Preliminary draft for discussion only, please do not quote

Chapter 3: Concentration, R&D, Foreign Ownership, and Exporting: Evidence from Taiwan's Manufacturing Industries and Electronics Plants

Chih-Hai Yang
Department of Economics, National Central University
chyang@mgt.ncu.edu.tw
and
Eric D. Ramstetter
International Centre for the Study of East Asian Development
and Graduate School of Economics, Kyushu University
ramst@icsead.or.jp

October 2008

3.1 Introduction

Taiwan is a small, open, newly industrialized economy, which has undergone very rapid technological change over the last few decades. Indeed, the island's healthy economic growth during this period primarily the result of technological progress which was in turn facilitated by innovation and the increased technological sophistication of both capital and workers. Taiwan's technology development strategy combined promotion of in-house research and development (R&D) as well as technology imports from advanced countries. As a result, Taiwanese firms have successfully in closed the technological gap with many of their counterparts in developed countries, especially in the electronics-related industries (referred to as "electronics" below).[1] This is evident from Trajtenberg's (2001) analysis of the international distribution of patents granted by various authorities, for example. It is also clear that Taiwan's firms have often depended on own research and development (R&D) efforts and contributed to making Taiwan and increasingly important center for many R&D activities.[2]

[1] In this chapter, electronics is broadly defined to include 4 major categories in revision 7 of Taiwan's standard industrial classification: (1) computers, communication, audio, video, (2) electronic parts and components, (3) electric machinery, and (4) precision machinery.

[2] Taiwan's R&D expenditures rose to 1.8 percent of GDP in 1997, 2.3 percent by 2003 and 2.6 percent in 2006 (National Science Council 2007). According to the National Science Council (2008) and World Bank (2008), Taiwan's R&D-GDP ratio ranked 14th out of 74 countries with available data in 1997 and 10th of 84 in 2003. Taiwanese businesses accounted

On the other hand, the speed of adjustment is much faster in Taiwan's markets than in most mature economies, and Chen and Yang (1997) thus suggest "the speed of invisible hand" (which results in changes in market structure) is relatively rapid. Taiwan is thus an interesting case in which to study the relationship between innovation and market structure but the previous literature has not analyzed this relationship or the dynamics involved in great detail.

Innovation behavior is strongly related to the technological environment surrounding a firm's location. The concept of technology regimes was introduced by Nelson and Winter (1977). They identified two technological regimes according to the nature of relevant knowledge bases: entrepreneurial regime and routinized regime. An entrepreneurial regime is characterized by the entry of innovative new firms, which is similar to the 'Schumpeter Mark I' regime that generates a relatively large number of opportunities to access relatively high-level technologies. If the force of '*creative destruction*' is strong enough, innovation should result in a lower market concentration in industries where the entrepreneurial regime is dominant. A routinized regime is characterized by the concentration of innovation in surviving incumbents, which is like the 'Schumpeter Mark II' regime where learning-by-doing makes it more likely that incumbents will be able to innovate and utilize those new technologies effectively. In this regime, the '*creative accumulation*' attributed to large established firms result in an industry with high market concentration.[3] The concept of technological regimes is important for theoretical and empirical understanding of the dynamics of market competition but we know of no study that investigates the impact of innovation on market structure dynamics in the context of alternative technological regimes.

The first purpose of this chapter is thus to provide new evidence about how industry-level

---

for about two-thirds of R&D expenditures in recent years (64 percent in 1999-2001, 62-63 percent in 2002-2003, 65-68 percent in 2004-2006).

[3] There are a number of papers proposing various classifications of technological regimes (e.g., Anderson and Tushman (1990), Malerba and Orsenigo (1996), and Marslli and Verspagen (2002).

affects producer concentration in Taiwan's manufacturing industries in recent years (Section 3.3 below). At the same time, this study also investigates whether in-house R&D and technology imports have different impacts on market structure and its dynamics in Taiwan. Panel data are used to control for industry heterogeneity and the Generalized Method of Moment (GMM) estimator is employed to deal with the potential causality between innovation and producer concentration. We also show how alternative technological regimes may affect the nature of the relationship between innovation and concentration. The chapter then examines how industry-level concentration, exporting, and presence of foreign multinational corporations (MNCs) affects R&D activity in Taiwan's electronics plants (Section 3.4). Before proceeding to these analyses the chapter first examines indicators of producer concentration and R&D activity in the following section (3.2). The final section (3.5) then concludes.

3.2. Trends in Concentration and R&D Intensity, Foreign Ownership, and Exporting

This study relies primarily on the manufacturing-plant surveys (hereafter MPS) conducted by Ministry of Economic Affairs (MOEA) to construct the first quasi-annual series used to examine market structure for 1997-2000 and 2002-003 period. These surveys are conducted annually, except in years when the quintennial *Industrial and Commercial Census* is conducted by Executive Yuan's Directorate-General of Budget, Accounting and Statistics (DGBAS).[4] The use of the MPS is motivated by the desire to analyze recent trends and at the same time avoid concordance problems various versions Taiwan's Standard Industry Classification (SIC).[5] It would of course be desirable to integrate the Census data for 2001

[4] See Chen and Yang (1997) and Yang and Kuo (2007) for studies using that used the quintennial census data. through 1996.

[5] For example, the 1996 census data and the 1997-1999 MPS publications used version 6 of the SIC, the 2001 Census and the 2000, 2002-2004 MPS publications used version 7, while

with the MPS data but this is impossible because of differences in sampling and variable definitions. One important difference is that the Census does not contain separate variables for R&D and technology imports but rather combines these two into one variable. Most variables in the Census are also reported at the firm level, not the plant level.

In 2001, the Census contained data on 140,539 manufacturing firms and 147,340 manufacturing plants where as the MPS covered an average of 82,562 manufacturing plants in 1997-2000 and an average of 75,385 plants in 2002-2003 (Directorate-General of Budget, Accounting and Statistics 2003; Ministry of Economic Affairs various years). The MPS are thus sample surveys, but they are representative samples and widely utilized to conduct research on Taiwan's manufacturing industries. Moreover, although MPS samples were only slightly over half the size of the Census population, these surveys appear to have covered most of the large firms. Thus, for example, MPS estimates of manufacturing sales in 2002-2003 were only 3 percent lower than Census estimates for 2001 (Table 1) and there was an identical difference between the 1996 census estimate (Directorate-General of Budget, Accounting and Statistics 1998) with 1997 MPS estimate.

Measures of producer concentration are sensitive to the degree of aggregation and the unit of accounting, with concentration being relatively low in broadly defined industries (e.g., the 2-digit level in Table 1) and when plants are used as the accounting unit. Nonetheless, even at the 2-digit level there is wide variation in four-plant or four-firm concentration ratios (CR4) across industries. In industries like tobacco and petroleum and coal, sales were highly concentrated in the four largest plants or firms.[6] On the other hand, the four largest firms or plants had much smaller market shares in industries like apparel, wood and bamboo,

the 2005 MPS publication used the new version 8. Fortunately, our data set contains version 7 codes for 1997-2000 and 2002-2003.

[6] Tobacco is nearly a monopoly because it is highly regulated by the government where several small plants compete with the large state-owned enterprise, Taiwan Tobacco and Liquor Company.

non-metallic mineral products, fabricated metals, general machinery, and miscellaneous manufacturing. Among the four electronics categories, electric machinery was the least concentrated, followed by computers, communication, audio and video, and electronic parts and components, while precision machinery was a bit more concentrated.

There was a weak trend toward increased concentration between 1998-1999 and 2002-2003, with average or mean concentration for the 24 2-digit manufacturing industries rising 2 percentage points each (Table 1). Similar increases were also observed in 14 of these industries, the largest increases (5 percentage points or more) being observed in leather and furs, chemical materials, fabricated metals, and precision machinery. However, most studies of concentration use more detailed industry definitions such as those in the 4-digit SIC classification, which usually results in much higher measures of concentration. For example, the mean of CR4 for the four 2-digit electronics categories in Table was 18 percent in both 1998-1999 and 2002-2003, but this rises to 40 percent for the 35 4-digit categories in the same industries. CR4 exceeded 50 percent in for both 1998-1999 and 2002-2003 in computer terminal equipment, television sets and video tape recorders, electronic tubes, air conditioning equipment, laundering machines, photographic equipment, and other photographic and optical equipment (Table 1). Large increases in CR4 (10 percentage points or more) were observed in one of these industries (electronic tubes) and five others (other computer components, telecommunications equipment, electric heating appliances, light bulbs and tubes, and spectacles and lens). There were also six industries in which CR4 fell by 10 percentage points (computers, data storage equipment, electronic passive devices, and photonics materials and equipment, other precision machinery, and other photographic and optical equipment).

The primary advantage of using a more detailed classification is that markets can be more clearly defined and this advantage is particularly obvious if product-level are available. However, the interpretation of concentration measures becomes complicated when they are calculated for multi-product plants or firms, or when firms control many plants or even other firms in a single industry. Although we cannot account for the role of intra-industry conglomerates with these data, comparisons of firm-level data from the 2001 census with plant-level compilations from the MPS highlight a number of industries where 4-firm concentration ratios were much higher than 4-plant ratios, implying that firms in these industries had substantial operations outside of their main industry (Table 1). The largest differences were in data storage units, electronic passive devices, laundering machines and equipment, and telecommunication equipment and apparatus.

According to the classification of large firms by China Credit Information Service (various years), these industries include some of Taiwan's largest and best-known firms. Hon Hai Precision has been Taiwan's largest firm in recent years with sales of NT$328 billion in 2003, or 89 percent more than the total reported by the MPS for its main industry, electronic passive devices in that year. Benq is another well known firm that had sales of NT$109 billion or 9 percent more than the MPS estimate for telecommunications equipment and devices in the same year. Quanta Computer and Compal Electronics are two large computer firms that had combined sales of NT$455 billion in 2003 or 68 percent more than the MPS total for the industry. Taiwan Semiconductor Manufacturing, United Microelectronics, and Texas Instruments (Taiwan) are well known semiconductor firms with combined sales of $364 billion, which was 110 percent more than the corresponding MPS total for electronic passive devices in 2003. In short, these data make it clear that many large Taiwanese electronics firms are engaged in many activities outside of their main 4-digit industry, probably including services. It is also highly likely that many plants also operate in multiple industries.

