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Abstract:
This paper examines the relationship between innovation and market structure and dynamics in Taiwan's manufacturing industries. In order to account for the causality between innovation and market structure and to deal with the problems caused by heterogeneity among industries, the generalized method of moment for (dynamic) panel data model is employed in this study. Meanwhile, I use the concept of technological regimes to examine the effect of innovation on market structure within high and low R&D intensity industries. The results show that innovation is positive related to market structure and the strength of the relationship is stronger in industries with relatively low R&D intensity. In samples containing all industries, R&D intensity seems to have no effect on market structure dynamics. However, in samples of industries with relatively high R&D intensity, R&D intensity is negatively correlated with concentration, whereas a positive correlation is observed in industries with relatively low R&D intensity. This result suggests that it is important to distinguish the nature of technological regimes when investigating the innovation–market structure dynamics nexus.

Key Words: Innovation, R&D, Technology import, Market Structure Dynamic
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1. Introduction

Market structure is a key topic in the field of industrial organization. Its importance is reflected in both the structure-conduct-performance (SCP) paradigm of the Harvard tradition and game theoretical approach of the 'New Empirical Industrial Organization' (NEIO), which both analyze the structural characteristics of markets and their determinants. Among the major determinants of market structure, the role of innovation is thought to be particularly important when an economy undergoes rapid technological change. Although it is widely recognized that innovation has an important influence on market structure and most of studies suggest that innovation is positive related to concentration, there are only a few studies that analyze the impact of innovation on market structure dynamics.

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 both in-house R&D and technology imports from advanced countries, Taiwanese firms have successfully in closed the technological gap between them and their counterparts in developed countries, especially in the electronics industry. This is evident from Trajtenberg's (2001) analysis of the international distribution of patents granted by various authorities, for example. 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. The purpose of this paper is thus to fill this gap in the literature by trying to answer two central questions. First, is there as a positive innovation – market structure nexus, or in other words, a positive correlation between innovation and concentration? Second, does innovation lead to higher concentration or lower concentration in subsequent years?

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.[1] 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.

This study attempts to contribute to the empirical literature in three respects. First, the study of Taiwan, which is characterized by rapid technological change and fast adjustment of market structure, can provide new evidence advancing understanding of the innovation – market structure dynamics nexus. Second, the panel data used in this study allows us to control for industry heterogeneity. Moreover, the technique of Generalized Method of

1 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).

Moment (GMM) is employed to deal with the potential causality between innovation and market structure. Third, I use the concept of technological regimes as the guiding framework to investigate the effect of innovation on market structure dynamics, aiming to test whether innovation has different effects on market structure dynamics in different technological regimes. To this end, section 2 briefly reviews the literature on the relationship between innovation and market structure dynamics. Section 3 describes the data, highlights the patterns and trends observed in market structure and innovative activity for Taiwan's manufacturing industries. The static relationship between innovation and market structure is examined in section 4 and section 5 investigates the impact of innovation on market structure dynamics. The final section offers some concluding remarks and policy implications.

2. Literature Review

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 increased or decreased concentration over time.

2.1 Innovation and Market Structure: Static Analyses

The traditional 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.[2] However, the empirical analyses included in this literature results have been criticized for

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

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 1 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 1 suggests that R&D had a positive static effect on market concentration.[3] 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.

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

[3] 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.

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.[4] 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 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.[5] Matraves (1999) also showed that R&D, one kind of endogenous sunk cost, plays a crucial role in determining market

[4] 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.
[5] 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.

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.

