The Influence of Industry-Level Concentration, Exporting and Foreign Ownership on Plant-Level Innovation: Evidence from Taiwanese Electronics

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Abstract

This paper examines the influence of three industry-level characteristics, producer concentration, exporting, and foreign ownership, on plant-level innovation in Taiwan's electronics industries. Electronics plants are particularly important in Taiwan, accounting for particularly large portions of the exports and innovation and this case is thus of interest to many analysts and policy makers. After controlling for numerous plant-level factors affecting innovation, the results provide evidence of an inverted-U relationship between concentration and innovation, with concentration leading to higher innovation propensities in plants when concentration is low and lower innovation when concentration is high. These results also reveal evidence that plant-level innovation propensities tended to be relatively high in industries where export propensities and MNC presence were high, with the influence of exporting being somewhat larger than that of MNC presence. However, both of these relationships were much stronger in 2002-2003 than earlier years, and the relationship to MNC presence was most likely insignificant in 1998-1999.

JEL Classification: F14, F23, L11,L63, O32

Keywords: Innovation, Producer concentration, Export, Foreign Ownership, Taiwan Electronics

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1. Introduction

In Taiwan, the electronics industries, defined broadly as a group of machinery plants or firms making electronics-intensive products such as semiconductors, computers and related equipment or parts, communications equipment, radios, televisions, electric appliances, photographic equipment, precision machinery, and medical equipment, is extremely important. The electronics industry is a particularly important source of innovative activity in Taiwan, which has become an important center for innovative activities, including research and development (R&D) and technology acquisition.[1] Relatively small firms are also thought to play an important role in the Taiwanese electronics industry, (and manufacturing in general), which are often thought to be highly competitive (Aw and Batra 1998).

These characteristics make Taiwan's electronics industries a particularly interesting case in which to examine the relationship between producer concentration and innovation. On the one hand, the Schumpeterian hypothesis and the important role many large firms or plants have played as a source of innovative activity in the post-World-War II era suggest that innovation has often been relatively large in industries where producer concentration is relatively high. On the other hand, Aghion et al (2005, p. 701) summarize the relevant literature by saying "theories of industrial organization typically predict that innovation should decline with competition while empirical work finds that it increases". The first purpose of this paper is to examine the evidence on the point for a large sample of Taiwanese electronics plants during 1998-2000 and 2002-2003.

The electronics industry is also a very large source of exports and an important host to

[1] According to National Science Council (various years) and World Bank (2008), Taiwan's R&D expenditures and the ratio of these expenditures to GDP were among the highest (top 10-15) in the world in recent years. The former source estimated Taiwan's total R&D expenditures at NT$243 billion in 2003, of which NT$153 originated in business enterprises and NT$135 came from manufacturing. Published data from surveys by the Ministry of Economic Affairs (various years a) indicate that R&D expenditures of manufacturing plants were NT$179 billion in the same year, of which NT$141 billion was spent by electronics plants. Manufacturing plants also spent NT$55 billion on acquisitions of technology, of which NT$41 billion came from electronics plants.

foreign-owned multinational corporations (MNCs) in Taiwan.[2] Exporting is an important way in which firms or plants are exposed to greater international competition and this is often thought encourage innovative activity in economies such as Taiwan, where innovation is an important source of competitiveness (Aw et al., 2007). Similarly, greater MNC presence is another source of competitive pressure that can lead to greater innovation, both because MNCs themselves tend to be relatively technology intensive, and because greater MNC presence can also increase competitive pressure that leads local firms or plants to increase innovative effort (i.e., MNC presence can create spillovers). It is also important to recognize that spillover effects can be negative if MNCs end up forcing the exit of local innovators or reducing their motives for innovation. These data sets do not contain information allowing one to examine the related question of whether exporting or MNC plants themselves engage greater innovative effort than local plants, but available data can facilitate examining the second major question addressed by this paper, that is whether the extent of industry-level exports and MNC presence affects innovation at the plant level.

In short, the paper examines three potentially important industry-level influences (concentration, exporting, and MNC presence) on plant-level innovation in Taiwanese electronics. Before examining these relationships, Section 2 first provides a brief literature review and Section 3 presents a summary of related industry-level characteristics in Taiwanese electronics. Section 4 then presents the econometric evidence compiled and the final section (5) concludes.

[2] For example, the share of electronics-related commodities (SITC revision 2, categories 75, 76, 77, 87, 88) in total exports increased from 41 percent in 1997 to 50 percent in 2000, before falling slightly to 49 percent in 2001-2003 (Taiwan Economic Data Center 2007). Electronics firms also accounted for a large portion of product sales by MNC affiliates in Taiwan, though official surveys by Ministry of Economic Affairs (various years c) indicate these shares fluctuated in a wide range, 26-36 percent in 1997-2000, 6 percent in 2001, and 43-55 percent in 2002-2003. A large portion of these fluctuations appear to be the result of changing survey coverage over time, however. For example, corresponding shares were less volatile for Japanese MNCs (20-27 percent in 1997-2003; Kishimoto 2007, Table 6.7), which constitute the largest nationality group of MNCs in Taiwan.

2. Literature Review

There are two rather distinct strands of the literature relevant to this paper. On the one hand, many previous studies of the determinants of innovative activity examine the Schumpeterian hypothesis, or the effects of concentration on innovation. On the other hand, the literature on MNCs and exporters often emphasize how these firms or plants tend to be more innovation or R&D intensive than others.

2a. Competition and Innovation

The Schumpeterian hypothesis that innovation tends to be relatively large in industries with relatively low levels of competition has spawned a number of studies that form the core of the economic literature examining how innovative effort varies across firms or industries. As highlighted in several previous reviews, the empirical findings of this literature are varied, but many studies tend to find evidence contrary to the Schumpeterian hypothesis.[3] One recent example analyzes the relationship between various measures of competition and R&D in Swedish firms (Gustavsson and Poldahl 2003), finding that greater competition is likely to lead to lower R&D expenditures at the firm level. However, they do not find strong evidence of the expected large-firm advantage in R&D through scale effects. Similarly, Rogers (2002) generally finds a negative relationship between concentration and R&D intensity in a sample of large Australian firms for 1994 and 1997. In contrast, a survey of the older literature on the relationship by Cohen and Levin (1989, p. 1075) observes that the most studies have tended to find a positive relationship between concentration and innovation, while acknowledging that some studies find a negative relationship. A recent Asian example is Lee and Hwang (2003), who find a negative relationship for non-IT manufacturing in Korea, but no significant relationship for IT manufacturing.

[3] For surveys of this literature, see, for example, Aghion et al (2005), Cohen (1995), Cohen and Levin (1989), Geroski (1995), and Symeonidis (1996).

Surveys by Cohen and Levin (1989) and Cohen (1995) also highlight how the relationship between concentration and innovation may depend on industry characteristics such as degree of product differentiation or unobserved inter-firm and inter-industry heterogeneity, which can be captured by fixed effects' estimation. Although they do not estimate determinants of innovation directly, Breschi et al. (2000) make another potentially important distinction between industries in which innovations are generally introduced by firms that did not previously innovate (i.e., industries dominated by creative destruction or the Schumpeter Mark I pattern) and industries in which innovations are generally introduced by firms that innovated previously (i.e., industries dominated by creative accumulation or the Schumpeter Mark II) pattern).

Another line of research argues that the relationship between innovation and concentration is non-linear and several studies find an inverted-U relationship, where concentration is positively correlated with innovation in industries with relatively low concentration and negatively correlated in industries with relatively high concentration. Aghion et al (2005) find this relationship in a panel of U.K. firms and relate their findings to a theoretical model emphasizing that "innovation incentives depend not so much upon postinnovation rents, …but upon the difference between postinnovation and preinnovation rents of incumbent firms" (p. 702).