Between 1998-1999 and 2002-2003, average R&D expenditures for manufacturing plants in the MPS increased 51 percent, with a more rapid (77 percent) increase observed for electronics plants. Because R&D expenditures grew more rapidly than sales, the average

R&D intensity rose from 1.2 percent to 1.6 percent during this period (Table 2). Among 2-digit categories, the highest R&D intensities were observed in the electronics categories as well as chemical products and transport machinery. There were relatively large increases (0.5 percentage points or more) in leather and furs and two of the 2-digit electronics categories (computers, communication, audio, and video as well as precision machinery) and a similar decrease in petroleum and coal, but changes were much smaller (0.3 percentage points or less) in all other industries. Increases (13 industries) were slightly more common than decreases (11 industries). Electronics plants accounted for an increasing majority of R&D expenditures which rose to over three-fourths in 2002-2003. As a result, average R&D intensities for all electronics plants increased from 2.4 percent to 3.0 percent. Among the 4-digit electronics categories, R&D intensities were highest in wired communication equipment, telecommunication equipment, semiconductors, electronic tubes, photonic materials and components, and other photographic and optical equipment. There were relatively large increases in other computer components, data storage equipment, batteries, photographic equipment, and spectacles and lens, and large decreases in electronic tubes and photonics materials and equipment.

Technology acquisitions (most of which are imported) were smaller and increased less rapidly than R&D (Tables 2, 3) with electronics plants accounting for three-fourths or a little more of these acquisitions. As a result, ratios of these acquisitions to sales were about two times larger for electronics plants (1.1 percent in 1998-1999 and 0.9 percent in 2002-2003) than for all manufacturing plants (0.5 percent in each period). Among the 2-digit categories, transport machinery (both periods) and chemical products (2002-2003 only) were the only industries outside of electronics in which ratios of acquisitions to sales exceeded the manufacturing average. Among the 4-digit electronics categories, these ratios were relatively high (above 1 percent) in both years in television sets and video tape recorders, semiconductors, electronic tubes, and photonics materials and components. In 1998-1999, they also exceeded this threshold in data storage equipment and batteries but ratios fell in these industries while R&D rose rapidly. Ratios of acquisitions to sales fell in 19 of the 35 4-digit electronics industries, while R&D-sales ratios increased in 26.

On average for all manufacturing, CR4 plants had slightly higher R&D intensities in both years and higher acquisition-sales ratios in 2002-2003 (Tables 2, 3). Among 2-digit categories, CR4 plants had notably higher R&D propensities in leather and furs in both years. CR4 plants also had relatively high R&D intensity (differences of 0.9 percentage points or more) in five other industries in 1998-99 (apparel, furniture, fabricated metals, transport machinery, and precision machinery), but only one other industry in 2002-03 (electronic parts and components). There were negative differentials of similar magnitude in chemical products in both years, but differences between CR4 plants and all plants were rather small in all other industries. Moreover, CR4 plants had relatively high and relatively low ratios of both R&D and technology acquisitions to sales in roughly equal numbers of industries.[7] In other words, these data do not suggest a strong tendency for technological activity to differ much between CR4 plants and all plants in these years.

In the Taiwanese context, it is also important to understand that new entrants and exiting plants both account for substantial portions of innovative activity in Taiwan's manufacturing industries. For example, new entrants, defined as plants that appeared in the MPS between 1998 and 2003, accounted for a little over one-third of the R&D and technology acquisitions by all manufacturing firms in 2003 (Table 4). In electronics, these averages for all plants were even higher at over two-fifths each. This definition of new entrants exaggerates the shares of

[7] R&D-sales ratios were higher than the average for all plants for CR4 plants in 12 of 24 2-digit categories and in 16 of 35 4-digit electronics categories in 1998-1999. In 2002-2003 these numbers were 14 of 24 and 17 of 35, respectively. For acquisition-sales ratios these distributions were 12 of 24 and 15 of 35 in 1998-1999 and 14 of 24 and 17 of 35 in 2002-2003, respectively.

this group a little because some of these plants were established in 1997 or earlier, but excluded from the MPS in 1998. However, these plants did not account for large shares of R&D or technology acquisitions in 2003, only 6 percent of each manufacturing total. In contrast, exiting plants, defined as plants included in the MPS sample in 1998 but not in 2003, accounted for about one fourth of R&D and technology acquisitions by all manufacturing plants in 1998.[8] In other words, Taiwan's manufacturing industries are often characterized by extremely rapid turnover with both new entrants and exiting plants accounting for substantial portions of innovative activity. High rates of entry and exit may also result in greater competition that is reflected in measures of concentration such as CR4.

International trade is another important factor to consider in small, open economies like Taiwan because if trade is large, industries can be extremely competitive even if producer concentration is high. According to data compiled from the 2001 census, for example, exports accounted for about one-third of the sales of all manufacturing firms and about one-half of the sales by electronics firms (Table 1). Outside of electronics, exports were relatively quite large in apparel, leather and fur, furniture, and miscellaneous manufacturing. Within electronics ratios were three-fifths in five of the 35 industries (computers, computer terminal equipment, computer components, record players and audio tape players, and other video and audio equipment) and less than one-fifth in only one (other precision machinery).

The role of MNCs is also important to consider because MNCs are known to operate in imperfectly competitive markets and to be very involved in R&D and other technology-related activities. Unfortunately, the data we have do not distinguish local MNCs, which are quite important in Taiwan and probably behave more like foreign MNCs than local non-MNCs. These data also appears to underestimate the scope of foreign MNC activity in

[8] Here again it is likely that this definition of exiting plants results in some exaggeration of the group's shares in Table 4 because some of the exiting plants were probably dropped from the MPS, but remained in operation. However, there is no way of checking the scope of this exaggeration.

Taiwan (Table 1). Regarding the latter point, the Census data suggest that foreign MNCs accounted about 6 percent of manufacturing firm sales in 2001 and about 8 percent of the sales by electronics firms. However, this estimate is much lower than suggested by an alternative Taiwanese source or by home country sources for Japanese and U.S. MNCs in Taiwan's manufacturing industries.[9] In addition to a relatively large presence in several electronics industries, the data in Table 4 also suggest a relatively large MNC presence in chemical materials and chemical products.

3.3. Industry-Level Determinants of Concentration

In this section we summarize major results from Yang's (2007) study of the relationship between innovation and market structure focusing primarily on the dynamic aspects of this relationship using a panel of 233 4-digit industries for 6 years, 1997-2000 and 2002-2003.[10] However, before this relationship is examined it is first helpful review some of the relevant literature and static aspects of the relationship.

3.3.1. The Literature on Determinants of Concentration

Studies of the relationship between innovation and market structure usually examine two distinct dimensions, static and dynamic. Static analyses usually focus on the question of whether innovative activities and concentration are positively correlated at a given point in time or not. Dynamic analyses then focus on the question of whether innovation contributes to

[9] For example, surveys of foreign MNCs by the MOEA (Ministry of Economic Affairs 2003) suggest that foreign MNCs accounted for 33 percent of manufacturing sales in 2001, 15 percent in 2000, and 27 percent in 1999. Although estimates from this source are notoriously volatile, they are also consistent with home country estimates which indicate that Japanese and U.S. MNCs alone accounted for 9 percent of manufacturing sales in 2001 (Research Institute for Economy, Trade and Industry 2007; Bureau of Economic Analysis 2005; International Monetary Fund 2008).

[10] At the four-digit level there are actually 234 industries but one industry reported zero sales for three years and was therefore excluded from the sample. Note that this summary will not present all econometric details; please see the source for those details.

increased or decreased concentration over time.

The traditional structure-conduct-performance (SCP) paradigm suggests that market structure is basically determined by exogenous variables such as basic supply and demand conditions facing an industry. This has led to much research on the market concentration in testing the SCP hypothesis.[11] However, the empirical analyses included in this literature results have been criticized for relying too heavily on descriptive statistics rather than rigorous analyses of causal relationships (Tirole, 1988). Mutual causality between innovation and market structure is a key element in this respect and one line of research adopts simultaneous equation models to deal with the endogeneity problem.

Table 5 summarizes the results of simultaneous equation estimates of the effect of innovation on market structure from selected previous studies of mature industrial countries and developing countries. In each case, the models include at least two equations estimating the determinants of concentration and innovation and the interaction between them. These studies measure market structure using either the four-firm concentration ratio and/or Herfindahl-Hischman Index (HHI). Innovative activity is alternatively measured as R&D intensity (the ratio of R&D expenditure to sales) or the value of R&D expenditures.

The sign of the R&D variable in the concentration equation reveals the static effect of innovation on market concentration. Except for the Brazilian case in Resende (2007), each of the studies listed in Table 5 suggests that R&D had a positive static effect on market concentration.[12] This positive relationship indicates that relative high market concentration is usually observed in industries with relatively large R&D activity, and is usually interpreted as reflecting the role innovation plays in deterring potential entrants into an industry.

---

[11] See Van Cayseele (1998) for surveys of research on the market structure – innovation nexus.

[12] Farber (1981) finds a negative relationship between R&D and concentration ratio, while the concentration index he measures refers to buyer concentration rather than seller concentration.

In some contrast to estimates for developed countries, Resende's (2007) study of Brazil (a developing country), does not reveal a significant relationship between R&D and concentration. One possible explanation for this result is the co-existence of modern and traditional segments of Brazilian manufacturing. Large heterogeneous industries are often characterized by different technology regimes and their existence weakens the strength of the innovation – concentration nexus in a sample of all industries. This point was raised by Koeller's (2005), who found a positive relationship in a sample of all industries and a subsample of 'technologically progressive' industries, but not in a subsample of 'technologically unprogressive' industries.[13] In other words, the nature of the technology regime, that is the technology intensity of an industry, may matter for the static innovation – market structure nexus.