2.2 Innovation and the Dynamics of 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.[6] 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 manufacturing for the years 1978-1993. Technological effort (R&D intensity) also results

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

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. Data Construction and Descriptive Analyses

This study uses the manufacturing-plant surveys (hereafter MPS) conducted by Taiwan's Ministry of Economic Affairs to construct the first quasi-annual series used to examine market structure for the 1997-2003 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. This distinguishes this study from previous ones (Chen and Yang 1997; Yang and Kuo 2007) that used the quintennial census data through 1996. The use of the MPS is motivated by the desire to analyze recent trends and at the same time avoid concordance problems between the old Standard Industry Classification (SIC) and the new one which has been used since 1996. It would of course be desirable to integrate the Census data for 2001 with the MPS data but this is impossible because of differences in sampling and variable definitions, for example. The most important difference is sampling with the Census covering over 140,000 manufacturing firms and over 147,000 manufacturing plants in 2001, whereas slightly more than 80,000 plants usually included in the MPS. The MPS are thus sample surveys, but they are representative samples and widely utilized to conduct research on Taiwan's manufacturing industries. Compiling the plant-level data at the four-digit SIC level (233 industries) for 6 years results in a sample containing 1398 observations.[7]

Before proceeding to the econometric analysis, it is helpful to examine a few indicators of market structure and technological activity. Averages of all 4-digit industries are shown in Table 2 for two measures of concentration, the four-plant concentration ratio (CR4 or the

7 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.

share of the largest four plants by sales in industry sales) and the HHI, and two indicators of technological activity, average R&D expenditures and the average value of technology imports. Both concentration indices exhibit similar trends, decreasing from 1997 to 2001 and then increasing slightly thereafter. In addition to the potential impact of innovation that will be examined later, there was an economic recession in 2001, which forced many inefficient plants to exit the market and contributed to an increase in concentration thereafter. One point worth noting is that the average CR4 generally exceeded 42% while the average HHI was slightly above 1000 for over the period examined. This degree of market concentration is to be higher than in several countries. For example, in U.S. manufacturing, HHI was 661.547 in 1992 (Delorme Jr. *et al*, 2002) and CR4 was 39 in 1977-1982 (Koeller, 2005). Intuitively, one might expect higher producer concentration ratios in relatively small and open economies like Taiwan, partially because these indices do account for import competition.[8]

Average R&D expenditures more than doubled over these seven years from NT$376 million in 1997 to NT$763 million in 2003, reflecting increased efforts by Taiwanese manufacturing plants to spur scientific and technological development as well as related industrial upgrading. Technology imports, which are an important source of advanced technologies, fluctuated more and were lower than the R&D expenditures. Between 1997 and 2003, these imports increased more than 50%, from NT$148 million to NT$234 million. The general, simultaneous trend toward higher R&D and higher technology imports seems to suggest a complementary relationship between in-house R&D and

[8] Unfortunately, it is impossible to create concentration indices that account for the effects of import competition for two reasons. First, imports are classified by commodity according to the Standard International Trade Classification (SITC) and it is very difficult to match the import data with the classification of plants by SIC in the MPS. Second, plants in a given SIC (e.g., food) often imports goods produced by firms in other industries (e.g., machinery), making it impossible to match trade classifications of import data and the plant-level data

technology imports. That is, both domestic R&D and learning from abroad through imported technologies are used to facilitate the upgrading of industries' technological capabilities. Moreover, the higher outlays on R&D indicate that in-house R&D is now the major source of innovation in Taiwanese manufacturing. It is also likely that innovative strategy may be related to plant size. For example, larger plants in an industry may tend to rely more heavily on R&D, while smaller ones may prefer to import technologies directly. If this is the case, R&D and technology imports may have the opposite effects on market structure dynamics.

One more important question is do innovations affect market structure, and if so, how? For example, the data in Table 2 suggest a negative correlation between trends in average concentration and average innovative activity. Does this imply that innovation results in lower concentration in Taiwanese manufacturing? To get further insight into the answer to this question, it is helpful to look more closely at more disaggregated data. To this end, Table 3 show averages of concentration and technological indicators for 4-digit industries at the 2-digit level of aggregation. These calculations allow grouping of industries by level of concentration: highly concentrated industries with CR4 above 0.5, moderately concentrated industries with CR4 between 0.4 and 0.5, and less concentrated industries with CR4 below 0.4.