For developing economies, Braga and Willmore (1991) find a similar inverted-U for several discrete indicators of innovation (the probability that firms obtain product designs or production engineering from foreign sources, or whether firms have a program of new product development) in Brazilian firms in 1978-1980. However, concentration had no significant effect on whether firms engaged in R&D. On the other hand, Lundin et al. (2007) find some weak evidence of the opposite, non-linear relationship in Chinese manufacturing in 1998-2004; namely R&D is negatively related to the price-cost margin when price-cost margins are low, but positively related when these margins are high. However, this result is not robust.[4]

Lee (2005) also fails to find strong evidence of the inverted-U in alternative samples of Korean manufacturing industries in 1983 and concludes that “market concentration is favorable to industry R&D intensity when the link between firm R&D intensity and market share is weaker, supplementing the weak incentives for R&D due to the low appropriability of R&D (in terms of market share)” (p. 118). Meanwhile, results for a sample of Malaysian manufacturers (Lee 2008) indicate little significant relationship between concentration on the one hand, and engaging in R&D or the level of R&D expenditures, on the other. Studies of Indian firms (Subodh 2002), U.S. firms (Levin et al. 1985) and U.K. firms (Love and Roper 1999) are qualitatively similar, finding that concentration does not exert a significant impact on R&D intensity and/or the rate of innovation.

2b. Exporting, MNC Presence, and Innovation

Most studies examining the relationship between exporting and innovation suggest that exporters tend to have higher innovation propensities or a greater probability of being innovators than non-exporters. This link is emphasized in one of the few previous studies estimating R&D determinants in Taiwan (Aw et al., 2007), which finds that the probability that firms engaged in R&D and worker training efforts (R&D/WT) in 1986, 1991, and 1996 was positively correlated with previous experience in both exporting and R&D/WT, but not with previous experience in only exporting or only R&D/WT. Meanwhile, Gustavsson and Poldahl (2003) find that exporting was positively related to R&D by Swedish firms. Braga and Willmore (1991) provide similar evidence that exporting firms had a greater probability of engaging in several innovative activities (R&D, product development, using foreign

[4] The relationship is significant when using GMM estimators for high tech firms, but not significant at standard levels OLS estimators are used. Note that the price-cost margin is interpreted as a measure of market power, but it might also be interpreted as a measure of profitability.

sources for product engineering and design) than non-exporters in Brazilian manufacturing. Recent (2002-2004) evidence for Malaysian manufacturing is somewhat weaker, indicating that exporting is positively related to the probability a firm engages in R&D, but not strongly correlated with the level of R&D propensities (Lee 2008). On the other hand, a study of slightly older data (2000-2001) found a significantly negative relationship between exporting status and the probability of innovating in a firm (Lee 2004). Lall (1983) also found evidence that exporting status negatively influenced R&D in a sample of the 100 largest engineering firms in India.

Evidence that affiliates of foreign MNCs are more innovative in host countries is weaker and more mixed than evidence regarding the influence of exporting status. Braga and Willmore (1991) suggest the probability that a firm engages in R&D is not significantly related to foreign ownership but that foreign firms do have a relatively high probability of using foreign sources for product design and production engineering more, and engaging in product development. Lall (1983) found that R&D was positively correlated with foreign ownership in Indian engineering firms. On the other hand, Lee (2004) found that the probability of innovation in Malaysian manufacturing was not related to foreign ownership but was higher in public limited and private limited companies than in others. For Chinese manufacturing, Lundin et al. (2007) find that private firms and two classes of foreign joint ventures tended to have relatively low R&D intensities, though these results were not always consistent. For Australian firms, Rogers (2002) finds that trade protection also has a negative influence on R&D for manufacturing firms, while firms (MNC parents) with operations in North American (manufacturing only) and European (manufacturing and non-manufacturing combined) markets were found to have relatively high R&D intensities. On the other hand, Australian affiliates of foreign MNCs were not found to have significantly higher R&D propensities. There are no known studies of related relationships for Taiwan, though several studies indicated that MNCs have played an important role in the development of Taiwan's electronics industries over the years (Aw 2006).

It should be noted that all of the studies reviewed above examine these relationships at the firm- or plant-level, asking whether an exporting firm or an MNC is more or less likely to innovate. In this paper we ask a related, but different question, are plants in industries with high exports or large MNC presence more or less likely to innovate than others? To our knowledge no previous studies addresses this question directly, but its analysis is qualitatively similar to analyses of spillovers, which examine how industry characteristics (e.g., MNC presence) affect firm or plant-level characteristics such as productivity or wage levels (Lipsey and Sjöholm, 2005).

2c. Other Determinants of Innovation

Firm size is another factor often thought to affect a firm's propensity to innovate. For example, Acs and Audretsch (1987) find that large firms tend to have relatively large innovation propensities in industries that are concentrated, capital intensive, highly unionized, and produce differentiated goods. On the other hand, they find that small firms have relatively large innovation propensities in industries which are relatively innovative, skilled-labor intensive, and have a relatively large share of large firms. Evidence from Rogers (2002) also suggests that more focused firms then to have higher R&D propensities, but that firm size was negatively related to R&D propensities for smaller firms and positively related for large firms.[5] More generally, Cohen and Levin (1989) survey a considerable body of literature on the relationship between firm size and innovation, concluding that the "most notable feature" of this research is its "inconclusiveness" (p. 1069). In studies of developing economies, Braga and Willmore (1991), Lall (1983) and (Subodh 2002), Lee and Hwang (2003), and Lee (2004,

[5] These results were stronger for samples manufacturers than samples of both manufacturers and non-manufacturers.

2008) also find positive relationships between size and innovation for firms in Brazil, India, Korea, and Malaysia, respectively, while Lundin et al (2007) found that the relationship was generally negative in Chinese firms.[6]

Numerous other determinants of innovation have also been examined. In their study of Chinese firms, Lundin et al (2007) find that lagged R&D intensity and skill intensity were often positively related to current R&D intensity. Lall's (1983) study of Indian firms finds that R&D was significantly and positively correlated with the share of wages paid to high-level managerial and technical staff and more weakly, positively correlated with technology licensing or royalty payments and with firm age. For Brazilian firms, Braga and Willmore (1991) find that both product development and R&D were positively and significantly related to the degree of product diversification and to whether the firm imports technology. They also find that profitability did not significantly affect product development and R&D, but was negatively and significantly related to the use of foreign sources for product design and production engineering. On the other hand, evidence for Australia (Rogers 2002) suggests that focused firms, not diversified ones, tended to have higher R&D intensities. In their study of Taiwanese firms, Aw et al. (2007) find that the probability a firm engaged in R&D/WT was significantly larger for new entrants and firms with relatively large capital stocks. Gustavsson and Poldahl (2003) find a positive relationship between a Swedish firm's R&D propensity and the R&D propensities of other firms in an industry, which they interpret as evidence of spillovers.

3. Patterns of Innovation, Concentration, Exporting and MNC Presence

Electronics firms and plants accounted for the vast majority of innovation expenditures, defined as the sum of expenditures on R&D and technology acquisitions, in Taiwanese

[6] Crepon et al. (1998) also find the probability of undertaking R&D increases for French firms when a probit estimator is used but is not significantly related when a tobit estimator is employed. They also find unambiguous positive correlations with market shares and product diversification.

manufacturing during recent years.[7] Moreover, the shares of electronics in the manufacturing total increased substantially in 1997-2003, from 67 percent to 78 percent (Table 1).[8] These time series come from the authors' compilation of plant-level data from surveys of about 76,000 to 83,000 plants in 1997-2000 and 2002-2003.[9] Electronics' shares from a 2001 census of over 140,000 firms that owned over 147,000 plants (Directorate-General of Budget, Accounting and Statistics 2003) were identical to those from the 2000 plant survey (73 percent), and lower than in the 2002 plant survey (78 percent). The electronics share of firm innovation in 2001 is thus slightly below that suggested by the trend of plant-level shares, perhaps reflecting the fact that some innovating electronics plants were owned by multi-plant firms classified in other industries.[10]

Although the census coverage of firm or plant numbers was much more comprehensive than survey coverage, there appears to be relatively little difference in the coverage of revenues or innovation expenditures (Table 1). Correspondingly, innovation propensities (innovation expenditures as a percentage of revenues) from the 2001 firm-level census data fall in between the 2000 and 2002 propensities from the plant-level surveys. Innovation propensities were also much larger in electronics (2.9-4.0 percent) than in manufacturing overall (1.6-2.1 percent). Thus, these data all suggest relatively consistent increases in innovation and revenues during the period examined, with innovation growing relatively rapidly. Relatively large plants or firms with 20 or more employees accounted for the vast majority of electronics' innovation (99 percent) and revenues (95-97 percent), despite accounting for much smaller shares of plant (28-29 percent) or firm numbers (26 percent).[11]

[7] Note that most technology acquisitions are from abroad, but some are also local purchases in Taiwan.
[8] These shares are the same regardless of whether one uses the largest possible sample of 248 manufacturing industries or a more consistently covered subset of 234 industries. We focus on the smaller, more consistently defined group of 234 industries in this paper.
[9] See Ministry of Economic Affairs (various years a) for published compilations of these data.
[10] The divergence might also be related to the 2001 recession, but electronics-related manufacturing actually contracted less than overall manufacturing in that year (-4.8 percent versus -7.4 percent, Directorate-General of Budget, Accounting and Statistics 2009)
[11] Compilations of plant and firm numbers come from the sources of Table 1.