Recently, Sutton (1991, 1996) developed theories explaining what determines a lower bound for concentration, eschewing detailed and sensitive game-theoretic approaches. He suggested that the lower bound of concentration is related to market size, exogenous sunk costs, and endogenous sunk costs (advertisement and R&D). That is, the lower bound is related to the nature of technology. Several empirical studies have also used the concept of the lower bound to investigate the relationship between innovation and market concentration. Lyons and Matraves (1996) used a stochastic frontier model that allows industries to be in disequilibrium, finding a positive association between innovation and market concentration in the European Union. Yang and Kuo (2007) employed the similar approach, indicating that R&D intensity has a significant positive impact on the deviation from lower bound of market concentration and implying that there is positive relationship between innovation and market structure. Using data for the United States, Robinson and Chiang (1996) found that the

[13] Koeller defines technologically progressive industries are those with relatively high R&D intensities, whereas technologically unprogressive industries are defined as those with lower R&D intensities.

competitive escalation of endogenous sunk cost spending on R&D in relatively large markets acts as an entry barrier, again implying a positive relationship between innovation and market concentration.[14] Matraves (1999) also showed that R&D, one kind of endogenous sunk cost, plays a crucial role in determining market structure in the global pharmaceutical industry.

Consistent with estimates obtained using the simultaneous equations approach, studies of using the lower bound approach generally find that innovation is positively related to concentration. However, it is also important to note that none of the lower bound approach studies described above address the issues arising from mutual causality between innovation and market structure.

Since the early 1980s, the relationship between innovation and industry dynamics has attracted the attention of many industrial economists. Recent theoretical articles have used more sophisticated models to explore this issue, but with mixed results.[15] Although the theoretical literature has advanced our understanding of important dimensions of the relationships involved among innovation and industry dynamics, empirical studies examining the impact of innovation on market structure dynamics are limited, largely because required data are often unavailable.

The pioneering work by Geroski and Pomroy (1990) proposed a model to examine the relationship between innovation and the evolution of market structure for a cross-section of U.K. industries, showing that innovation reduces concentration and that most of the impact of innovation on concentration occurs very quickly. More specifically, although innovation results in lower concentration, most of the innovation and subsequently lower concentration results from the entry of new, innovative firms. Paci and Usai (1998) use this model to analyze the relationship between technology and change in market structure in Italian

---

[14] This study uses data provided by the Profit Impact of Market Strategy of the Strategic Planning Institute. These data cover a wide range of firms typically among the *Fortune* 1000.

[15] The review for theoretical studies on the relationship between innovation and the dynamics and evolution of industries, please refer to Malerba (2007).

manufacturing for the years 1978-1993. Technological effort (R&D intensity) also results in lower concentration in this case, implying some sort of 'creative destruction' in Italy during that period. They further examine the effects of different technological environments, defined in terms of technological opportunity and the appropriability of returns to the innovators, finding that the strength of the negative correlation between technological effort and concentration may vary depending on the technological conditions prevailing in each industry. Relatively numerous technological opportunities are found to lower the entry barriers and result in relatively large declines in concentration. At the same time, relatively high appropriability conditions make it possible for innovative behavior increase market shares of innovating firms, and increases concentration.

Unlike the aforementioned industry-level studies, Davies and Geroski (1997) integrated firm- and industry-level U.K. data for 1979-1986 to describe the relative magnitudes and determinants of changes in concentration and the fluctuations of market shares. Their estimates show that the impact of innovation on changes in market shares is insignificant, because the effects are complex and multifaceted. Their conclusion suggests that R&D and innovation does play a major role in determining concentration levels and fluctuations, but emphasizes the complexity of the effects of innovation on market structure dynamics.

Recently, there have been two shifts in the empirical literature examining the SCP paradigm. . The first is to capture dynamic effects in the context of simultaneous equation models based on the SCP paradigm. Delorme Jr. *et al* (2002) attempt to introduce dynamics by lagging regressors one-period, showing that lagged R&D has a significantly positive impact on current market concentration in U.S. manufacturing. In contrast with the analyses of European experiences mentioned above, their results indicate that innovation resulted in higher concentration during the 1980s. The second shift is highlighted by Marslli and Verspagen's (2002) who emphasize the potential importance of technological regimes for the innovation – market structure dynamics nexus. However, even though technological regimes affect industry dynamics, there is no econometric analysis of the innovation-market concentration relationship in alternative technological regimes.

3.3.2. The Static Relationship between Innovation and Market Structure

To investigate the static innovation – market structure nexus, the traditional formulation that relates the steady-state (long-run equilibrium) concentration level in an industry to market conditions and industry characteristics is not appropriate because the dataset is continuous and covers a moderate time span. Alternatively, the panel data used in this study have the advantage of facilitating control for the large degree of heterogeneity across industries, which cannot be accomplished with the cross section data underlying most previous studies. Compiling the plant-level data at the four-digit SIC level (233 industries) for 6 years results in a sample containing 1398 observations.

The static model estimated in this section is an extension of the exogenous sunk cost function approach developed by Sutton (1991) where the concentration is hypothesized to increase as a result of relatively small market size, relatively large minimum efficient scale relative to industry sales, or relatively large capital requirements.[16] Note that the latter two variables are widely employed as indicators of entry barriers in the SCP paradigm. The effects of two other performance control variables, the price-cost margin and the growth of industry sales are also considered, though the effects of these variables on concentration are unclear *a priori*. The traditional SCP paradigm suggests a positive relationship between the price-cost margin and concentration because plants in more concentrated industries usually can exploit their market power to earn higher profits. On the other hand, higher profitability may attract potential entrants and then lead to lower concentration. Similarly, the expansion of demand

[16] To obtain a suitable convex form, the variables typically are in the logarithm form.

generally creates greater entry opportunities in industries with high growth rates and small plants are usually expected to grow faster than their larger counterparts, creating the expectation of a negative relationship between growth and concentration.[17] However, the relationship may also be positive if large plants exploit economies of scale or use new production technologies to meet market demand. To check the robustness of the results to alternative measures of concentration, the dependent variable is alternatively defined as the CR4, which was examined in the previous section, and the Herfindahl-Hirschman Index (HHI), which is the sum of the squares of market shares of all plants in an industry.

This basic model is then extended to consider the effects of R&D intensity (the ratio of R&D to sales) and technology import intensity (technology imports as a ratio of sales). R&D intensity is a widely employed measure of innovative activity in the literature and, as described above, technology imports are another important source of innovative resources in economies like Taiwan. Most previous studies suggest a positive static relationship between innovation and market structure and a positive sign is therefore expected for the coefficients on R&D intensity and the technology import ratio.[18] However, the nature the relationship between from technology imports and market concentration has never been examined and it is important to allow for the possibility that this relationship may differ from the relationship between R&D intensity and concentration.

As mentioned above, one critical advantage of using the dataset employed in this study is that the use of panel estimation techniques facilitates the control of inter-industry heterogeneity that has been ignored in most previous studies. When exploring the relationship between innovation and market structure, we allow for the existence of individual effects

[17] Many previous studies testing the Gibrat Law of proportional growth conclude that smaller firms have higher growth than their larger counterparts. See Sutton (1997) for a comprehensive survey.

[18] Sutton (1991) claims that advertisement devoted by incumbents or potential entrants is an important endogenous cost, while advertising information is unavailable in our dataset.

which are potentially correlated with other explanatory variables in these regressions. Using a "within-plant" panel estimator, the fixed effect (FE) or the random effect (RE) techniques are standard estimation methods to eliminate the individual effect. However, these results fail to account for a crucial econometric problem, mutual the causality among concentration, innovation, and industry performance. To deal with this endogeneity problem, the Generalized Method of Moments (GMM) estimator for panel data model is employed in this study. Specifying the regression models with predetermined, rather than exogenous, right-hand side variables, GMM is preferred because it is robust to the presence of heteroscedasticity across industries and autocorrelation within industries over time. It can also be efficient even under a weak assumption about the disturbance term. We thus focus on GMM estimates, which use lagged innovation variables and lagged profitability as instrumental variables.

GMM estimates of the static effects of technological activity on alternative measures of producer concentration are shown for three different samples, all industries, high R&D industries, and low R&D industries in the top half of Table 6. In the samples containing all industries, these estimates suggest a positive and statistically significant static relationship between R&D intensity and concentration after controlling for entry barriers, profitability, and industry growth.[19] This result is consistent with results from most previous studies. In other words, as suggested by theoretical literature, higher R&D intensity appears to deter potential entrants and increase concentration in this formulation. Although industries with relatively high R&D intensity (e.g., electronics, chemical manufacturing, transport equipment, and

[19] Note that the Sargan statistic (also know as Hansen's J-statistic) was used to test the null hypothesis of no over-identification and the hypothesis was not rejected for all estimates, indicating that these GMM estimates are well-behaved (see Yang 2007 for details and for comparisons with alternative fixed effects' estimates that do not account for endogeneity). Three more points are also worth noting. First, when endogoneity is accounted for, coefficients on the exogenous sunk cost variable become significantly positive in all equations, lending support to Sutton's predictions described above. Second, the relationship between the price-cost margin and market structure remains the same (significantly positive) after considering the causality between PCM and market concentration. Third, the coefficient on the market growth variable becomes significant in all equations.

precision industries; see table 3) are often not highly concentrated, R&D intensity is positively related to concentration if other factors and endogeneity are properly controlled for. Technology imports also exert a significantly positive effect in the HHI equation, but an insignificant, positive effect in the CR4 equation. Thus, here again there is some indication of a positive association with the concentration bound, but the results are sensitive the measure of concentration.

Next, following Koeller's (2005) approach, this study divides the sample into 'technologically progressive' industries and 'technologically unprogressive' industries defined by the degree of R&D intensity. Because the system equations approach were sensitive to the presence of outliers (Uri, 1988), the median value of R&D intensity is used as the criterion for this distinction rather than mean.[20] GMM estimates for these subsamples are also shown Table 5.

The coefficients on R&D intensity are positive and significant in all estimates, suggesting a positive R&D – market structure nexus. On the other hand, the coefficient on the technology import variable is again sensitive to the measure of concentration, being significant in the HHI equations but not the CR4 equations. These results suggest the existence of a positive relationship between innovation and concentration, which is robust to the measure of concentration in the case of R&D. They also indicate that the same positive relationships between R&D and technology imports on the one hand, and concentration on the other, exist in both samples, but are somewhat stronger in the sample of industries with relatively low R&D intensity. The results with respect to technology imports further suggest that they matter to the size distribution of plants in the industry but not as much to the share of top plants in an industry.

[20] According to the mean of R&D intensity to divide the sample, only 66 industries are classified as technologically progressive industries, whereas there are 167 industries belonging to technologically unprogressive industries.