The highly concentrated group is mainly comprised of capital intensive industries and some traditional industries, such as Petroleum and Coal Products, Chemical Materials, Transport Equipment, Food and Beverages, Tobacco, and Textiles Mills. 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. The moderately concentrated group is largely comprised of metal and electronics industries, such as Basic Metals, Non-metallic Mineral Products, Machinery and Equipment, Computer, Communication, and Electronic Products, Electronic Machinery, and so on.

Finally, Leather, Fur and Allied Products, Furniture and Fixtures, Printing, and Plastic Products are among the industries with relatively low concentration. Such structural peculiarities are often attributed to variation in exogenous sunk costs and market conditions in each industry. However, does the industry-wise variation in concentration have any relation to innovation? For example, these data suggest that moderately concentrated industries tend to a larger higher R&D intensity than highly concentrated industries, on average, while industries with relatively low concentration had the lowest average R&D intensity. This suggests a weak relationship between innovation and CR4, with is also reflected in a small, negative correlation coefficient between R&D intensity and CR4 in 1997 (-0.054). However, this simple calculation ignores the important influences of other determinants and any mutual causality that may exist between innovation and concentration.

Moreover, rather than focusing on the static industrial differences, this paper emphasizes the dynamic features of the relationship between concentration and innovative activity. In addition to declines in the means for all industries noted above, CR4 declined in most of the industries with low concentration and all moderately concentrated industries (Table 3). In highly concentrated industries, trends were more varied, with CR4 increasing in some industries, but declining in most. The overall correlation between the change of R&D intensity and the change of CR4 is 0.259, implying that innovation and concentration are positively correlated. However, here again it is important to emphasize that this simple correlation ignores other relevant factors and the potential for mutual causality.

Some more interesting and potentially important trends are observed when industries are grouped by technological regimes. For example, among moderately concentrated industries that are relatively R&D-intensive, most industries which experienced a decline in CR4 also experienced an increase in R&D intensity. In other words, there appears to be a negative correlation between innovation and concentration in many R&D-intensive industries. On the contrary, among industries with relatively low concentration and R&D

intensity trends in CR4 and R&D intensity appear positively correlated between 1997 and 2003. This suggests that the use of innovation to introduce new goods could result in higher concentration in this group of industries. Furthermore, among highly concentrated industries, the correlation between trends in CR4 and R&D intensity seem to be rather weak.

Static comparisons yield no clear evidence as to how innovation is related to market structure dynamics. Rather they indicate the potential importance of technological regimes for investigating the innovation – market structure dynamics nexus. In the following section, we will construct an econometric model to assess the direction and relative strength of the impact of innovation on market structure and its dynamics.

4. The Static Relationship between Innovation and Market Structure

4.1 The Empirical Specification and Estimating Techniques

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. Correspondingly, the static model estimated in this paper is an extension of the exogenous sunk cost function approach developed by Sutton (1991):[9]

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

$$\ln\left[\frac{CR_{it}}{(1-CR_{it})}\right] = \beta_0 + \beta_1 \frac{1}{\ln(S_{it}/\sigma_{it})} + \varepsilon_{it} \quad (1)$$

where *CR* is the concentration ratio, *S* is market size, σ is setup costs, *i* is a subscript indicating industry i, and *t* is subscript for year t. Market size (*SIZE*) is measured by industry sales. The setup cost variable is the minimum efficient scale relative to industry sales (*MESS*) multiplied by the capital requirement of an industry (*CAP*). That is, σ = *MESS***CAP*. A positive sign for the coefficient β_1 implies a that concentration increases as a result of relatively small market size (*SIZE*), relatively large minimum efficient scale relative to industry sales (*MESS*), or relatively large capital requirements (*CAP*). Note that the latter two variables are widely employed as indicators of entry barriers in the SCP paradigm.