In other words, small plants with 19 or fewer employees are of little consequence to analyses of innovation expenditures. They are excluded from the statistical analysis, partially for this reason, and partially because their inclusion introduces a substantial number of outlier observations (see Section 4 below for more details).

Among electronics plants with 20 or more employees, semiconductor plants had by far the largest innovation expenditures, accounting for 37-38 percent of the electronics subtotal in both 1998-1999 and 2002-2003 (Table 2). Among the 35 electronics industries, innovation propensities were also highest in semiconductors for the later period (6.7 percent) and third highest in the earlier period (7.6 percent). Innovation propensities were also high for both periods (ranked among the top 11 of the 35 industries; values of 2.9 or 3.5 percent or higher in the two periods, respectively) in another eight industries, computer peripheral equipment, wired communication equipment, telecommunication equipment, data storage equipment, electronic tubes, photonic materials, photographic equipment, and other photographic and optical equipment. However, in addition to semiconductors, only computer peripheral equipment ranked highly in terms of both propensities and expenditure. Moreover, among the top industries, changes in the rankings of expenditures were relatively large between the two periods as only three other industries (computers, computer terminal equipment, and computer components) consistently ranked highly. In other words, variation of technology intensity across the top industries did not change as much as the ranking of expenditure. In addition, although there was also a fairly wide variation in innovation propensities across electronics industries, very few electronics industries had propensities which were below the means for all manufacturing, indicating that most of the 35 electronics industries were more technology intensive than the manufacturing mean. Moreover, innovation propensities increased in about two-thirds (22) of the electronics industries, despite a relatively small increase in the mean propensity for these industries.

Table 2 also shows innovation propensities for the four largest plants in each industry because the share of these plants in industry revenue (i.e., the 4-plant concentration ratio or CR4) is an often-used measure of producer concentration. CR4 plants did have relatively high mean innovation propensities, but differences between propensities for CR4 plants and for all plants were not very large (3.0 versus 2.8 percent in 1998-1999 and 3.1 percent versus 3.0 percent in 2002-2003). Moreover, innovation propensities were higher for CR4 plants than for all plants in only 16 of the 35 industries in 1998-1999 and in 19 of 34 industries in 2002-2003. Thus, these data provide little evidence that CR4 plants are themselves more innovation intensive than the average.

Table 3 then suggests that there was little overall change in producer concentration during this period. Mean CR4s were unchanged in samples 234 manufacturing industries (at 43 percent) and in the 35 electronics industries (at 39 percent) for both periods. Similarly, a roughly equal number of electronics industries experienced increases (18) and decreases (17) in CR4. There were a number of industries experiencing rather large changes in concentration (more than 10 percentage points in absolute value), but here again the number of large increases exactly equaled the number of large decreases (6 each). Not surprisingly, if CR4 is calculated from the firm-level data from the 2001 census data, it tended to be somewhat higher for most electronics industries. This difference suggests that multi-plant firms are common in electronics and is consistent with the observation that they tend to be disproportionately represented among the largest firms in Taiwan (China Credit Information Service, various years). This contrasts with the pattern observed for the 234 manufacturing industries combined, where mean CR4 is the same in both the plant- and the firm-level data.

Among the nine industries with consistently high innovation propensities, only three (electronic tubes, photographic equipment, and other photographic equipment) had similarly and consistently high ranks for producer concentration (Tables 2, 3). A fourth industry (photonic materials) was highly concentrated in 1998-1999 and almost so (ranked 12) in 2002-2003. A fifth (data storage equipment) was highly concentrated in the early period but not the later one. On the other hand, none of the nine industries was consistently ranked lowly (25 or lower) in terms of concentration, though two industries (computer peripherals, data storage equipment) were lowly concentrated in the later period but not the earlier one. Thus, among the top innovating industries, there appears to be a moderately strong, positive correlation between innovation and concentration. Calculations of simple correlation coefficients (0.34-0.37) suggest a similar pattern for the overall sample of 35 industries.

Unfortunately, the annual surveys of manufacturing plants do not contain information on exporting or MNC presence, but it is possible to get this information from the firm-level information in the quinquennial firm censuses. Not surprisingly, these data show that export propensities (ratios of foreign sales to the sum of foreign and domestic sales) were large in Taiwan's electronics industries, with the mean export propensity rising from 47 percent in 1996 to 52 percent in 2001 (Table 3).[12] Export propensities fell in more electronics industries than in which they rose (19 vs. 16), but the mean rose because relatively large increases (10 percentage points or more) outnumbered similarly large decreases (12 vs. 8). Like innovation propensities (Table 2), mean export propensities for electronics industries were substantially higher than in overall manufacturing. Export propensities were consistently high (among the top 11) in three industries with highly ranked innovation propensities (computer peripherals, telecommunication equipment, data storage equipment). A similar pattern was also observed for one period and almost in another (export propensity rank of 13 or 14) in three more

[12] Propensities for the 35 electronics industries are substantially higher than the mean ratios in Table 3 (56 percent in 1996 and 65 percent in 2001) if calculated as the ratio of foreign sales for electronics to the sum of domestic and foreign sales in published data (Directorate-General of Budget Accounting and Statistics 1998, 2003). This reflects the concentration of large exports in relatively few industries and the existence of several industries with relatively low propensities. Calculations of the ratio of electronics exports from merchandise trade data (Taiwan Economic Data Center 2007) to total electronics output reported in the national accounts (Directorate-General of Budget Accounting and Statistics 2009) suggest even higher propensities, 65 percent in 1996 and 72 percent in 2001. However, all sources are consistent in suggesting relatively high export propensities in electronics, and a similar upward trend in export propensities during this period.

industries (semiconductors, electronic tubes, and photographic equipment). The remaining three industries with consistently high innovation propensities (wired communication equipment, photonic materials, and other photographic and optical equipment) also had high export propensities in at least one of the two periods. Thus, consistent with the findings of previous research (Aw and Batra 1998; Aw et al 2007), there appears to be a relatively strong, positive correlation between innovation and exporting among the top innovating industries. However, if simple correlation coefficients are calculated for all 35 electronics industries, the correlations (0.35-0.37) were no stronger than those between concentration and innovation.

Majority-foreign-owned MNCs accounted for much smaller shares of revenues than exports did and the mean share of these MNCs in the electronics industries fell from 15 percent in 1996 to 9 percent in 2001. Estimates of MNC shares must be calculated from a small subsample (about 10%) of census firms and may therefore be less accurate than estimates of export propensities, for example, which can be calculated for all firms in the census. However, data from China Credit Information Service (various years) also suggest that 69 (1996) or 70 (2001) large, majority-foreign MNCs accounted for similar shares of electronics firm sales, 17 percent in 1996 and 12 percent in 2001.[13] In short, locally-controlled firms grew more rapidly than majority-foreign MNCs during this period. Similarly, MNC shares fell in many more of the electronics industries than in which they rose (22 versus 11). Among the nine industries with consistently high innovation propensities, MNC shares were also consistently high (ranked 10 of 32 or higher in 1996 and 11 of 35 or higher in 2001) in two (photographic equipment and watches and clocks) and high for one period in two more (telecommunication equipment and electronic tubes). MNC shares were also consistently low in data storage equipment and low for one period in two more industries (computer peripherals and other photographic and optical equipment). Similarly, correlations

[13] As above, total electronics sales are estimated as the sum foreign and domestic sales reported in the censuses for these years Alternative estimates of MNC sales are also available from Ministry of Economic Affairs (various years c), but they are not limited to majority-owned affiliates and fluctuate greatly as noted above.

of innovation propensities to MNC shares were relatively low (0.12-0.27) compared with correlations to concentration or exporting, though this correlation did strengthen over time.