The magnitude of the coefficient on R&D intensity is about 2 times larger in the sample of industries with low R&D intensity than in the sample of industries with high R&D intensity. A similar, but even larger difference (about 4.7 times) is observed on the coefficient on technology imports in the HHI equations. This result is consistent with Koeller's (2005) finding that the effect of innovative activity on market structure is stronger in industries with relatively low technology intensity. It is also interesting to note that the magnitude of the coefficient on exogenous sunk costs is more than 2.5 times larger in industries with low R&D intensity than in industries with high R&D intensity. Similar to the results regarding barriers related to R&D and technology imports, this result suggests that entry barriers are particularly important in industries with low R&D intensity.

Finally, the simultaneous existence of positive relationships between technology imports and R&D on the one hand, and concentration on the other, suggests technology imports and R&D are complementary in the sense that the both create entry barriers and lead to higher concentration. However, larger plants tend to rely more on R&D, while smaller firms rely more on technology imports. This is an important reason why the significance of the coefficient on technology imports differs between the CR4 and HHI equations.

3.3.3. The Impact of Innovation on Market Structure Dynamics

Although the results of the forgoing analysis are generally consistent with traditional views regarding the innovation –market structure nexus, it is also important to ask how innovation affects the market structure dynamics. In other words, does innovation lead to higher or lower concentration over time in Taiwan? To address this question, this study extends Sutton's lower bound model in a disequilibrium model of concentration adjustment.[21]

The change in concentration is assumed to be a function of the actual concentration bound

[21] Sutton does not consider the process of adjustment of concentration and his model is a static equilibrium specification.

relative to steady-state concentration bound. Any deviation of the actual lower bound of concentration from its equilibrium level will result in an adjustment process. Because the time span in our dataset is rather short and continuous, the adjustment process is likely to be incomplete for the period. Econometrically, this accomplished by adding another control variable, the lagged lower concentration bound to the equation estimated in the previous section. However, the interpretation of the coefficients on R&D intensity and technology imports changes because we are now accounting for the dynamic adjustment process and in effect examining how changes in technology activity affect not concentration, not whether concentration is high in industries with high technology intensity.

When examining market structure dynamics, mutual causality among concentration innovation, and performance remains a crucial econometric problem that none of the studies reviewed above have dealt with. Thus, the within-plant, GMM estimator for dynamic panel models is used (Anderson and Hsiao 1982; Ahn and Schmidt 1995). Lagged values of R&D intensity, technology import intensity, and the price-cost margin are used as instrumental variables to generate the estimation results in bottom half of Table 6.

Although not reported in Table 6, coefficients on the lag of both lower bound concentration measures are significantly positive at the 1% level (see Yang 2007, Table 6). Thus, the null hypothesis of full adjustment to equilibrium during the 1-yaer interval is rejected. How fast does adjustment occur in Taiwan's industries? Does a rapidly growing, small open economy experience a particularly rapid or slow adjustment path? The estimated coefficient for lagged concentration is 0.758 in CR4 equation and 0.599 in the HHI equation, implying an annual adjustment rate of about 24% and 40%, respectively. Estimates by Bhattacharya and Bloch (2000) suggest an HHI adjustment rate of about 10% adjustment per annum for Australia in 1978-1985, which is higher than earlier estimates for the United States, the United Kingdom, and France.[22] Therefore, the speed of invisible hand is apparently much faster in Taiwan, which is rather consistent with the high rates of plant turnover illustrated in Table 4 above. This result suggests the rapidly growing, small, and open Taiwanese economy experiences faster adjustments of market structure than more developed industrialized countries and Australia. Moreover, the findings of Chen and Yang (1997) suggest an annual CR4 adjustment rate of about 26% for Taiwan's manufacturing in 1986-1991. Comparisons with these estimates further indicate that the speed of adjustment appears to have accelerated some compared to the late 1980s. In addition, coefficients on the other control variables (the sunk cost term, the price-cost margin, and the industry growth) are almost always positive and significant (the sunk cost term in one of the HHI equations being the only exception). This indicates that these factors also contribute to increased concentration over time.

After controlling for the adjustment speed and other factors, does innovation lead to higher or lower concentration? In the CR4 equation for all industries, the answer seems to be that innovation has no effect on the changes in concentration over time as coefficients on R&D intensity and technology imports are all very close to zero and statistically insignificant. In contrast, coefficients on both these variables are positive and significant in the HHI equations, suggesting that the effects of innovation on market structure dynamics are sensitive to the measure of concentration. This indicates that innovation leads to increased concentration over time, in addition to higher concentration at a given point in time. Moreover, the coefficient on technology imports is almost twice the size of the coefficient on R&D intensity in the HHI equation. In other words, technology imports appear to exert a much stronger effect on subsequent increases in concentration than R&D.

These above results seems to contradict previous studies that find innovation leads to lower CR4 ratios in the United Kingdom (Geroski and Pomroy, 1990) and Italy (Paci and Usai,

[22] For a review of the estimated speed of adjustment in matured economies, see Bhattacharya and Bloch (2000).

1998). On the other hand, it is more consistent with results from Delorme *et al* (2002), who find that lagged R&D intensity has a significantly positive impact on current HHI, that is, innovation leads to subsequent increases in this measure of concentration. The use of different measures of concentration may be one reason for the variety of results in previous studies and here as well. The CR4 index focuses on the combined market share of the largest four plants in an industry and does not capture the impact of average plant size in the industry. Alternatively, the HHI index pays more attention on the role of large plants because in it is the sum of the squares of market shares of all plants in an industry. Thus, if innovative activity contributes to the growth of sales, the change in HHI gives a larger weight to the effects of innovation by larger plants but a smaller weight to the impacts of innovation by small and medium-sized plants, which are quite numerous in Taiwan.[23]

More importantly, as discussed by Davies and Geroski (1997), Paci and Usai (1998), and Marslli and Verspagen (2002), as well as in previous sections, there are potentially important differences in the relationship between innovation and market structure dynamics across technological regimes. To investigate this possibility, industries are again classified by the degree of R&D intensity, using the median value of this indicator as the distinguishing criterion as in the previous section. Results of GMM estimates for these subsamples first suggest much more similar rates of adjustment across subsamples and CR4 or HHI equations, with adjustment coefficients varying between 0.80 and 0.83 in the CR4 equations and between 0.62 and 0.83 in the HHI equations (Table 6). Coefficients on the other control variables are again positive and significant in almost all equations, the coefficient on the sunk cost variable in the HHI equation for plants with high R&D being the sole exception.

Innovation variables, both R&D and technology imports, are also positively and significantly related to concentration in both the CR4 and HHI equations for industries with

[23] According to the 2001 census, for example, 98% of Taiwan's manufacturing plants had under 99 or fewer employees.

low R&D intensity and in the HHI equation for industries with high R&D intensity (Table 7). In contrast, the CR4 equation for industries with high R&D intensity suggests a significantly negative relationship to R&D and a weakly significant correlation with technology imports. The results thus suggest that innovative activity leads to higher concentration in industries with low R&D intensity, but that the relationship is sensitive to the measure of concentration in industries with high R&D intensity.

These results also highlight the importance of technological regimes for the innovation – market structure dynamics nexus. The most conspicuous difference between these regimes is the relatively strong relationship between innovation and market structure in industries with low R&D intensity. In both the CR4 and HHI equations, coefficients on the innovation variables are more than 10 times larger in absolute value for industries with low R&D intensity than for industries with high R&D intensity. The observation of a consistently positive relationship between innovation and concentration in industries with low R&D intensity contrasts with previous results, for Taiwan, but may be related to "innovation accumulation", where innovative activity is increasingly concentrated in large firms and plants (Yang and Huang, 2006).[24] These results are also consistent with the 'Schumpeter Mark II' hypothesis, which suggests that industries with low R&D intensity are often characterized by routinized regimes where innovation is usually concentrated in incumbents, leading to 'creative accumulation' that deters potential entrants.

On the other hand, the large differences between the results of the CR4 and HHI equations for industries with high R&D intensity are more difficult to explain. One potential cause of the relatively large sensitivity of the results to the measure of concentration is the relatively weak effects of both R&D and technology imports on concentration in this group of industries. In other words, although the CR4 results suggest significant (R&D) or weakly significant

[24] For example, in 1999 small and medium-sized plants accounted for 97% of the number of plants but only 30% of the R&D expenditures.

(technology imports) negative relationships to concentration, while the HHI results suggest significantly positive relationships, both results are suggest a relatively weak relationship, the nature of which is sensitive to the measure of concentration. However, together, the results for these industries cannot clarify whether 'creative destruction' prevails as suggested by the CR4 equations or whether 'creative accumulation' prevails as suggested by the HHI equation and both equations for industries with low R&D intensity.[25]

The relative magnitude of correlations between technological activities on the one hand, and concentration on the other, are also sensitive to the measure of concentration. In the CR4 equations, R&D has a larger effect on concentration than technology imports, but the opposite is true in the HHI equations. Differences between the effects of these two kinds of technological activities are relative large in industries with high R&D intensity and particularly small in the CR4 equation for industries with low R&D intensity.

3.4. Determinants of R&D Propensities in Electronics Plants

In the previous section, we have seen how R&D and technology imports tend to increase concentration at the industry level. In this section, we examine the other side of the coin, how industry-level concentration then affects plant-level R&D.

3.4.1. The Literature on Determinants of R&D Propensities

A very preliminary review of some recent studies of examining how concentration affects firm- and/or plant-level R&D (and sometimes other indicators of technological effort) follows below.

A couple of studies of firms in developed economies have found a negative relationship

[25] For example, as suggested by the CR4 equation, 'creative destruction' may prevail in Taiwan's R&D-intensive industries such as electronics, where large firms have expanded relatively rapidly in recent years.

between concentration and R&D propensities. For example, using a model based on Aghion and Howitt (1992), Gustavsson and Poldahl (2003) analyze the impact of various measures of competition on R&D in Swedish firms. They find that that competition is likely to contract firm R&D expenditures but they do not find strong evidence of the expected large-firm advantage in R&D through scale effects. In addition, firm R&D appears positively correlated with its own export and to the R&D-intensity of other firms within the same concern, indicating the existence of knowledge spillovers. 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. He also controls for the influences of firm size, market share, diversification, and trade protection. Trade protection also has a negative influence on R&D for manufacturing firms, while more focused firms and firms with operations in North American and European markets are found to have relatively high R&D intensities.

