in this regression by total output instead of total revenue to avoid endogeneity, is positively and significantly associated with R&D intensity in all three models. This result is robust across all of the tobit regressions. Private ownership is negatively and significantly associated with R&D intensity, confirming the result obtained from the logit regression based on the R&D Survey. This result is robust across most of the tobit regressions. Vertical integration is positively and significantly associated with R&D intensity in the first two models. In the third model, the association turns negative but is insignificant. This result is robust across most of the tobit regressions. Comparative advantage is negative and significantly associated with R&D intensity in all the models. This result, too, is robust across most of the tobit regressions. Herfindahl index is positively and significantly associated with R&D intensity in only the second model. In the other tobit regressions, both the sign and the significance of this variable change without a definite pattern. The year dummy variables are mostly negative but not all significant.

Random-Effects Tobit Results for R&D Employment Intensity

According to table 5.4, foreign ownership is positively and significantly associated with an establishment's R&D employment intensity (the establishment ratio of total R&D FTE employment to total employment) in the first model. This association is strongest, however, for the first foreign ownership group 2, with 1 to 20 percent. In the third model, on the other hand, the association is significantly negative across all share groups—i.e., relative to the foreign establishments in the 1 to 20 percent foreign ownership group 2, foreign establishments with higher foreign ownership percentage have markedly lower R&D employment intensity. Sectoral FDI concentration is positively and significantly associated with the R&D employment intensity in all three models. There is a positive and significant spillover effect from foreign establishments to national establishments.

Table 5.4 Random-effects tobit results for R&D employment intensity (total R&D FTE personal to total employment)

Variable	Model (1): All establishments	Model (2): National establishments	Model (3): Foreign establishments
Constant	–1.18435e–01 (14.23)**	–1.36673e–01 (19.09)**	–1.59042e–02 (2.21)*
Foreign ownership group 2 (1–20 percent)	5.27645e–02 (11.13)**	n.a.	n.a.
Foreign ownership group 3 (21–40 percent)	4.41409e–02 (8.17)**	n.a.	n.a.
Foreign ownership group 4 (41–60 percent)	3.10452e–02 (6.84)**	n.a.	n.a.
Foreign ownership group 5 (61–80 percent)	4.85842e–02 (7.10)**	n.a.	n.a.
Foreign ownership group 6 (81–100 percent)	3.40671e–02 (7.35)**	n.a.	n.a.
Foreign ownership share group 2 (21–40 percent)	n.a.	n.a.	–3.38735e–02 (5.57)**
Foreign ownership share group 3 (41–60 percent)	n.a.	n.a.	–3.42875e–02 (5.59)**
Foreign ownership share group 4 (61–80 percent)	n.a.	n.a.	–2.53224e–02 (3.37)**
Foreign ownership share group 5 (81–100 percent)	n.a.	n.a.	–3.30750e–02 (5.71)**
Employment-weighted sector FDI share	6.37011e–04 (5.33)**	4.46969e–04 (3.20)**	1.07963e–03 (5.41)**
Total revenue	6.50696e–09 (11.99)**	1.12227e–08 (18.51)**	6.13397e–09 (8.71)**
Observations	30,573	29,654	919
Groups	12,871	12,568	376
Wald chi^2	670.90	506.12	285.91
Prob > chi^2	0.0000	0.0000	0.0000
Log likelihood	118.83522	–.31301305	111.07835
Rho	.8697904	.9028705	.9222484
Likelihood-ratio test of rho = 0: $chibar^2(01)$	1,448.25	1,179.05	221.98
Prob ≥ chibar	0.000	0.000	0.000

$chibar^2$ = The likelihood ratio test statistic of rho.
FTE = full-time equivalent
n.a. = not applicable
Wald chi^2 = The Wald hypothesis test statistic for the model.

Notes: The absolute value of z statistics is in parentheses (* = significance at 5 percent; ** = significance at 1 percent). The cells for the other explanatory variables are omitted due to space restrictions. Rho is the proportion of the total variance contributed by the panel-level variance component. If rho equals zero, then the panel estimator and the pooled estimator are not different. The likelihood-ratio test compares the panel estimator with the pooled estimator through the null hypothesis that they are not different.

Random-Effects Tobit Results for R&D Salary Intensity

According to table 5.5, foreign ownership is positively and significantly associated with an establishment's R&D salary intensity (the establishment ratio of total R&D full FTE total salary to total employment compensation) in the first model. In the third model, however, the foreign ownership percentage is significantly negative across two of the four share groups. Sectoral FDI concentration is positively and significantly associated with the R&D salary intensity in all three models. There is a positive and significant spillover effect from foreign establishments to national establishments.

To sum up the random-effects tobit results, foreign ownership has a positive and significant association with the 13 different R&D activity measures among all establishments. The strength of this association, however, does not increase linearly with the percentage of foreign ownership. On the contrary, the association is relatively stronger for establishments with minority foreign ownership (1 to 20 percent and 21 to 40 percent). Among only foreign establishments, however, the association is mostly negative relative to the foreign establishments in the 1 to 20 percent foreign ownership group, although not always significant. As for sectoral FDI concentration, it is positively and significantly associated with the R&D activity measures in all but a very few of the regressions.