4. Econometric Evidence

The simple descriptive statistics in the previous section and more sophisticated evidence from previous studies both suggest that a positive relationship between innovation and exporting exists in Taiwan's electronics industries. The descriptive statistics also suggest innovation has a positive relationship to concentration but that the relationship to MNC presence was weaker, especially in the late 1990s. However, the precise nature of the relationships involved cannot be understood from descriptive statistics alone. This section thus attempts to model the relationships among plant-level innovation propensities, on the one hand, and industry-level concentration, exporting, and MNC presence, on the other.

The model first attempts to control for a number of plant-level characteristics that might affect innovative activity. The first plant-level control is the likelihood of persistence in innovative activity and the innovation propensity of a plant. Thus, innovation propensities in year t are posited to depend on whether the plant had innovative activity in the previous year. The second plant-level control is plant size, measured as the log of plant employment in the previous year. Similarly, the possibility that plant growth may affect innovative activity is allowed for by including the growth rate of plant employment between year t-1 and year t. Generally, larger and more rapidly growing plants are expected to have higher innovation propensities, though the previous evidence on this point is mixed as mentioned above. Profitability is another potential determinant about with the previous evidence is not very consistent and potential effects varied.[14] Plant vintage is also thought to be another potential

[14] For example, higher profitability increases available funds and might thus encourage innovation expenditures but high profitability might also reduce pressure on the plant to innovate and reduce expenditures.

influence on innovation, though the influence of this factor is also unclear *a priori*.[15] This factor is considered in two ways, first as a simple measure of plant age in years, and second as a dummy variable distinguishing very young plants (4 years or less in operation).

To these plant-level controls, measures of industry-level concentration, exporting, and MNC presence are added. Concentration is measured as the 4-plant concentration ratio and enters in quadratic form in order to allow for the possibility of the inverted-U found in several previous studies. The resulting equation is:

$$(1) \quad INN_{ijt}=a0+a1(DINN_{ijt-1})+a2(\ln(EMP_{ijt-1}))+a3(EMG_{ijt})+a4(PRF_{ijt})+a5(AGE_{ijt})+a6(DNW_{ijt}) +a7(CR4_{jt-1})+a8(CR4_{jt-1}^{2})+a9(EXP_{j96,01})+a10(MNC_{j96,01})$$

where
AGE_{ijt}=the age of plant i of industry j in year t (years),
$CR4_{jt-1}$=the four-plant concentration ratio in industry j for year t-1,
$DINN_{ijt-1}$=a dummy variable equal to 1 if plant i of industry j had positive R&D in year t-1,
DNW_{ijt}=a dummy variable equal to 1 if the age of plant i of industry j was less than 4 in year t,
EMG_{ijt}=growth rate of employment in plant i of industry j in year t-1 (percent),
$EXP_{j96,01}$=export propensity (foreign sales divided by the sum of foreign and domestic sales) of industry j in 1996 (when year t is 1998, 1999, or 2000) or 2001 (when year t is 2002 or 2003),
$\ln(EMP_{ijt-1})$ =natural log of the number of employees in plant i of industry j in year t-1,
$MNC_{j96,01}$=MNC share of sales in industry j (from subsamples [about 10%] of census firms) in 1996 (when year t is 1998, 1999, or 2000) or 2001 (when year t is 2002 or 2003).
PRF_{ijt}=moving average of operating profit rate from in plant i of industry j in year from year t-1 to year t (sales less operating costs as a percentage of sales).

Equation (1) is estimated using single equation techniques because data constraints make it virtually impossible to specify appropriate instruments for potentially endogenous variables in this context. On the other hand, the use of lagged values for many potentially endogenous, independent variables should minimize simultaneity-related difficulties in the estimates. Because the dependent variable is by definition greater than zero, and in the vast majority of cases less than 100, a tobit estimator is used. The sample data cover 1997-2003 excluding 2001, and estimates are performed for 1998-1999, 2002-2003, and 1998-2003 excluding 2001; 2000 is considered the previous year when observations for 2002 are used.

[15] On the one hand, one might expect that older, more experienced plants may innovate more than others, but on the other, it is also true that many new plants are established with the precise purpose of carrying out innovative activity and may be subject to greater pressure to innovate than older plants.

The high rate of turnover in Taiwan's electronic industries and numerous missing or strange observations create sampling problems that need special attention. For example, in the 5-year sample there were 254 observations reporting innovation propensities in excess of 100 percent. 178 of these plants also had employment of 19 or less and the innovation propensity exceeded 200 percent for 72 of these small plants versus only 28 of the 76 plants with employment above this threshold. Moreover, revenues or output (maximum value used) were only NT$5 million or less for 115 of the 178 small plants, while this was true in only 1 of the 76 larger plants. These small plants were dropped from the sample both because this removed many apparently unrealistic outliers from the samples, and because small plants accounted virtually no innovative activity or revenues in Taiwanese electronics, making them of little relevance here (see Section 3 above). Limiting samples to plants with 20 or more employees also had the benefit of removing many records affect by missing observations, but there were still a number of additional records with missing observations, which also had to be dropped.

High rates of plant entry and exit from these datasets were by far the most important factors that reduced the sizes of regression samples far below the number of plants for which descriptive statistics were analyzed in the previous section. Table 4 provides a simple example showing that, even if one limits the sample to relatively large plants with 20 or more employees, new entrants between 1999 and 2003 accounted for over two-fifths of both total innovation and total revenues of electronics plants in 2003. Likewise plants exiting the sample in 1999 or thereafter accounted for 30 percent of innovation expenditures in electronics and a 34 percent of sales in 1998. Both entry and exit rates were higher in electronics than in other manufacturing industries, again highlighting the dynamic nature of these industries. Because the data come from sample surveys, some of new entrants were plants omitted in 1998 but included in the sample after that year, while some of the exiting plants did not close down but were dropped from the survey sample. However, the vast majority of entering plants did report initiating operations in 1999 or later.[16]

In other words, although there are important advantages to be gained from using balanced panels with data such as these, the high rate of turnover means that the creation of a balanced panel spanning 1998-2003 forces the researcher to pay an extremely high price in terms of the reduction in sample coverage. Moreover, the 2001 recession was an important event that led to large restructuring among many of Taiwan's electronics industries and plants, and perhaps to important changes in the relationships being studied. These two factors suggest that analysis of larger, shorter samples may be more appropriate than a panel analysis for the entire period in this case.

Correspondingly, random effects panel tobit estimates and pooled tobit estimates (with year dummies) are performed for three alternative panels, covering 1998-1999, 2002-2003, and 1998-2003 excluding 2001. In the short panels, the lack of a substantial time dimension means that panel estimates are probably less reliable than the pooled estimates, while it is more meaningful to compare the results of alternative estimation techniques in the long panel.[17] For the reasons discussed above, the long panel contains a much smaller number of observations per year (1516) than the short panels (3016 for 1998-1999 and 2802 for 2002-2003). Primarily because of high entry and exit rates combined with the need to include at least three years of data in each panel (to facilitate use of lagged variables), all panels contain markedly fewer plants than covered in the descriptive statistics (Tables 1, 5). The 1998-1999 and 2002-2003 samples covered 61 and 57 percent, respectively, of the plants with positive employment and revenues or output in these periods, while the 5-year sample covered 31 percent only of the plants operating over the period.

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[16] Plants reporting they started operation in 1999 or later amounted to 87 percent of the number of new entrants and these plants accounted for 88 percent of the revenues and 92 percent of the innovation expenditures by the new entrants summarized in Table 4. Unfortunately there are no data indicating the portion of exiting plants that actually closed down.