Although the above studies are among many positing a linear relationship between concentration and R&D intensities, Aghion, et al. (2005) is one of several studies finding an inverted-U relationship, where concentration is positively correlated with the number of citation-weighted patents in industries with relatively low concentration and positively correlated in industries with relatively high concentration in a panel of U.K. firms. One of the early studies examining the effect of competition on technological efforts in developing economies (Braga and Willmore 1991), also find evidence of an inverted-U relationship between competition and several discrete indicators of technological activities in Brazilian firms (whether firms obtain product design from a foreign source, whether firms obtain production engineering from a foreign source, or whether firms have a program of new product development). The also find that these indicators as well as the existence of R&D or quality control efforts tended to increase with foreign ownership, exports, & firms size. However, concentration had no significant effect on the presence of R&D efforts.

Similarly, Lundin et al. (2007) find an inverted-U relationship between R&D and firm-level price-cost margins (which are interpreted as an indicator of market competition) when using GMM estimators for Chinese high tech firms in 1998-2004. However, a similar relationship is not found in several other samples examined. On the other hand, lagged R&D intensity and skill intensity were positively related to current R&D intensity, while firm size was generally negatively related. Private firms and two classes of foreign joint ventures also tended to have relatively low R&D intensities, though these results were not always consistent.

Although he did not examine the relationship between industry-level competitions and R&D, Lall's (1983) analysis of R&D propensities of the 100 largest engineering firms in India is also of some relevance here. His results suggested that technological effort was positively influenced by the size, age and technical absorptive capacity of sample firms. Foreign ownership was found to promote R&D while export orientation reduced it. Similarly, Hu et al (2005) used production function estimates to examine the roles of domestic R&D, technology transfer, and foreign direct investment in medium and large firms in China. Their results show that in-house R&D significantly complements technology transfer regardless of whether of domestic or foreign origin. Foreign direct investment, which is assumed to be an important channel of proprietary technology transfer, does not facilitate the transfer of market-mediated foreign technology.

3.4.2. Determinants of R&D Propensities in Taiwan's Electronics plants

Table 7 presents some preliminary results for estimates of how industry level concentration, exporting propensities and foreign ownership affect R&D intensities in Taiwan's electronics plants that existed in all years 1997-2003.[26] As explained above this choice of sample is

[26] These preliminary estimates exclude plants in the 2-digit electric machinery subsector, but plants in this industry, which are often related to plants in other parts of the electronics industry and owned by firms operating in them, will be added in a revision.

rather standard and designed to take advantage of the panel techniques as well as to facilitate use of lagged variables as regressors or instruments to minimize problems related to simultaneity. However, the large turnover observed Taiwanese manufacturing (c.f., Table 4 above) means that this sampling technique has a very large penalty associated with it because one must through away information on plants that perform very large portions of the R&D in Taiwan. This may also create a serious sample selection bias as only 19 percent of the plants in our panel for 1998-2003 (1997 is omitted to facilitate use of lagged variables) had positive R&D whereas the corresponding figure in published data for all plants (Ministry of Economic Affairs, various years) was much higher at 30 percent. As explained in many of the studies reviewed above, there are important advantages to panel data in studies like this but it also seems that the dynamism of Taiwan's electronics industries may make cross sectional techniques more appropriate because they could allow for use of much more information.

The estimates in Table 7 first account for a number of plant-level characteristics thought to affect R&D as discussed in the literature review above. These controls include a dummy variable indicating whether a plant had a positive R&D in the previous year, the number of employees in the plant (a control for size), capital intensity of the plant, employment growth, profitability, firm age, and a dummy for new entrants with an age of four years or less. Results for these variables are not presented in Table 7 to conserve space but are available from the authors. Rather Table 7 focuses on the three industry-level influences of primary concern here, CR4, the export propensity and the foreign ownership share. Note that we have yet to investigate the possibility of an inverted-U relationship between CR4 and R&D intensity and that this should probably be considered in a revision.

A Tobit estimator was initially used because the R&D intensity is in principal a bounded variable. However, examination of the dataset revealed many plants with extremely large R&D intensities, which usually appear to result from small estimates of total revenues. Hence this procedure may have to be reconsidered. Simultaneity issues will also need close consideration in a revision.

Previous R&D experience, size, and capital intensity are all positively correlated with R&D intensity, as the dummy for new firms. On the other hand, firm age and profitability (price-cost margin) are usually negatively correlated with R&D intensity. Most of these results are as expected with the exception of the result for profitability.

Lagged concentration, measured as CR4, is then positively correlated with R&D intensity in all equations and periods (Table 7). In other words, this suggests that Taiwanese electronics plants are more likely to engage in R&D if they operate in relatively concentrated industries. This result is quite robust being observed in Tobit and weighted Tobit estimates for the full period 1998-2003 and two subperiods, 1998-1999 and 2002-2003. Here again we have important evidence of the positive nexus between innovation and concentration in Taiwan.

In marked contrast, coefficients on foreign ownership are almost never statistically significant. The one exception is the weighted Tobit estimate where the coefficient is negative. As explained in the previous section, one usually would want to use foreign ownership and as a plant-level control because we have firm expectations that MNCs are likely to be relatively technology intensive compared to non-MNCs. On the other hand, MNC affiliates abroad, especially those in developing countries, are often though to have relatively low R&D propensities. Moreover, industry-level MNC presence is likely to act more as a spillover measure, reflecting whether local plants will have higher or lower R&D as a result of larger foreign presence. However, even this effect is not clear in this sample because it contains local non-MNCs, local MNCs, and foreign MNCs. Hence, the failure to find a consistently significant relationship to MNC presence may not be surprising.

R&D propensities do appear to be relative high in plants operating in industries with large export propensities in 2002-2003, but industry-level export propensities have no significant effect on plant-level R&D in the full sample or in the earlier sample for 1998-1999. Further research is necessary to clarify the reasons for this finding but we speculate that it may have something to do with the large effects of the 2001 recession, which may have resulted in the greater concentration of R&D in plants operating in industries with relatively high export propensities.

Note: these results are still very tentative and this section may need to be completely redone

3.5. Conclusions

NOTE: The following conclusions apply to section 3.3 only. Major results from sections 3.2 and 3.4 will be added when the contents of those sections are clarified.

Analysis of the innovation – market structure nexus has been a longstanding issue of importance for industrial economists and the close interrelationships between innovation on the one hand, and market structure and its dynamics on the other, is well recognized. Although there are a large number of studies on investigating the static relationship between innovation and market concentration, there are fewer studies analyzing dynamic aspects of relationship between innovation and market structure. These relationships are particularly important in Taiwan because it is a small open economy in which technological progress and changes in market structure have been extremely rapid over the past two decades.

Utilizing a panel data for Taiwan's four-digit industries in 1997-2003 (excluding 2001) and a GMM estimator, this paper first analyzed the relationships among innovation and the level of concentration in several important ways not observed in most previous studies. First, it controlled for inter-industry heterogeneity and accounted for the mutual causation between innovation and concentration or changes in concentration. Moreover, this study distinguishes between two types of innovative activity R&D and technology imports. This distinction appears to be important because the effects of these two kinds of activity often differ greatly and are highly significant statistically. R&D intensity is always positively and significantly associated with concentration and the effect of R&D is usually quite a bit stronger than that of technology imports. On the other hand, results with respect to technology imports are sensitive to the measure of concentration, being significant in the HHI equations but not in the CR4 equations. Second, the analysis also distinguishes between industries with high R&D intensity and those with low R&D intensity. This distinction also appears to be important with the positive effect of R&D always being stronger in industries with relatively low R&D intensity. A similar result is obtained for technology imports when concentration is measured with HHI.

Next, the paper uses the same basic approach to analyze the effects of innovation on market structure dynamics. These results are particularly sensitive to the measure of concentration and to the distinction between industries with high R&D intensity and those with low R&D intensity. If no distinction among industries is made, all types of innovative activity have no significant effect on changes in concentration when measured by CR4 but lead increases in concentration when measured by HHI. However if low- and high-R&D industries are distinguished, the results changes markedly, again suggesting that this distinction is important. In industries with low R&D intensity, both types of innovative activity lead to higher concentration over time. The effect of R&D is stronger than the effect of technology imports when CR4 is used to measure concentration but weaker when HHI is the concentration measure. In industries with high R&D intensity, the results are qualitatively similar when HHI is used to measure concentration, the positive effect of R&D being weaker than the effect of imports. However, when CR4 is the concentration measure, results differ greatly with both R&D and technology imports leading to lower concentration and the effects of R&D being much stronger than the effects of technology imports.

These results thus suggest the coexistence of "creative destruction", where innovation leads to lower entry barriers, and "creative accumulation", where innovation leads to higher entry barriers, in Taiwan's manufacturing industries, though "creative accumulation" appears to be more common. However, the results leave several unanswered questions that should be addressed in future research. For example, does the sensitivity of the results to differences in concentration measures suggest that the innovation–market structure dynamics nexus is nonlinear? Alternatively, how would using a higher level of industrial aggregation affect the results given that many Taiwanese firms and plants produce a variety of products belonging to several different 4-digit industries?

Although this study leaves these and several other questions unanswered, the results do have one important policy implication regarding interactions between competition policy and policies to promote innovative activity and increase technological capabilities. On the one hand, the government has generally provided strong incentives to all firms to engage in innovative activity. These include tax incentives, R&D grants, and other types of financial assistance. The results of this paper suggest that innovative activity has generally been concentrated in larger firms and that these incentives are thus likely to have contributed to higher concentration and to increases in concentration over time, especially in industries with low R&D intensity. On the other hand, the major aim of competition policy and the Fair Trade Law is to insure that large firms do not exert excessive market power and engage in uncompetitive practices. This creates a potential conflict between these two important policy goals. On possible way of resolving the conflict is to target incentives for innovative activity more heavily on small and medium enterprises. In this way, policies can become more consistent, allowing Taiwan to benefit both from more rapid technological progress and the maintenance of competitive markets.

References

Aghion, P. and Howitt, P. 1992. A Model of Growth Through Creative Destruction. Econometrica, 60(2), 323-351.

Aghion, P. and Howitt, P. 1999. *Endogenous Growth Theory*. Cambridge, MA: MIT Press.