This basic model is then extended to consider the main factor of concern here, innovation, as well as other industry characteristics that potentially affect concentration, as follows:

$$\ln\left[\frac{CR_{it}}{(1-CR_{it})}\right] = \beta_0 + \beta_1 \frac{1}{\ln(S_{it}/\sigma_{it})} + \beta_2 RDR_{it} + \beta_3 TIR_{it} + \beta_4 PCM_{it} + \beta_5 GR_{it} + \varepsilon_{it} \quad (2)$$

where *RDR* is R&D intensity, *TIR* is the ratio of technology imports to sales, *PCM* is the price-cost margin, and *GR* is the growth of sales; all other variables are as defined above.[10] 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

[10] Variable definitions and summary statistics are presented in the Appendix.

between innovation and market structure and a positive sign is therefore expected for the coefficients on R&D intensity and the technology import ratio.[11] One alternative specification is to use the sum of R&D expenditures and technology imports (*IINNO*) to measure innovative activity. 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.

Two performance variables are also added to equation (2). The price-cost margin is defined as the ratio of industry sales minus total operation outlays to industry sales. 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. Thus, even though most previous studies find a positive relationship between profitability and concentration, the nature of this relationship is best considered an empirical issue. Likewise the relationship between industry growth and concentration is unclear *a priori*. The expansion of demand 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.[12] However, the relationship may also be positive if large plants exploit economies of scale or use new production technologies to meet market demand. Finally, although the concentration ratio is the dependent variable in equation (2), specifications using HHI as the dependent variable are

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

[12] 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.

also estimated in order to examine the sensitivity of the results to alternative definitions of market 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 which are potentially correlated with the regressors on the right-hand side of equation (2), as follows:

$$\varepsilon_{it} = v_{it} + u_i \quad (3)$$

Here, u is an industry-specific effect that varies across industries but within an industry over time, and v is a "white noise" error term. Using a "within-plant" panel estimator, the fixed effect (FE) or a random effect (RE) techniques are standard estimation methods to eliminate the individual effect. The fixed effect and random effect techniques both have advantages and disadvantages (Hsiao, 2003) and the Huasman test is used to judge which model is more appropriate.

4.2 Empirical Results

Regression results for equation (2) are shown in table 4. The Hausman test values are used to test the null hypothesis that the random-effect model is more appropriate than the fixed-effect model. As the values of this test statistic are larger than the critical values at the 1% level, the fixed effects estimates are judged to be preferable and shown in the table. The coefficient for variable $1/\ln(S/\sigma)$ is positive all equations as expected and statistically significant in the *CR4* equations, but not the *HHI* equations. Although this result suggests some sensitivity to the definition of concentration, the result is generally in accordance with

Sutton's prediction that the lower bound of concentration will decline indefinitely as the ratio of market size to setup costs rises. This result can also be interpreted that a higher values of *MESS* and/or capital requirements results in fewer plants operating at a minimum efficient scale in that industry, *ceteris paribus*. This deters potential entrants, resulting in higher concentration. All coefficients on *PCM* are positive and statistically significant as expected. This indicates that industries with a higher price-cost margin will tend to be more concentrated but it is also important to note that causation may run from concentration to the price-cost margin, not the other way around. The growth of industry sales is also found to contribute to higher concentration in most specifications. This suggests that large incumbents account for a disproportionally large share of the growing market pie.

Turning to the major variables of concern, the coefficient on the combined R&D and technology variable, *INNO*, is positive in both the *CR4* and *HHI* equations but has a significant effect on market structure only in the *HHI* equation. This suggests a positive innovation – concentration ratio nexus but again indicates some sensitivity to the measure of concentration. The more interesting question is which of these sources of innovative activity contribute to this positive relationship? When these factors are separated, the coefficient on R&D intensity bears the expected positive sign but is not significant at the conventional 5% level. This implies that scale economies in R&D do not act as entry barrier important that is important enough to induce a significantly higher concentration bound. On the other hand, even in this static specification, the coefficient on technology import intensity is positive and significant at the standard 5% level in the HHI equation but insignificant in the CR4 equation.