[17] The failure to identify a value for the variance of firm-specific effect (sigma-u) is one indication that the short panel estimates may not be reliable compared to the long panel (Table 5, Appendix Tables 2-3).

Despite large differences in sampling, results from the various samples are similar in several important respects, indicating that they may be representative (Table 5). For example, all results suggest that the probability of plants having relatively high innovation propensities was positively and significantly correlated with previous innovative experience and negatively and significantly related to plant age.[18] In the long sample, the result that newer plants were more likely to have innovation propensities was further amplified for very young (4 years or younger) plants, but this result did not obtain in the short samples. Innovation propensities were also negatively and significantly correlated with profitability in all but one of the cases examined (panel estimates for 1998-1999). These results suggest that older and more profitable plants were under less pressure to innovate than others.

Results regarding the relationship of innovation propensities to plant size and growth were less consistent, however. Pooled estimates suggest that the relationship to plant size was significantly positive in all samples, as was the relationship to plant growth in the early, short period. In contrast, panel estimates indicate that the relationship to plant size was significantly negative while the relationship to growth was significantly positive in the two short periods, but that both of these relationships were insignificant in the long period. The contrast between results from the short panels and the alternatives (results from pooled samples or the long panel) is another indication that the estimates in short panels are probably less reliable than the others in Table 5.

Most importantly in this context, results regarding industry-level influences on plant-level innovation are relatively consistent and straightforward. There is clear evidence of an inverted-U relationship between innovation and concentration in five of the six cases examined, panel estimates for 1998-1999 being the sole exception. Thus, innovation and concentration were most likely positively correlated in industries with low concentration and

[18] All tests of coefficient significance use heterscedasticity-consistent standard errors and the standard (5 percent) level of significance (two-tailed tests), unless otherwise specified..

negatively correlated in highly concentrated industries.

Both estimates for the entire period and 2002-2003 reveal a significantly positive relationship between plant-level innovation propensities and export propensities. A similar result was also observed for 1998-1999 in the panel estimates, but not in the pooled estimates which, again, are probably more reliable in the short panels. Regardless of the estimator, the coefficient on the export variable was at least two times larger for 2002-2003 than for 1998-1999 or the entire period, suggesting that industry-level exporting had greater effect on plant-level innovation in the later period.

The relationship between MNC presence and innovation propensities was also significantly positive at standard levels for 2002-2003. Here again coefficients were also larger for later period than the early period or the entire period, indicating that this relationship also strengthened over time. However, coefficients on MNC presence were smaller than those on export propensities, both of which are measured in identical units (percent) and therefore comparable. There were also some indications of weakly significant (at the 10 percent level) and positive (whole sample, pooled estimates) or negative (early period, panel estimates), but it is difficult to attach much meaning to these rather loose correlations. Because there is a possibility that export propensities and MNC presence might be correlated, regressions that omitted one or the other of these variables were tried and the full results are shown in Appendix Tables 1-3. However, correlations between the industry-level variables (shown in Table 3) were not strong (0.14 in 1996 and 0.15 in 2001) and the results in Table 5 were generally consistent with those when one or both of these variables were dropped.

In short, the evidence summarized in this section suggests that innovation propensities were highly correlated with most of the independent variables in this simple model. The most important results in this context were indications of an inverted-U relationship between concentration and innovation throughout the period studied, and positive relationships of plant-level innovation to industry-level export propensities and MNC presence that were especially strong in 2002-2003.

5. Conclusions

This paper began by reviewing the literature on determinants of firm- or plant-level innovation propensities. This review stressed that previous results regarding the relationship between concentration and plant-level innovation have been mixed. However, it also highlighted a number of studies that have found an inverted-U relationship, that is a positive relationship when concentration is low and a negative relationship when concentration is high. Estimation of an econometric model accounting for other firm-level determinants of innovation, revealed evidence generally consistent with the existence of an inverted-U in Taiwanese electronics during 1998-2003.

The literature review also highlighted the fact that many previous studies have generally found a positive relationship between exporting and innovation. Industrial level data also provided evidence that export propensities tended to be relatively high in a number of Taiwan's electronics industries where innovation propensities tended to be large. The results of the econometric model also suggested that plant-level innovation propensities were positively related to industry-level export propensities and MNC presence in 2002-2003, with the relationship to exporting being stronger. Moreover, there were indications that these relationships may not have been significant in 1998-1999 and clear evidence that both relationships became stronger in 2002-2003 than in previous years. This analysis cannot provide direct evidence about the cause of the change, but one might speculate that that the 2001 recession forced plants in industries with large exports and MNC presence to innovate more than in previous years. Increased maturity among many Taiwanese manufacturers, many of which are MNC parents with increasing global reach, may also have been a factor behind increased sensitivity to external competition.

There are of course many shortcomings to this kind of analysis that demand caution when interpreting the results. Unfortunately, it is impossible to do much about the most important shortcomings, the inability to expand samples to be more comprehensive and representative, and the inability to find adequate instruments to account for potential simultaneity. On the other hand, the model has been designed to facilitate use of the largest possible samples and to reduce the potential for simultaneity. It would also be interesting to consider the effects of adding or changing the set of plant-level controls and see if that influences the major results described above.[19] In this regard, we suspect that the major results described above may turn out to be relatively robust to the alternative sets of controls. It would also be informative to compare these results regarding the impact of industry-level exporting and MNC presence on plant-level innovation, with firm-level analysis (e.g., from the Census data for 1996 and 2001) comparing innovation propensities in exporters and MNCs with those in non-exporters and non-MNCs.

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[19] For example, the authors also tried to use capital intensity as a control, but this variable was unavailable in the 2002-2003 surveys so it had to be dropped.

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Table 1: Number of plants or firms, revenues, and innovation by year

Item	Plants (surveys) 1997	1998	1999	2000	2002	2003	Firms (census) 2001
Number of plants or firms							
Manufacturing (248 industries)	81,272	81,908	82,350	81,608	73,952	76,479	140,613
Manufacturing (234 industries)	81,247	81,860	82,285	81,341	73,612	76,270	139,790
Electronics (35 industries)	10,619	10,808	11,014	11,243	10,262	10,516	15,817
Number of plants or firms with innovative activity							
Manufacturing (248 industries)	6,435	6,902	7,184	7,733	6,706	6,242	5,184
Manufacturing (234 industries)	6,432	6,898	7,178	7,720	6,679	6,227	5,177
Electronics (35 industries)	1,901	2,173	2,378	2,635	2,549	2,554	1,676
Number of plants or firms with innovative activity & 20 or more employees							
Manufacturing (248 industries)	4,835	5,170	5,351	5,563	5,044	4,991	3,445
Manufacturing (234 industries)	4,832	5,166	5,345	5,552	5,025	4,979	3,439
Electronics (35 industries)	1,537	1,770	1,957	2,105	2,119	2,183	1,292
Revenue in all plants or firms (NT$ billions)							
Manufacturing (248 industries)	7,799	8,314	9,039	10,295	10,097	11,095	10,500
Manufacturing (234 industries)	7,791	8,304	9,026	10,281	10,064	11,083	10,477
Electronics (35 industries)	2,416	2,812	3,358	4,292	4,251	4,584	4,224
Revenue in plants or firms with 20 or more employees (%)							
Manufacturing (248 industries)	6,978	7,482	8,188	9,389	9,288	10,229	9,461
Manufacturing (234 industries)	6,969	7,473	8,176	9,378	9,259	10,220	9,443
Electronics (35 industries)	2,302	2,687	3,214	4,143	4,117	4,458	4,081
Innovation in all plants or firms (NT$ billions)							
Manufacturing (248 industries)	123	144	161	175	209	232	191
Manufacturing (234 industries)	123	144	161	174	209	232	191
Electronics (35 industries)	81	98	113	127	161	181	139
Innovation in plants or firms with 20 or more employees (%)							
Manufacturing (248 industries)	119	141	158	171	205	229	188
Manufacturing (234 industries)	119	141	158	171	205	229	188
Electronics (35 industries)	80	97	113	125	159	180	138
Innovation propensities in all plants or firms (%)							
Manufacturing (248 industries)	1.6	1.7	1.8	1.7	2.1	2.1	1.8
Manufacturing (234 industries)	1.6	1.7	1.8	1.7	2.1	2.1	1.8
Electronics (35 industries)	3.3	3.5	3.4	2.9	3.8	4.0	3.3
Innovative propensities in plants or firms with 20 or more employees (%)							
Manufacturing (248 industries)	1.7	1.9	1.9	1.8	2.2	2.2	2.0
Manufacturing (234 industries)	1.7	1.9	1.9	1.8	2.2	2.2	2.0
Electronics (35 industries)	3.5	3.6	3.5	3.0	3.9	4.0	3.4

Note: For plants (survey data), revenue is replaced by output for plants or firms in which output exceeds revenue.