Aghion, Philippe, Nick Bloom, Richard Blundell, Rachel Griffith, and Peter Howitt (2005), “Competition and Innovation: An Inverted-U Relationship”, *Quarterly Journal of Economics*, ??(2), 701-728

Ahn, S.C. and P. Schmidt (1995), Efficient Estimation of Models for Dynamic Panel Data, *Journal of Econometrics*, 68, 5-27.

Anderson, T.W. and C. Hsiao (1982), Formulation and Estimation of Dynamic Models Using Panel Data, *Journal of Econometrics*, 18, 47-82.

Anderson, P. and M.L. Tushman (1990), Technological Discontinuities and Dominant Designs: A Cyclical Model of Technological Change, *Administrative Science Quarterly*, 35, 604-633.

Bhattacharya, M. and H. Bloch (2000), The Dynamics of Industrial Concentration in Australian Manufacturing, *International Journal of Industrial Organization*, 18, 1181-1199.

Bureau of Economic Analysis (2005), *U.S. Direct Investment Abroad: Operations of U.S. Parents and Their Foreign Affiliates, Revised 2001 Estimates.* Washington, D.C.: Bureau of Economic Analysis.

Braga, Helson and Larry Willmore (1991), "Technological Imports and Technological Effort: An Analysis of their Determinants in Brazilian Firms" *Journal of Industrial Economics*, 39(4), pp. 421-432.

Chang, C.L. and S. Robin (2004), Doing R&D and Importing Technology: An Empirical Investigation on Taiwan’s Manufacturing Firms, Paper Presented at the 21st Journees de Microeconomie Appliquee, Lillee, France.

Chen, J.R. and C.H. Yang (1997), The Dynamic Evolution of Market Structure – Evidence from Taiwan’s Manufacturing, *Academia Economic Papers*, 25(3), 351-373.

China Credit Information Service (various years), *The Largest Corporations in Taiwan*, 1997-2007 issues. Taipei: China Credit Information Service.

Connolly, R.A. and M. Hirschey (1984), R&D, Market Structure and Profit: A Value-Based Approach, *Review of Economics and Statistics*, 66, 682-686.

Davies, S.W. and P. Geroski (1997), Changes in Concentration, Turbulence, and the Dynamic of Market Shares, *Review of Economics and Statistics*, 79(3), 383-391.

Delorme Jr., C.D., D.R. Kamerschen, P.G. Klein and L.F. Voeks (2002), Structure, Conduct and Performance: A Simultaneous Equations Approach, *Applied Economics*, 34(17), 2135-2142.

Directorate-General of Budget Accounting and Statistics (1998), *The Report on 1996 Industry, Commerce and Service Census Taiwan-Fukien Area, The Republic of China*, Vol. 1 General Report and Vol. 3 Manufacturing. Taipei: Directorate-General of Budget Accounting and Statistics.

Directorate-General of Budget Accounting and Statistics (2003), *The Report on 2001 Industry, Commerce and Service Census Taiwan-Fuchien Area, The Republic of China*, Vol. 1 General Report and Vol. 3 Manufacturing. Taipei: Directorate-General of Budget Accounting and Statistics.

Farber, S. (1981), Buyer Market Structure and R&D Effort: A Simultaneous Equation Model, *Review of Economics and Statistics*, 63, 336-345.

Geroski, P.A. and R. Pomroy (1990), Innovation and the Evolution of Market Structure, *Journal of Industrial Economics*, 38(3), 299-314.

Geroski, P.A., R.T. Masson and J. Shaanan (1987), The Dynamics of Market Structure, *International Journal of Industrial Organization*, 5(1), 1987, 93-100.

Gustavsson, Patrik and Andreas Poldahl (2003). Determinants of Firm R&D: Evidence from Swedish Firm Level Data, FIEF Working Paper Series 2003, No. 190.

Hu, Albert G. Z., Gary H. Jefferson and Qian Jinchang (2005), R&D and Technology Transfer: Firm-Level Evidence from Chinese Industry, *Review of Economics and Statistics,* November, 87(4), 780–786

Koeller, C.T. (1995), Innovation, Market Structure and Firm Size: A Simultaneous Equations Model, *Managerial and Decision Economics*, 16(3), 259-269.

Koller, C.T. (2005), Technological Opportunity and the Relationship and Innovation Output and Market Structure, *Managerial and decision Economics*, 26(3), 209-222.

Lall, Sanjaya (1983), Determinants of R&D in an LDC: The Indian Engineering Industry, *Economc Letters*, 13(?), 379-383.

Levy, D. (1985), Specifying the Dynamics of Industrial Concentration, *Journal of Industrial Economics*, 34(1), 55-68.

Lundin, Nannan, Fredrik Sjöholm, Ping He, and Jinchang Qian (2007), FDI, Market Structure and R&D Investments in China, Working Paper Series 2007-04, International Centre for the Study of East Asian Development, Kitakyushu.

Lunn, J. (1989), R&D, Concentration and Advertising: A Simultaneous Equations Model, *Managerial and Decision Economics*, 10(2), 101-105.

Lyons, B.R. and C. Matraves (1996), Industrial Concentration, in Davies, S.W. and Lynos, B.R. *et al*., *Industrial Organization in the European Union: Structure, Strategy and the Competitive Mechanism*, Oxford University Press, Oxford.

Malerba, F. (2007), Innovation and the Dynamics and Evolution of Industries: Progress and Challenge, *International Journal of Industrial Organization*, 25(4), 675-699.

Malerba, F. and L. Orsenigo (1997), Technological Regimes and Sectoral Patterns of Innovative Activities, *Industrial and Corporate Change*, 6, 83-117.

Marsili, O. and B. Verspagen (2002), Technology and the Dynamics of Industrial Structures: An Empirical Mapping of Dutch Manufacturing, *Industrial and Corporate Change*, 11(4), 791-815.

Matraves, C. (1999), Market Structure, R&D and Advertising in the Pharmaceutical Industry, *Journal of Industrial Economics*, 47, 169-194.

Ministry of Economic Affairs (2001), *The Statistic Yearbook of Small and Medium Enterprises 2001*, Taipei: Ministry of Economic Affairs.

Ministry of Economic Affairs (2002), *A Survey of Overseas Chinese and Foreign Firms and Their Effects on National Economic Development*, 2001 issue. Taipei: Investment Commission (in Chinese).

Ministry of Economic Affairs (various years), *Report on the Survey of Industry*, 1997-2000 and 2001-2005 issues. Taipei: Ministry of Economic Affairs (in Chinese).

National Science Council (2007), *Indicators of Science and Technology*. Taipei: National Science Council.

Nelson, R.R. and S.G. Winter (1977), In Search of a Useful Theory of Innovation, *Research Policy*, 6, 36-76.

Nelson, R.R. and S.G. Winter (1982), *An Evolutionary Theory of Economic Change*, Belknap Press of Harvard University Press: Cambridge, MA.

Nelson, R.R. and S.G. Winter (1988), Force Generating and Limiting Concentration under Schumpeterian Competition, *Bell Journal of Economics*, 9, 524-548.

Paci, R. and S. Usai (1998), Innovation Effect, Technological Opportunity and Changes in Market Structure in Italian Manufacturing, *Economics of Innovation and New Technology*, 7(4), 345-369.

Research Institute of Economy, Trade and Industry (RIETI), 2007. "Foreign Direct Investment Database [Kaigai Chokusetu Toshi Database]", data downloaded 12 July from www.rieti.go.jp (in Japanese).

Resende, M. (2007), Structure, Conduct and Performance: A Simultaneous Equations Investigation for the Brazilian Manufacturing Industry, *Applied Economics*, 39(7), 937-942.

Robinson, W.T. and J. Chiang (1996), Are Sutton's Predictions Robust? Empirical Insights into Advertising, R&D, and Concentration, *Journal of Industrial Economics*, 44, 389-408.

Scherer, F.M. and D. Ross (1990), *Industrial Market Structure and Economic Performance*, 3rd ed, Houghton Mifflin, Boston.

Sutton, J. (1991), *Sunk Costs and Market Structure－Price Competition*, *Advertising and Evolution and Concentration*, MIT Press, Cambridge, Mass.

Sutton, J. (1996), Technology and Market Structure, *European Economic Review*, 40, 511-530.

Sutton, J. (1997), Gibrat's Legacy, *Journal of Economic Literature*, 35, 40-59.

Trajtenberg, M. (2001), Innovation in Israel, 1968-97: A Comparative Analysis Using Patent Data, *Research Policy*, 30, 363-389.

Uri, N.D. (1988), A Re-examination of the Relationship between Industry Structure and Economic Performance, *Applied Economics*, 20(10), 1383-1400.

Van Cayseele, P.J.G. (1998), Market Structure and Innovation: A Survey of the Last Twenty Years, *De Economist*, 143 (3), 391-417.

Wagner, J. and J.M.G. von der Schulenburg (1992), Unobservable Industry Characteristics and the Innovation-Concentration-Advertising-Maze: Evidence from an Econometric Study Using Panel Data for Manufacturing Industries in the FRG, 1979-1986, *Small Business Economics*, 4(4), 315-326.

Yang, C.H. and CH. Huang (2006), Persistence of Innovation in Taiwan's Manufacturing: Do Technological Opportunities Matter? Paper presented at the 2006 International Conference of Business, Economics and Management Disciplines, Beijing, China.

Yang, C.H. and C.C Kuo (2007), Lower Bounds of Concentration in Taiwan Manufacturing: Do Exports Matter? *Applied Economics*, 39 (18), 2389-2401.

Yang, C.H. (2007), Innovation and Market Structure Dynamics in Taiwan's Manufacturing, Working Paper Series 2007-22, International Centre for the Study of East Asian Development, Kitakyushu.

Yoon, S. (2004), A Note on the Market Structure and Performance in Korean Manufacturing Industries, *Journal of Policy Modeling*, 26, 733-746.

World Bank (2008). *World Development Indicators 2008*. Washington, D.C.: World Bank.