The R&D result contrasts sharply with most of previous studies, but is consistent with Resende's (2007) finding that R&D intensity exerts no significant positive effect on concentration in Brazil. As described above, Resende explains this result by pointing to the different composition of manufacturing in developing countries and the large, heterogeneous nature of Brazilian manufacturing. This interpretation in turn suggests the potential influence of technological regimes on the innovation–concentration nexus. Does Taiwanese manufacturing exhibit similar features? On the other hand, the results do suggests that technology imports may create entry barriers, similar to those R&D are often thought to create, resulting in higher concentration. Technology imports are important in developing economies like Taiwan so this result seems plausible, though here again the results are sensitive to the definition of concentration. Finally, it should be reiterated that mutual causality among both indicators of innovation and market structure may affect the innovation-market structure nexus and that this is not accounted for in these estimates.

4.3 Further Investigation

The results described in the previous section suggest that innovation plays a relatively minor role in the determination of market structure in Taiwan. 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. Table 5 presents the estimates of the GMM estimates which use lagged innovation variables and lagged profitability as instrumental variables.

We first look at the probability value for the Sargan statistic (also know as Hansen's J-statistic) in the bottom of table 5, which tests the joint null hypothesis that the model is correctly specified and that the instruments are valid[13] The null hypothesis of no over-identification is not rejected for all estimates, indicating that these GMM estimates are well-behaved. Most of these GMM results are quite qualitatively similar to those in Table 4, including the estimates of the coefficient on the *INNO* variable.

However, the coefficients on the R&D and technology import variables change substantially. Most importantly, these results suggest that the coefficients on R&D intensity are significantly positive at the standard 5% level or better in both equations, which 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 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. In contrast, controlling for endogeneity does not appear to affect the qualitative results much regarding technology imports. As in table 4, these imports exert a significantly positive effect in the HHI equation, but an insignificant, negative 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.

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

[13] Formally, the Sargan statistic is a test that the over-identification restrictions are asymptotically distributed $\chi^2_{(n-p)}$, where *n* is the number of instruments and *p* is the number of parameters.

coefficient on the market growth variable becomes significant in all equations.

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.[14] GMM estimates for these subsamples are then shown in table 6.

Estimates of equations using the combined R&D-technology import variable (*INNO*), suggest a significantly positive relationship to concentration in all subsamples. Similarly, the coefficients on R&D intensity are also all positive and significant when R&D and imports are distinguished. 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 had, 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.

Why is the coefficient on *INNO* significant in both subsamples but not in the full sample? The answer seems to be that the strength of the innovation – concentration ratio varies substantially across technological regimes, creating relatively large standard errors

[14] 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.

when estimates are made for the full sample (Scherer and Ross, 1990; Koeller, 2005). For example, the magnitude of the coefficient on *RDR* is about 2 times larger in the sample of industries with low R&D intensity than in industries with high R&D intensity. A similar, but even larger difference (about 4.7 times) is observed on the coefficient on *TIR* 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 *TIR* differs between the CR4 and HHI equations.

5. 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.[15]

The change in concentration is assumed to be a function of the actual concentration bound relative to steady-state concentration bound (*H**). 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. This results in the following partial adjustment model:

$$\Delta H_{it} = H_{it} - H_{i,t-1} = \lambda\left(H_{it}^{*} - H_{i,t-1}\right) \quad (4)$$

where H is the lower bound of concentration shown in the left hand of equation (1) and ΔH_{it} is the change in concentration bound between years t and $t\text{-}1$ for industry i. λ is the partial adjustment coefficient which takes a value between zero and one. H^* is the equilibrium level of the lower concentration bound of concentration in time t. Unlike previous studies which assume a steady-state, this analysis assumes H^* is a short-term equilibrium and as described in Eq. (2). Substituting Eq. (2) into Eq. (4) to remove the unobservable equilibrium concentration bound, generates the following equation:

$$H_{it} = \lambda\left(\beta_0 + \beta_1 \frac{1}{1n\left(S_{it}/\sigma_{it}\right)} + \beta_2 RDR_{it} + \beta_3 TIR_{it} + \beta_4 PCM_{it} + \beta_5 GR_{it} \right) \quad (5)$$

$$+ \left(1 - \lambda\right) H_{i,t-1}$$

When Eq. (5) is estimated using fixed effect of panel data model, we can control for the industry heterogeneity that is not well dealt with in previous studies. Further, the coefficient

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

of the lagged concentration bound ($H_{i,t-1}$), provides the estimate of one minus the partial adjustment coefficient. More importantly, the sign and significance level coefficient of the innovation variables gives the information about how innovation variables affect market structure dynamics.