Sources: Authors' compilations from Ministry of Economic Affairs (various years b); Directorate-General of Budget, Acccounting and Statistics (various years)

Table 2: Innovation in Plants with 20 or more employees (annual averages)

Industry	NT$ billions		Propensities (% of revenue)			
	All plants		All plants		CR4 plants	
	1998-9	2002-3	1998-9	2002-3	1998-9	2002-3
Manufacturing, 234 industries, means	0.6	0.9	1.1	1.2	1.4	1.4
Electronics, 35 industries, means	3.0	4.8	2.8	3.0	3.0	3.1
Computers	8.6	7.4	2.4	2.3	2.5	3.0
Computer terminal equipment	3.4	5.4	2.6	2.5	2.8	2.5
Computer peripheral equipment	6.1	9.3	2.9	3.5	1.8	2.1
Computer components	5.9	11.6	2.8	2.8	2.0	2.2
Other computer components	1.5	5.6	1.7	3.1	0.9	3.2
Wired communication equipment	4.2	5.3	4.2	5.0	2.4	4.2
Telecommunication equipment	1.1	5.4	4.7	5.7	3.8	5.6
Television sets & video tape recorders	1.8	1.3	2.5	4.1	2.5	1.4
Record player & radio tape recorders	0.7	1.0	1.5	1.9	1.4	2.0
Other video & radio electronics	2.3	1.6	3.0	2.9	2.5	2.0
Data storage equipment	3.8	3.3	4.0	3.8	1.9	3.8
Semiconductors	39.9	63.3	7.6	6.7	5.5	8.5
Electronic passive devices	2.8	4.9	1.7	3.0	1.9	5.8
Bare printed circuit boards	1.8	2.5	1.3	1.2	1.1	1.4
Electronic tubes	7.0	5.0	8.1	5.2	9.4	5.7
Photonics materials & components	1.5	15.3	12.1	4.5	9.5	3.9
Other electronic parts & components	1.9	9.2	2.9	4.1	5.5	6.0
Power generation & related equipment	2.1	2.2	1.7	2.4	1.2	1.9
Electric wires & cables	0.6	0.7	0.6	0.8	0.4	0.2
Air conditioning equipment	1.8	1.9	2.7	2.9	3.0	4.0
Laundering machines & equipment	0.0	0.0	0.0	-	0.0	-
Electric heating appliances	0.2	0.1	2.3	2.1	3.5	3.2
Electric fans	0.2	0.1	1.0	1.2	1.1	2.1
Other electrical appliances & housewares	0.1	0.3	1.4	2.2	2.0	3.7
Light bulbs & tubes	0.0	0.1	0.8	1.7	0.9	1.9
Lighting fixtures	0.1	0.1	0.8	1.5	1.3	2.9
Batteries	0.4	0.9	2.4	3.1	2.1	1.6
Other electronic appliances	2.9	1.1	3.4	1.7	13.9	2.8
Measuring & controlling equipment	0.4	0.8	2.3	3.2	2.7	3.0
Other precision machinery	0.1	0.1	1.8	2.7	2.5	1.7
Photographic equipment	0.8	1.7	2.9	4.0	2.8	3.1
Spectacles & lens	0.1	0.3	0.9	2.2	0.7	3.4
Other photographic & optical equipment	0.3	1.0	4.1	4.6	4.1	3.9
Medical materials & equipment	0.2	0.4	2.4	3.1	1.8	1.8
Watches & clocks	0.1	0.1	1.4	1.0	2.9	1.1

Note: Revenue is replaced by output for plants or firms in which output exceeds revenue
Sources: Authors' compilations from Ministry of Economic Affairs (various years b)

Table 3: Shares of Revenues in Plants or Firms (percent, annual averages)

	CR4 ratios, all			Shares of revenues			
	Plants		Firms	Export		MNCs	
Industry	1998-9	2002-3	2001	1996	2001	1996	2001
Manufacturing, 234 industries, means	43	43	43	28	28	7	6
Electronics, 35 industries, means	39	39	46	47	52	15	9
Computers	55	39	56	72	86	0	2
Computer terminal equipment	63	73	64	91	90	4	23
Computer peripheral equipment	30	23	42	84	76	2	3
Computer components	29	21	41	82	82	2	3
Other computer components	34	62	41	39	51	17	0
Wired communication equipment	34	37	42	49	70	16	10
Telecommunication equipment	31	46	66	85	77	52	6
Television sets & video tape recorders	71	69	82	52	24	28	4
Record player & radio tape recorders	31	36	47	81	53	33	8
Other video & radio electronics	48	40	32	25	64	40	0
Data storage equipment	51	23	71	78	79	1	1
Semiconductors	37	32	39	69	62	10	9
Electronic passive devices	39	17	59	55	41	21	7
Bare printed circuit boards	23	16	25	56	50	9	0
Electronic tubes	62	80	81	77	61	6	90
Photonics materials & components	64	44	45	74	51	20	2
Other electronic parts & components	25	22	31	0	68	-	18
Power generation & related equipment	27	29	42	18	30	9	2
Electric wires & cables	26	27	36	31	34	1	1
Air conditioning equipment	60	58	57	28	19	10	15
Laundering machines & equipment	63	72	96	11	4	8	5
Electric heating appliances	30	49	23	47	36	16	0
Electric fans	23	32	25	72	59	11	1
Other electrical appliances & housewares	27	36	30	0	41	-	0
Light bulbs & tubes	36	59	67	27	17	0	0
Lighting fixtures	15	15	13	16	36	4	16
Batteries	44	37	42	55	56	29	24
Other electronic appliances	10	13	20	26	38	25	11
Measuring & controlling equipment	27	25	25	38	37	1	9
Other precision machinery	38	24	24	10	10	5	0
Photographic equipment	60	62	54	61	83	48	14
Spectacles & lens	21	33	26	53	52	21	14
Other photographic & optical equipment	93	75	92	0	73	-	0
Medical materials & equipment	25	25	35	28	63	4	13
Watches & clocks	23	30	31	67	54	22	17
Correlation with innovation propensities	0.37	0.34	-	0.35	0.37	0.12	0.27

Note: For CR4, revenue is replaced by output for plants in which output exceeds revenue.
Sources: Authors' compilations from Ministry of Economic Affairs (various years b); Directorate-General of Budget, Acccounting and Statistics (various years)

Table 4: New Entrants and Exiters in 1999-2003: Shares of Innovation and Revenues in Plants with 20 or more Employees in 1998 and 2003 (percent)