Table 1: Total Revenue and Shares of Total Revenues (percent, annual averages)

	CR4 plants		Firms in 2001		
Industry	1998-99	2002-03	CR4	Exports	Foreign
TOTAL REVENUE (NT$ billions)					
Manufacturing total	8,564	10,224		10,500	
Electronics-related	3,034	4,194		4,224	
CONCENTRATION RATIOS AND EXPORT OR MNC SHARES (percent)					
Manufacturing, average of 2-digit units	17	19	25	33	6
Manufacturing, mean of 2-digit categories	20	22	26	27	4
Food & beverages	12	12	23	9	3
Tobacco	97	100	100	1	0
Textile mills	11	14	11	23	1
Apparel	6	9	11	48	2
Leather & furs	15	23	26	39	3
Wood & bamboo	9	13	9	18	1
Furniture	11	10	13	43	2
Pulp & paper	13	16	28	7	3
Printing	12	8	8	5	1
Chemical materials	19	25	39	25	9
Chemical products	13	10	10	19	11
Petroleum & coal	91	88	97	3	3
Rubber products	19	24	37	34	5
Plastic products	13	16	28	26	3
Non-metallic mineral products	8	8	23	11	2
Basic metals	21	26	25	11	1
Fabricated metals	3	8	7	27	3
General machinery	5	3	9	31	5
Computers, communication, audio, video	15	14	19	57	7
Electronic parts & components	20	16	24	44	9
Electric machinery	12	12	18	34	5
Transport machinery	23	27	26	37	4
Precision machinery	22	28	28	50	9
Miscellaneous manufacturing	6	9	15	46	4

Table 1 (continued)

Industry	Concentration Ratios			2001 Shares	
	1998-99	2002-03	2001	Exports	Foreign
CONCENTRATION RATIOS AND EXPORT OR MNC SHARES (percent)					
Electronics-related, average of 4-digit units	40	36	46	51	8
Electronics-related, mean of 4-digit categories	40	40	46	44	7
Computers	56	39	56	70	7
Computer terminal equipment	64	73	64	72	10
Computer peripheral equipment	30	24	42	58	4
Computer components	29	21	41	60	8
Other computer components	34	62	41	39	0
Wired communication equipment	35	37	42	52	7
Telecommunication equipment	32	46	66	59	9
Television sets & video tape recorders	71	71	82	20	1
Record player & radio tape recorders	30	37	47	62	17
Other video & radio electronics	48	41	32	61	0
Data storage equipment	51	24	71	48	2
Semiconductors	38	32	39	41	11
Electronic passive devices	39	17	59	44	10
Bare printed circuit boards	23	17	25	32	2
Electronic tubes	62	81	81	30	25
Photonics materials & components	63	46	45	46	14
Other electronic parts & components	25	22	31	57	8
Power generation, transmission & distrib. mach.	27	28	42	24	6
Electric wires & cables	26	27	36	32	5
Air conditioning equipment	61	58	57	24	13
Laundering machines & equipment	63	72	96	26	1
Electric heating appliances	30	49	23	33	0
Electric fans	23	32	25	49	0
Other electrical appliances & housewares	27	36	30	40	0
Light bulbs & tubes	37	59	67	29	4
Lighting fixtures	15	15	13	37	2
Batteries	45	38	42	47	11
Other electronic appliances	10	13	20	38	10
Measuring instruments & controlling equipment	27	26	25	45	4
Other precision machinery	39	24	24	2	0
Photographic equipment	60	62	54	53	16
Spectacles & lens	22	33	26	50	15
Other photographic & optical equipment	93	77	92	66	0
Medical materials & equipment	25	25	35	53	8
Watches & clocks	23	30	31	59	7

Sources: Directorate-General of Budget, Accounting and Statistics (2003) and authors' compilations from underlying firm-level data; Ministry of Economic Affairs (various years) and authors' compilations from underlying plant-level data; National Science Council (2008)

Table 2: R&D Expenditures and R&D-Sales Ratios (annual averages)

Industry	All plants		CR4 plants	
	1998-99	2002-03	1998-99	2002-03
R&D EXPENDITURES (NT$ billions)				
NSC estimates, Taiwan total	183	234	-	-
Business enterprise, NSC estimate	-	146	-	-
Manufacturing	-	135	-	-
Sample plants, Manufacturing total	112	169	20	32
Electronics-related	75	132	12	24
R&D-SALES RATIOS (percent)				
Manufacturing, average for all sample plants	1.2	1.6	1.4	1.7
Manufacturing, mean of 2-digit categories	0.9	1.0	1.1	1.2
Food & beverages	0.4	0.3	0.9	0.2
Tobacco	0.1	0.0	0.1	0.0
Textile mills	0.5	0.4	1.2	0.8
Apparel	0.3	0.3	1.2	1.1
Leather & furs	0.9	1.6	3.3	5.0
Wood & bamboo	0.1	0.1	0.0	0.1
Furniture	0.5	0.4	1.5	1.3
Pulp & paper	0.3	0.2	0.3	0.3
Printing	0.3	0.5	0.1	1.0
Chemical materials	0.7	0.5	0.4	0.3
Chemical products	1.5	1.7	0.2	0.5
Petroleum & coal	0.6	0.0	0.0	0.0
Rubber products	1.1	1.0	1.8	1.2
Plastic products	0.7	0.7	1.2	1.1
Non-metallic mineral products	0.6	0.4	0.3	0.2
Basic metals	0.3	0.3	0.6	0.5
Fabricated metals	0.4	0.3	1.5	0.2
General machinery	0.8	0.8	0.6	0.7
Computers, communication, audio, video	2.1	2.7	2.0	2.1
Electronic parts & components	3.5	3.7	2.8	5.4
Electric machinery	1.2	1.5	1.5	2.1
Transport machinery	1.4	1.4	2.3	1.9
Precision machinery	1.8	3.1	3.0	2.8
Miscellaneous manufacturing	0.6	0.9	0.3	1.0

Table 2 (continued)

Industry	All plants		CR4 plants	
	1998-99	2002-03	1998-99	2002-03
R&D-SALES RATIOS (percent)				
Electronics-related, average for all sample plants	2.4	3.0	2.2	3.2
Electronics-related, mean of 4-digit categories	1.9	2.4	2.0	2.5
Computers	2.1	2.0	2.1	2.5
Computer terminal equipment	1.6	2.2	1.4	2.0
Computer peripheral equipment	2.5	3.1	1.8	1.4
Computer components	2.0	2.3	1.0	1.8
Other computer components	1.7	2.8	0.9	2.9
Wired communication equipment	3.9	4.6	1.9	3.6
Telecommunication equipment	4.3	5.0	3.8	4.4
Television sets & video tape recorders	1.6	1.8	1.5	1.1
Record player & radio tape recorders	1.3	1.7	1.2	1.9
Other video & radio electronics	1.6	2.4	1.7	1.3
Data storage equipment	1.9	3.1	1.5	3.3
Semiconductors	4.8	4.8	3.2	5.9
Electronic passive devices	1.0	2.5	1.2	4.8
Bare printed circuit boards	1.2	1.1	1.0	1.4
Electronic tubes	5.4	3.5	6.7	3.7
Photonics materials & components	4.1	3.1	1.9	2.6
Other electronic parts & components	1.9	3.1	5.4	4.0
Power generation, transmission & distrib. mach.	1.4	1.6	1.0	1.5
Electric wires & cables	0.5	0.7	0.3	0.2
Air conditioning equipment	2.0	2.1	2.0	2.9
Laundering machines & equipment	0.0	0.0	0.0	0.0
Electric heating appliances	1.8	1.5	2.8	2.2
Electric fans	1.2	1.1	1.0	2.1
Other electrical appliances & housewares	0.6	1.6	1.3	2.5
Light bulbs & tubes	0.7	1.6	0.9	1.9
Lighting fixtures	0.7	1.1	1.2	2.9
Batteries	1.5	2.6	1.1	1.0
Other electronic appliances	1.5	1.4	3.7	2.8
Measuring instruments & controlling equipment	1.8	2.7	2.5	2.3
Other precision machinery	1.4	2.1	2.5	1.6
Photographic equipment	2.7	3.8	2.7	3.1
Spectacles & lens	0.3	1.9	0.7	3.4
Other photographic & optical equipment	3.6	4.3	3.9	3.7
Medical materials & equipment	2.3	3.1	1.7	2.1
Watches & clocks	0.9	0.9	2.8	1.1

Sources: Ministry of Economic Affairs (various years) and authors compilations from underlying plant-level data; National Science Council (2008)

Table 3: Technology Acquistions and Propensities (annual averages)

	All plants		CR4 plants	
Industry	1998-99	2002-03	1998-99	2002-03
TECHNOLOGY ACQUISITIONS (NT$ billions)				
Sample plants, Manufacturing total	41	52	9	13
Electronics-related	31	39	5	7
RATIOS TO TOTAL SALES (percent)				
Manufacturing, average for all sample plants	0.5	0.5	0.6	0.7
Manufacturing, mean of 2-digit categories	0.2	0.3	0.4	0.4
Food & beverages	0.1	0.1	0.0	0.0
Tobacco	0.0	0.0	0.0	0.0
Textile mills	0.1	0.1	0.2	0.1
Apparel	0.0	0.1	0.0	0.0
Leather & furs	0.0	0.0	0.0	0.0
Wood & bamboo	0.0	0.2	0.0	1.3
Furniture	0.0	0.0	0.0	0.0
Pulp & paper	0.1	0.2	0.3	0.4
Printing	0.1	0.0	0.0	0.0
Chemical materials	0.2	0.1	0.2	0.1
Chemical products	0.4	0.7	0.4	0.8
Petroleum & coal	0.0	0.1	0.0	0.0
Rubber products	0.1	0.2	0.3	0.2
Plastic products	0.0	0.3	0.1	0.2
Non-metallic mineral products	0.1	0.1	0.2	0.0
Basic metals	0.1	0.1	0.3	0.4
Fabricated metals	0.0	0.0	0.2	0.1
General machinery	0.1	0.1	0.7	0.3
Computers, communication, audio, video	0.7	0.4	0.5	0.2
Electronic parts & components	2.2	1.5	1.6	2.0
Electric machinery	0.2	0.4	0.8	0.9
Transport machinery	0.7	1.0	1.8	2.3
Precision machinery	0.1	0.2	0.1	0.0
Miscellaneous manufacturing	0.1	0.2	0.8	0.7

Table 3 (continued)