Ordered Logit Results

The regression coefficients from the random-effects tobit results are hard to interpret to understand how the increasing percentage of foreign ownership, relative to national ownership, affects R&D activities. In order to deal with this issue, I ran ordered logit (proportional odds) estimations with the same explanatory variables but on the ordered grouping of the dependent variables into six groups.[17] The first group of each dependent variable contains those establishments for which the dependent variable is zero; the next five groups are the quintiles ranging from the smallest to the largest. Table 5.6 contains the results for only the first model, which includes all establishments, and for only the first 3 of the 13 R&D activity measures.[18] According to the comparison of the odds ratios, although foreign ownership is positively and significantly associated with the R&D activity variables, this association becomes progressively weaker in terms

17. Since ordered logit, which is not yet available as a panel-data estimator, is normally applied to cross-section data, its application to my study is open to question. However, I can defend the use of ordered logit with panel data by accounting for the clustering of the observations on establishments—i.e., specifying that observations are independent across establishments but not necessarily within clusters of establishments.

18. The complete ordered logit results, omitted due to space restrictions, are available from the author upon request.

Table 5.5 Random-effects tobit results for R&D salary intensity (total R&D FTE compensation to total employment compensation)

Variable	Model (1): All establishments	Model (2): National establishments	Model (3): Foreign establishments
Constant	–2.58662e–01 (22.21)**	–2.86576e–01 (17.41)**	–7.6635e–02 (7.49)**
Foreign ownership group 2 (1–20 percent)	9.67897e–02 (7.52)**	n.a.	n.a.
Foreign ownership group 3 (21–40 percent)	1.00096e–01 (6.27)**	n.a.	n.a.
Foreign ownership group 4 (41–60 percent)	9.25064e–02 (8.87)**	n.a.	n.a.
Foreign ownership group 5 (61–80 percent)	1.05639e–01 (5.96)**	n.a.	n.a.
Foreign ownership group 6 (81–100 percent)	4.75605e–02 (4.14)**	n.a.	n.a.
Foreign ownership share group 2 (21–40 percent)	n.a.	n.a.	–5.66511e–03 (0.70)
Foreign ownership share group 3 (41–60 percent)	n.a.	n.a.	–2.26059e–02 (2.63)**
Foreign ownership share group 4 (61–80 percent)	n.a.	n.a.	–1.90467e–02 (1.86)
Foreign ownership share group 5 (81–100 percent)	n.a.	n.a.	–6.03924e–02 (6.55)**
Employment-weighted sector FDI share	1.03392e–03 (4.24)**	8.66017e–04 (2.32)*	9.44466e–04 (3.24)**
Total revenue	1.51032e–08 (11.42)**	1.75203e–08 (11.23)**	1.03965e–08 (10.58)**
Observations	30,573	29,654	919
Groups	12,871	12,568	376
Wald chi^2	465.28	285.45	226.08
Prob > chi^2	0.0000	0.0000	0.0000
Log likelihood	–159.89006	–225.37648	95.780304
Rho	.8287291	.8441411	.8778222
Likelihood-ratio test of rho = 0: $chibar^2$ (01)	1238.27	1016.07	244.69
Prob ≥ $chibar^2$	0.000	0.000	0.000

$chibar^2$ = The likelihood ratio test statistic of rho.
FTE = full-time equivalent
n.a. = not applicable
Wald chi^2 = The Wald hypothesis test statistic for the model.

Notes: The absolute value of z statistics is in parentheses (* = significance at 5 percent; ** = significance at 1 percent). The cells for the other explanatory variables are omitted due to space restrictions. Rho is the proportion of the total variance contributed by the panel-level variance component. If rho equals zero, then the panel estimator and the pooled estimator are not different. The likelihood-ratio test compares the panel estimator with the pooled estimator through the null hypothesis that they are not different.

Table 5.6 Ordered logit results

Variable	Total R&D expenditure to total revenue ratio	R&D employment to total employment ratio	R&D total salary to total employment compensation ratio
Foreign ownership group 2 (1–20 percent)	12.25886 (5.99)**	11.93809 (5.74)**	12.12679 (5.79)**
Foreign ownership group 3 (21–40 percent)	10.77301 (3.97)**	11.25853 (4.38)**	11.07071 (4.29)**
Foreign ownership group 4 (41–60 percent)	7.90234 (4.58)**	7.421534 (4.16)**	7.305323 (4.26)**
Foreign ownership group 5 (61–80 percent)	6.339716 (2.91)**	5.952683 (2.69)**	5.433879 (2.50)*
Foreign ownership group 6 (81–100 percent)	3.971396 (2.98)**	4.093725 (3.11)**	4.040593 (3.12)**
Employment-weighted sector FDI share	1.033751 (3.76)**	1.03197 (3.56)**	1.031915 (3.58)**
Observations	30,573	30,573	30,573
Wald chi^2	349.42	364.50	374.39
Prob > chi^2	0.0000	0.0000	0.0000
Log pseudo-likelihood	–2,495.9931	–2,501.8354	–2,500.5778
Pseudo R^2	0.1546	0.1527	0.1531

$chibar^2$ = The likelihood ratio test statistic of rho.
Wald chi^2 = The Wald hypothesis test statistic for the model.