	Entrants 2003		Exiters 1998	
Industry	nnovation	Sales	nnovation	Sales
Manufacturing, 234 industries	37	29	24	22
Electronics, 35 industries	42	43	30	34
Computers	75	58	64	56
Computer terminal equipment	9	8	68	52
Computer peripheral equipment	45	54	28	24
Computer components	51	51	32	54
Other computer components	18	19	63	54
Wired communication equipment	57	61	32	49
Telecommunication equipment	76	80	33	44
Television sets & video tape recorders	97	64	68	52
Record player & radio tape recorders	41	45	30	38
Other video & radio electronics	68	74	39	33
Data storage equipment	73	72	21	38
Semiconductors	20	27	21	20
Electronic passive devices	22	29	46	30
Bare printed circuit boards	37	32	4	13
Electronic tubes	53	47	14	22
Photonics materials & components	85	80	90	50
Other electronic parts & components	31	45	27	34
Power generation & related equipment	41	16	35	26
Electric wires & cables	23	10	8	8
Air conditioning equipment	18	25	14	11
Laundering machines & equipment	-	-	-	14
Electric heating appliances	17	21	8	36
Electric fans	1	14	35	26
Other electrical appliances & housewares	29	33	20	16
Light bulbs & tubes	24	23	14	31
Lighting fixtures	65	43	68	32
Batteries	58	54	25	27
Other electronic appliances	30	26	46	29
Measuring & controlling equipment	42	47	13	33
Other precision machinery	93	73	18	30
Photographic equipment	68	59	49	39
Spectacles & lens	22	16	11	23
Other photographic & optical equipment	72	28	3	1
Medical materials & equipment	73	72	22	36
Watches & clocks	9	17	36	40

Note: Because data are taken from sample surveys, a portion of new entrants and exiters are plants that existed in either year, but were omitted from respective surveys.
Sources: Authors' compilations from Ministry of Economic Affairs (various years b)

Table 5: Determinants of Innovation Propensities (INN_{ijt}), Alternative Tobit Estimates

Variable, Indicator	1998-1999 Pooled	1998-1999 RE Panel	2002-2003 Pooled	2002-2003 RE Panel	5yrs, 1998-2003 Pooled	5yrs, 1998-2003 RE Panel
Constant	-17.803***	0.189***	-22.259***	-1.812***	-15.238***	-0.919**
	(0.913)	(0.067)	(1.156)	(0.241)	(0.679)	(0.417)
$DINN_{ijt-1}$	15.983***	4.355***	13.665***	4.441***	12.061***	3.773***
	(0.392)	(0.054)	(0.397)	(0.158)	(0.272)	(0.155)
$\ln(EMP_{ijt-1})$	0.883***	-0.078**	0.985***	-0.263***	0.758***	-0.024
	(0.143)	(0.030)	(0.148)	(0.049)	(0.095)	(0.062)
EMG_{ijt}	0.004***	0.693E-03***	0.0004	0.0015***	-0.425E-03	-0.508E-03
	(0.0015)	(0.243E-03)	(0.001)	(0.464E-03)	(0.894E-03)	(0.683E-03)
PRF_{ijt}	-0.040***	-0.039	-0.060***	-0.057***	-0.032***	-0.032***
	(0.003)	(0.025)	(0.005)	(0.006)	(0.002)	(0.003)
AGE_{ijt}	-0.135***	-0.070***	-0.126***	-0.070***	-0.110***	-0.063***
	(0.022)	(0.006)	(0.020)	(0.007)	(0.014)	(0.006)
DNW_{ijt}	0.633	0.126	-0.285	0.003	1.367*	0.603***
	(0.699)	(0.221)	(1.187)	(0.570)	(0.728)	(0.071)
$CR4_{jt-1}$	0.114***	0.044*	0.259***	0.120***	0.162***	0.069***
	(0.036)	(0.024)	(0.042)	(0.002)	(0.026)	(0.008)
$CR4_{jt-1}^2$	-0.857E-03**	-0.251E-03	-0.003***	-0.001***	-0.0016***	-0.642E-03***
	(0.417E-03)	(0.397E-03)	(0.511E-03)	(0.375E-04)	(0.298E-03)	(0.132E-03)
$EXP_{j96,01}$	0.007	0.0058***	0.065***	0.035***	0.021***	0.018***
	(0.006)	(0.0016)	(0.010)	(0.001)	(0.005)	(0.003)
$MNC_{j96,01}$	-0.003	-0.0038*	0.035**	0.028***	0.014*	0.007
	(0.010)	(0.0016)	(0.013)	(0.006)	(0.008)	(0.0045)
Year dummy	Yes	No	Yes	No	Yes	No
Sigma	9.036***		9.590***		7.303***	
	(0.129)		(0.138)		(0.088)	
Sigma_u		n.a		n.a		0.066
						(0.051)
Sigma_e		5.653***		6.320***		4.872***
		(0.262)		(0.061)		(0.140)
Log-likelihood	-9999	-1415	-10551	-1415	-13437	-3537
No. of obs.	6032	6032	5604	5604	7580	7580
No. of obs.>0	2439	2439	2686	2686	3622	3622

Notes: Figures in parentheses are heteroscedasticity-consistent standard deviations. ***, **, and * indicate significance at the 1%, 5%, and 10% statistical levels, respectively; RE=random effects; 1998-2003 excludes 2001; when t=2002, t-1 is defined as 2000.

Appendix Table 1: Determinants of Innovation Propensities (INN_{ijt}), 1998-1999, 2002-2003: Pooled Tobit Estimates

Variable, Indicator	1998-1999 (1)	1998-1999 (1a)	1998-1999 (1b)	1998-1999 (1c)	2002-2003 (1)	2002-2003 (1a)	2002-2003 (1b)	2002-2003 (1c)
Constant	-17.803***	-17.839***	-17.852***	-17.870***	-22.259***	-19.254***	-21.510***	-18.857***
	(0.913)	(0.913)	(0.892)	(0.893)	(1.156)	(1.057)	(1.119)	(1.031)
$DINN_{ijt-1}$	15.983***	16.004***	15.987***	16.006***	13.665***	13.880***	13.698***	13.896***
	(0.392)	(0.391)	(0.391)	(0.391)	(0.397)	(0.399)	(0.394)	(0.399)
$\ln(EMP_{ijt-1})$	0.883***	0.905***	0.883***	0.905***	0.985***	1.059***	0.943***	1.028***
	(0.143)	(0.142)	(0.143)	(0.142)	(0.148)	(0.149)	(0.148)	(0.248)
EMG_{ijt}	0.004***	0.004***	0.004***	0.004***	0.0004	0.0008	0.0004	0.0008
	(0.0015)	(0.0015)	(0.0015)	(0.0015)	(0.001)	(0.001)	(0.001)	(0.001)
PRF_{ijt}	-0.040***	-0.040***	-0.040***	-0.040***	-0.060***	-0.060***	-0.060***	-0.060***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.005)	(0.005)	(0.005)	(0.005)
AGE_{ijt}	-0.135***	-0.138***	-0.136***	-0.138***	-0.126***	-0.161***	-0.124***	-0.158***
	(0.022)	(0.022)	(0.022)	(0.022)	(0.020)	(0.020)	(0.020)	(0.020)
DNW_{ijt}	0.633	0.658	0.640	0.662	-0.285	-0.366	-0.172	-0.290
	(0.699)	(0.698)	(0.698)	(0.698)	(1.187)	(1.191)	(1.189)	(1.192)
$CR4_{jt-1}$	0.114***	0.128***	0.115***	0.128***	0.259***	0.290***	0.260***	0.298***
	(0.036)	(0.035)	(0.036)	(0.035)	(0.042)	(0.042)	(0.042)	(0.042)
$CR4_{jt-1}^2$	-0.857E-03**	-0.001**	-0.861E-03**	-0.001**	-0.003***	-0.003***	-0.003***	-0.003***
	(0.417E-03)	(0.406E-03)	(0.417E-03)	(0.406E-03)	(0.511E-03)	(0.512E-03)	(0.511E-03)	(0.512E-03)
$EXP_{j96,01}$	0.007		0.007		0.065***		0.061***	
	(0.006)		(0.006)		(0.010)		(0.096)	
$MNC_{j96,01}$	-0.003	-0.0016			0.035**	0.023*		
	(0.010)	(0.0099)			(0.013)	(0.013)		
Year dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sigma	9.036***	9.039***	9.036***	9.039***	9.590***	9.652***	9.605***	9.659***
	(0.129)	(0.129)	(0.129)	(0.129)	(0.138)	(0.139)	(0.138)	(0.139)
Log-likelihood	-9999	-9999	-9999	-9999	-10551	-10572	-10554	-10574
No. of obs.	6032	6032	6032	6032	5604	5604	5604	5604
No. of obs.>0	2439	2439	2439	2439	2686	2686	2686	2686

Notes: Figures in parentheses are heteroscedasticity-consistent standard deviations. ***, **, and * indicate significance at the 1%, 5%, and 10% statistical levels, respectively; when t=2002, t-1 is defined as 2000.