Industry	All plants		CR4 plants	
	1998-99	2002-03	1998-99	2002-03
R&D-SALES RATIOS (percent)				
Electronics-related, average for all sample plants	1.1	0.9	1.0	1.1
Electronics-related, mean of 4-digit categories	0.7	0.5	0.9	0.6
Computers	0.5	0.3	0.5	0.5
Computer terminal equipment	0.7	0.4	1.4	0.5
Computer peripheral equipment	0.2	0.4	0.1	0.6
Computer components	0.4	0.4	0.0	0.5
Other computer components	0.1	0.2	0.0	0.3
Wired communication equipment	0.6	0.4	0.5	0.6
Telecommunication equipment	0.1	0.8	0.1	1.2
Television sets & video tape recorders	1.2	2.5	0.9	0.3
Record player & radio tape recorders	0.2	0.1	0.3	0.1
Other video & radio electronics	0.4	0.4	0.7	0.7
Data storage equipment	6.1	0.7	0.4	0.6
Semiconductors	3.7	2.1	1.9	2.7
Electronic passive devices	0.3	0.4	0.7	1.0
Bare printed circuit boards	0.2	0.1	0.1	0.1
Electronic tubes	2.2	1.7	3.3	1.9
Photonics materials & components	2.5	1.6	6.4	1.3
Other electronic parts & components	0.1	0.8	0.1	2.0
Power generation, transmission & distrib. mach.	0.2	0.6	0.2	0.4
Electric wires & cables	0.1	0.1	0.1	0.1
Air conditioning equipment	0.7	0.8	1.0	1.2
Laundering machines & equipment	0.0	0.0	0.0	0.0
Electric heating appliances	0.3	0.4	0.8	0.8
Electric fans	0.1	0.0	0.1	0.0
Other electrical appliances & housewares	0.1	0.3	0.4	0.8
Light bulbs & tubes	0.1	0.1	0.1	0.0
Lighting fixtures	0.1	0.1	0.0	0.0
Batteries	1.1	0.6	1.0	0.6
Other electronic appliances	0.1	0.1	10.2	0.0
Measuring instruments & controlling equipment	0.0	0.3	0.2	0.7
Other precision machinery	0.1	0.0	0.0	0.0
Photographic equipment	0.2	0.2	0.0	0.0
Spectacles & lens	0.1	0.1	0.0	0.1
Other photographic & optical equipment	0.8	0.3	0.2	0.2
Medical materials & equipment	0.0	0.2	0.1	0.0
Watches & clocks	0.0	0.0	0.0	0.0

Sources: Ministry of Economic Affairs (various years) and authors compilations from underlying plant-level data; National Science Council (2008)

Table 4: Shares New Entrants in 2003 R&D Expenditures, Technology Aquisitions and Sales
Exiting Plants in 1998 R&D Expenditures, Technology Acquisitions, and Sales (percent)

	Entrants 2003			Exiters 1998		
Industry	R&D	Aqu.	Sales	R&D	Aqu.	Sales
Manufacturing, average for all sample plants	37	36	29	25	23	23
Manufacturing, mean of 2-digit categories	24	26	22	17	23	21
Food & beverages	30	15	16	9	65	13
Tobacco	0	-	0	0	-	3
Textile mills	7	40	12	18	10	15
Apparel	12	17	27	16	14	31
Leather & furs	39	0	17	10	100	25
Wood & bamboo	11	0	12	19	8	26
Furniture	18	10	19	20	13	33
Pulp & paper	1	0	10	15	8	16
Printing	9	73	31	41	100	30
Chemical materials	17	20	16	2	2	4
Chemical products	27	25	17	11	7	18
Petroleum & coal	77	49	41	0	0	1
Rubber products	14	0	16	8	2	14
Plastic products	17	41	20	9	3	19
Non-metallic mineral products	17	8	19	30	3	17
Basic metals	22	2	19	18	0	17
Fabricated metals	29	16	21	16	9	22
General machinery	32	23	26	24	21	23
Computers, communication, audio, video	51	71	48	43	57	47
Electronic parts & components	35	35	41	22	20	22
Electric machinery	30	44	21	31	23	23
Transport machinery	12	8	13	7	1	17
Precision machinery	62	70	43	29	62	33
Miscellaneous manufacturing	18	22	22	20	2	25

Table 4 (continued)

Industry	Entrants 2003			Exiters 1998		
	R&D	Aqu.	Sales	R&D	Aqu.	Sales
Electronics-related, average for all sample plants	42	43	42	32	28	34
Electronics-related, mean of 4-digit categories	46	49	39	32	46	33
Computers	71	92	58	62	73	57
Computer terminal equipment	9	2	8	55	92	54
Computer peripheral equipment	47	25	52	25	65	25
Computer components	50	53	51	40	5	55
Other computer components	18	66	19	62	82	54
Wired communication equipment	57	65	60	29	44	49
Telecommunication equipment	76	96	80	33	100	47
Television sets & video tape recorders	91	100	65	45	100	55
Record player & radio tape recorders	39	69	43	36	11	40
Other video & radio electronics	69	64	69	52	1	33
Data storage equipment	74	72	72	22	27	39
Semiconductors	21	20	28	23	18	19
Electronic passive devices	22	17	28	31	79	31
Bare printed circuit boards	41	10	32	4	0	14
Electronic tubes	61	38	47	16	10	23
Photonics materials & components	81	94	82	57	99	55
Other electronic parts & components	40	7	43	23	98	35
Power generation, transmission & distrib. mach.	19	76	15	35	40	27
Electric wires & cables	25	6	10	8	9	10
Air conditioning equipment	23	7	25	13	17	13
Laundering machines & equipment	-	-	43	-	-	12
Electric heating appliances	33	0	16	10	3	35
Electric fans	0	37	11	37	4	27
Other electrical appliances & housewares	41	8	27	25	0	26
Light bulbs & tubes	24	89	20	55	43	30
Lighting fixtures	56	78	31	64	100	35
Batteries	63	32	55	32	14	27
Other electronic appliances	32	5	22	47	42	31
Measuring instruments & controlling equipment	39	74	41	16	0	33
Other precision machinery	93	21	51	20	100	30
Photographic equipment	69	57	58	47	95	39
Spectacles & lens	27	1	14	13	0	26
Other photographic & optical equipment	71	99	28	0	100	3
Medical materials & equipment	76	84	64	22	12	37
Watches & clocks	13	100	14	35	81	43

Sources: Ministry of Economic Affairs (various years) and authors compilations from plant-level data underlying this source; National Science Council (2008)

Table 5 Estimates of Innovation – Market Concentration Nexus from Previous Studies

Study	Country	Period	No. of equations	Estimated innovation–market structure nexus
Connolly and Hirschey (1984)	US	1977	4 (concentration, advertising intensity, R&D intensity, relative excess value)	+
Uri (1988)	US	1977	4 (concentration, advertising expenditures, R&D expenditure, profitability)	+
Lunn (1989)	US	1973-1976	3 (R&D spending, market structure, advertising.)	+ (weak)
Wagner and von der Schulenburg (1992)	Germany	1979-1986	3 (innovation, advertisement, market concentration)	+
Koller (1995)	US	1977-1982	2 (innovation and market concentration)	+ (weak)
Koller (2005)	US	1982	2 (concentration, innovation)	+
Resende (2007)	Brazil	1996	4 (concentration, advertising expenditures, R&D expenditure, profitability)	No

Table 6: The Effects of R&D, Technology Imports, Exporting, and Foreign Ownership on Producer Concentration: Industry-level, GMM Estimates for 1997-2000, 2002-2003, after Controlling the Effects of Entry Barriers, Growth, Profitability, and Lagged Concentration

	All Industries		High R&D Industries		Low R&D Industries	
Determinant	CR4 Determinant	HHI Determinant	CR4 Determinant	HHI Determinant	CR4 Determinant	HHI Determinant
STATIC ESTIMATES (lagged concentration not controlled for)						
R&D Intentsity	0.030 ***	0.040 **	0.042 ***	0.050 ***	0.090 ***	0.101 ***
Technology Import Intensity	-0.008	0.033 ***	0.004	0.022 ***	0.003	0.103 ***
DYNAMIC ESTIMATES (lagged concentration controlled for)						
R&D Intentsity	-0.006	0.018 **	-0.013 ***	0.012 ***	0.144 ***	0.258 ***
Technology Import Intensity	-0.002	0.033 ***	-0.003 *	0.024 ***	0.112 ***	0.007 ***
Number of 4-digit Industries	233	233	117	116	117	116

Note: ***=significant at 1 percent level; **=signficant at 5 percent level; *=significant at 10 percent level.

Table 7: The Effects of Industry-Level Concentration, Export Propensity, and MNC Presence on R&D Propensities in Incumbent Plants

Explanatory variable	Tobit Estimation				Weighted Tobit Estimation			
	Eq. (1)	Eq. (2)	Eq. (3)	Eq. (4)	Eq. (1)	Eq. (2)	Eq. (3)	Eq. (4)
1998-2003 (21,495 total observations and 4,113 postive observations), cross section estimates								
Lagged Concentration	2.795***	2.901***	2.784***	2.913***	2.770***	2.872***	2.722***	2.900***
Export Propensity	-	0.005	-	0.012	-	0.005	-	0.016*
MNC Presence	-	-	-0.002	-0.031	-	-	-0.009	-0.046
1998-2003 (21,495 total observations and 4,113 postive observations), panel estimates								
Lagged Concentration	0.633***	0.698***	0.676***	0.698***	-	-	-	-
Export Propensity	-	0.004*	-	0.004	-	-	-	-
MNC Presence	-	-	0.009	-0.002	-	-	-	-
1998-1999 (8,601 total observations and 1,713 positive observations), cross section estimates								
Lagged Concentration	2.494**	2.323**	2.584**	2.600**	2.597**	2.437**	2.629**	2.625**
Export Propensity	-	-0.009	-	-0.031*	-	-0.008	-	-0.024
MNC Presence	-	-	0.010	0.074	-	-	-0.003	0.051
2002-2003 (8,574 total observations and 1,485 positive observations), cross section estimates								
Lagged Concentration	4.109***	4.884***	4.225***	5.326***	3.691***	4.890***	3.787***	5.534***
Export Propensity	-	0.022**	-	0.051**	-	0.023**	-	0.063***
MNC Presence	-	-	0.024	-0.123*	-	-	0.011	-0.159**

Weighted estimates use lagged employment (size), current capital intensity, and lagged *CR4* as weights.