Notes: In each cell, the first entry is the odds ratio, and the second entry, in parentheses, is the absolute value of the z statistics (* = significance at 5 percent; ** = significance at 1 percent). The cells for the other explanatory variables are omitted due to space restrictions. The robust (Huber/White/sandwich variance estimator–based) standard errors are adjusted for clustering on establishment, specifying that the observations are independent across clusters (establishments) but not necessarily within clusters.

of decreasing odds ratios as the percentage of foreign ownership increases. Sectoral FDI concentration is positively and significantly associated with all the R&D activity variables, but this association is weaker than the association for foreign ownership. In other words, the direct effect of foreign ownership is relatively much more important than its indirect effect. In summary, the ordered logit results regarding the direct and indirect association between foreign ownership and R&D activities confirm those from the random-effects tobit regressions.

Summary and Conclusions

The FDI literature suggests that R&D activities of foreign firms may help strengthen host country capability for R&D directly or indirectly by stimulating the R&D activities of national firms. In this study, I investigated the R&D activities of Turkish manufacturing establishments, using panel data

for 1993–95 from two different sources of the Turkish State Institute of Statistics. I bridged these two sources of data through common establishment codes to shed light on the presence, types, and levels of R&D activities, focusing on the differences between nationally owned and foreign-owned establishments and on spillover effects from foreign to national establishments. In doing so, I controlled for establishment characteristics such as private versus public ownership, size, vertical (backward) integration, and regional location as well as for sector characteristics such as international competitiveness and industrial concentration.

My three basic conclusions about the association between foreign ownership and R&D activities (the presence of aggregate R&D activity and the 13 R&D activity measures):

- Among all (national and foreign) establishments, foreign ownership is, on the whole, positively and significantly associated with R&D activities. This association does not become stronger, however, with increasing percentage of foreign ownership. On the contrary, it becomes weaker. The association is relatively strongest for the two lowest foreign ownership percentage groups (1 to 20 percent and 21 to 40 percent)—i.e., for minority foreign ownership.
- Among only foreign establishments, however, the rising percentage of foreign ownership is, on the whole, negatively although not often significantly associated with R&D activities. This negative association is most often significant for establishments with the highest foreign ownership percentage (81 to 100 percent). In other words, foreign establishments close to or with wholly foreign ownership seem to have markedly lower R&D propensity relative to other foreign establishments.
- Sectoral FDI concentration is positively and significantly associated with R&D activities among all or only national establishments. Among all establishments, this indirect effect of foreign ownership is relatively weaker, however, than its direct effect, measured in terms of an establishment's foreign ownership percentage. Among only national establishments, this indirect effect, although not always statistically significant, represents a spillover effect from foreign establishments to national establishments. Among only foreign establishments, this indirect effect is also positive but not always statistically significant.

In summary, my empirical results strongly support the positive role of FDI in the Turkish manufacturing-sector R&D activities but indicate that this positive role is stronger in establishments with minority foreign ownership than those with majority or full foreign ownership. My results also support the indirect role of FDI in terms of the positive spillover effect of foreign ownership on R&D activities of national establishments. In future research, these results should be extended with additional Turkish data,

covering more years and more establishment characteristics. They should also be extended to other developing countries with the use of comparable data and techniques to discover whether the Turkish case is generalizable.

My results suggest that just as the internationalization of R&D has become increasingly important among developed countries, developing countries, too, can benefit from R&D internationalization through inward FDI. R&D activities of foreign firms can serve as a crucial channel for not only the transfer of technology but also the ability to absorb and even create technology. These specific empirical results need to be carefully interpreted and their policy implications properly considered. Even if a foreign establishment, especially a majority- or wholly owned one, does not conduct much R&D, it could have access to its parent's R&D and could use the parent's best technology.[19] Therefore, we cannot conclude that the lower R&D propensity of majority- or wholly owned foreign establishments necessarily implies their technological laggardness. The inverse association between percentage of foreign ownership and R&D propensity could indicate the reluctance of foreign parents to share their R&D activities and best technologies with national partners, in the absence of effective control and especially in the absence of effective intellectual property protection. This could induce minority-owned foreign establishments to perform more R&D to compensate for that reluctance. Accordingly, the proper policy implication for host country governments is not to insist on minority foreign ownership by imposing performance requirements in order to promote local R&D, but to provide the environment and the infrastructure, including the protection of intellectual property rights, that are most conducive to R&D activities of both foreign and national firms.

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19. As Theodore H. Moran commented, export-oriented versus domestic market–oriented foreign establishments can differ in their R&D activities. Export-oriented establishments can utilize their foreign parents' best technology without requiring much R&D, whereas domestic market–oriented establishments might need extensive R&D to customize their parents' products and processes to local market conditions. Unfortunately, I could not investigate this possibility due to lack of establishment-specific international trade data.

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