Appendix Table 2: Determinants of Innovation Propensities (INN_{ijt}), 1998-1999, 2002-2003: Random Effects Panel Tobit Estimates

	1998-1999 (1)	1998-1999 (1a)	1998-1999 (1b)	1998-1999 (1c)	2002-2003 (1)	2002-2003 (1a)	2002-2003 (1b)	2002-2003 (1c)
Constant	0.189***	0.161**	0.105	0.100	-1.812***	-0.108	-1.146***	0.355**
	(0.067)	(0.064)	(0.073)	(0.080)	(0.241)	(0.074)	(0.073)	(0.159)
$DINN_{ijt-1}$	4.355***	4.367***	4.361***	4.371***	4.441***	4.558***	4.455***	4.563***
	(0.054)	(0.056)	(0.061)	(0.055)	(0.158)	(0.180)	(0.159)	(0.146)
ln(EMP_{ijt-1})	-0.078**	-0.059	-0.077**	-0.059	-0.263***	-0.223***	-0.296***	-0.253***
	(0.030)	(0.041)	(0.035)	(0.037)	(0.049)	(0.067)	(0.046)	(0.050)
EMG_{ijt}	0.693E-03***	0.674E-03**	0.693E-03***	0.675E-03***	0.0015***	0.0017***	0.0015***	0.0016***
	(0.243E-03)	(0.254E-03)	(0.231E-03)	(0.239E-03)	(0.464E-03)	(0.511E-03)	(0.501E-03)	(0.444E-03)
PRF_{ijt}	-0.039	-0.039	-0.039*	-0.039	-0.057***	-0.057***	-0.057***	-0.057***
	(0.025)	(0.025)	(0.023)	(0.025)	(0.006)	(0.008)	(0.007)	(0.007)
AGE_{ijt}	-0.070***	-0.072***	-0.071***	-0.072***	-0.070***	-0.090***	-0.068***	-0.087***
	(0.006)	(0.007)	(0.006)	(0.006)	(0.007)	(0.010)	(0.007)	(0.008)
DNW_{ijt}	0.126	0.146	0.138	0.154	0.003	-0.101	0.083	-0.029
	(0.221)	(0.249)	(0.196)	(0.239)	(0.570)	(0.725)	(0.634)	(0.649)
$CR4_{jt-1}$	0.044*	0.053**	0.045*	0.054**	0.120***	0.135***	0.116***	0.131***
	(0.024)	(0.023)	(0.024)	(0.022)	(0.002)	(0.012)	(0.006)	(0.014)
$CR4_{jt-1}^2$	-0.251E-03	-0.331E-03	-0.265E-03	-0.338E-03	-0.001***	-0.001***	-0.001***	-0.001***
	(0.397E-03)	(0.405E-03)	(0.403E-03)	(0.391E-03)	(0.375E-04)	(0.165E-03)	(0.892E-04)	(0.0002)
$EXP_{j96,01}$	0.0058***		0.0055***		0.035***		0.033***	
	(0.0016)		(0.0017)		(0.001)		(0.001)	
$MNC_{j96,01}$	-0.0038*	-0.003			0.028***	0.023***		
	(0.0016)	(0.002)			(0.006)	(0.008)		
Sigma_u	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Sigma_e	5.653***	5.654***	5.653***	5.654***	6.320***	6.344***	6.328***	6.349***
	(0.262)	(0.299)	(0.289)	(0.275)	(0.061)	(0.080)	(0.070)	(0.073)
Log-likelihood	-1415	-1415	-1415	-1415	-1415	-1415	-1415	-1415
No. of obs.	6032	6032	6032	6032	5604	5604	5604	5604
No. of obs.>0	2439	2439	2439	2439	2686	2686	2686	2686

Notes: Figures in parentheses are heteroscedasticity-consistent standard deviations. ***, **, and * indicate significance at the 1%, 5%, and 10% statistical levels, respectively; when t=2002, t-1 is defined as 2000.

Appendix Table 3: Determinants of Innovation Propensities (INN_{ijt}), 5-year Samples, 1998-2000, 2002-2003: Pooled Tobit and Random Effects Panel Tobit Estimates

	(1) Pooled	(1a) Pooled	(1b) Pooled	(1c) Pooled	(1) Panel Tobit	(1a) Panel Tobit	(1b) Panel Tobit	(1c) Panel Tobit
Constant	-15.238***	-15.042***	-14.919***	-14.677***	-0.919**	-0.710**	-0.772	-0.517**
	(0.679)	(0.679)	(0.655)	(0.653)	(0.417)	(0.296)	(0.510)	(0.257)
$DINN_{ijt-1}$	12.061***	12.130***	12.062***	12.134***	3.773***	3.759***	3.738***	3.759***
	(0.272)	(0.272)	(0.272)	(0.272)	(0.155)	(0.202)	(0.194)	(0.184)
$\ln(EMP_{ijt-1})$	0.758***	0.814***	0.740***	0.795***	-0.024	0.030	-0.030	0.021
	(0.095)	(0.095)	(0.095)	(0.094)	(0.062)	(0.068)	(0.065)	(0.068)
EMG_{ijt}	-0.425E-03	-0.355E-03	-0.426E-03	-0.354E-03	-0.508E-03	-0.505E-03	-0.546E-03	-0.513E-03
	(0.894E-03)	(0.895E-03)	(0.894E-03)	(0.895E-03)	(0.683E-03)	(0.585E-03)	(0.621E-03)	(0.533E-03)
PRF_{ijt}	-0.032***	-0.032***	-0.032***	-0.033***	-0.032***	-0.032***	-0.032***	-0.032***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)	(0.002)
AGE_{ijt}	-0.110***	-0.120***	-0.107***	-0.117***	-0.063***	-0.070***	-0.062***	-0.070***
	(0.014)	(0.014)	(0.014)	(0.014)	(0.006)	(0.006)	(0.006)	(0.005)
DNW_{ijt}	1.367*	1.442**	1.321*	1.393*	0.603***	0.637***	0.598***	0.623***
	(0.728)	(0.729)	(0.727)	(0.729)	(0.071)	(0.074)	(0.095)	(0.072)
$CR4_{jt-1}$	0.162***	0.189***	0.162***	0.190***	0.069***	0.091***	0.068***	0.090***
	(0.026)	(0.025)	(0.026)	(0.025)	(0.008)	(0.009)	(0.010)	(0.007)
$CR4_{jt-1}^2$	-0.0016***	-0.0019***	-0.0017***	-0.0019***	-0.642E-03***	-0.849E-03***	-0.625E-03***	-0.831E-03***
	(0.298E-03)	(0.293E-03)	(0.298E-03)	(0.294E-03)	(0.132E-03)	(0.151E-03)	(0.153E-03)	(0.117E-03)
$EXP_{j96,01}$	0.021***		0.022***		0.018***		0.018***	
	(0.005)		(0.005)		(0.003)		(0.004)	
$MNC_{j96,01}$	0.014*	0.015**			0.007	0.0092*		
	(0.008)	(0.008)			(0.0045)	(0.0055)		
Year dummy	Yes	Yes	Yes	Yes	No	No	No	No
Sigma	7.303***	7.322***	7.305***	7.326***				
	(0.088)	(0.088)	(0.088)	(0.088)				
Sigma_u					0.066	0.164**	0.069	0.156*
					(0.051)	(0.072)	(0.043)	(0.082)
Sigma-e					4.872***	4.884***	4.873***	4.885***
					(0.140)	(0.164)	(0.163)	(0.183)
Log-likelihood	-13437	-13446	-13439	-13448	-3537	-3537	-3537	-3537
No. of obs.	7580	7580	7580	7580	7580	7580	7580	7580
No. of obs.>0	3622	3622	3622	3622	3622	3622	3622	3622

Notes: Figures in parentheses are heteroscedasticity-consistent standard deviations. ***, **, and * indicate significance at the 1%, 5%, and 10% statistical levels, respectively; when t=2002, t-1 is defined as 2000.