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 Table 7.

Coefficients on the lag of both lower bound concentration measures are significantly positive at the 1% level (Table 7). 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 about 0.72-0.76 in CR4 equation and 0.54-0.60 in the HHI equations This implies annual adjustment rates of about 25% and 42% 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.[16] Therefore, the speed of invisible hand is apparently much faster in Taiwan. 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)

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

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 both CR4 equations, the answer seems to be that innovation has no effect on the changes in concentration over time as coefficients on *INNO*, *RDR*, and *TIR* are all very close to zero and statistically insignificant. In contrast, coefficients on all of 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, when the R&D and technology import effects are distinguished, the coefficient on *TIR* is almost twice the size of the coefficient on *RDR*. In other words, technology imports appear to exert a much stronger effect on subsequent increases in concentration than R&D.

These 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, 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.[17]

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 8). 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 are also positively and significantly related to concentration in both the CR4 and HHI equations for industries with low R&D intensity and in the HHI equation for industries with high R&D intensity (Table 8). These results suggest that innovative activity generally leads to higher concentration when differences in technology regimes are accounted for. There is one exception, the CR4 equation for industries with high R&D intensity. In this case, coefficients on the innovation variables are all negative,

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

and they are statistically significant when R&D and technology imports are distinguished, though the latter coefficient is only weakly significant at the 10% level. The result that innovative activity generally leads to higher concentration, especially in industries with low R&D intensity, contrasts with results from previous studies, but may be reasonable in the Taiwanese case. During this period, Taiwan's large plants appear to have experienced some sort of "innovation accumulation", with innovative activity concentrated in large firms and plants (Yang and Huang, 2006). 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. This result is again inconsistent results from most of previous studies, but sheds lights on the importance of technological regimes for the innovation – market structure dynamics nexus, and supports the 'Schumpeter Mark II' hypothesis. Industries with low R&D intensity are often characterized by the routinized regime where innovation is usually concentrated in incumbents, leading to '*creative accumulation*' that deters potential entrants.

Distinguishing R&D and technology imports also appears to be important in the other three specifications (HHI equation for high R&D industries and both equations for low R&D industries) because the coefficients on these variables differ and are both highly significant. Correspondingly, it is probably best to focus on these equations rather than the equations where the two kinds of innovative activity are combined into one variable. As in the static case, the effects of both kinds of innovative activity are relatively large (in absolute value) in industries with low R&D intensity. However, the results are again sensitive to the measure of concentration with R&D having a larger effect than technology imports on CR4 but a smaller effect on HHI. The importance of differences in concentration measurement are further underscored by the fact the effect of R&D is also relatively small in the HHI equation for industries with high R&D. In other words, the HHI equations tell the same qualitative story for both subsamples: the effects of technological activity are positive and the effects of R&D are weaker than the effects of technology imports. In contrast the results of the CR4 equations differ markedly from the results of the HHI equations by suggesting R&D has a stronger positive effect than technology imports in industries with low R&D and a stronger negative effect in industries with high R&D. This latter result contrasts markedly with others, implying some sort of 'creative destruction' in Taiwan's R&D-intensive industries, for example the electronics industry, that is not observed when concentration is measured with HHI or in industries with low R&D. Here again it is important to recall that there are important differences between CR4 and HHI, with the latter giving more weight to large plants and perhaps leading to overestimation of the effects of innovation by large plants on the innovation – market structure dynamics nexus.

6. Concluding Remarks and Policy Implications

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. The results of this approach suggest that innovation is positively associated with the level of concentration. Second, it 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. Third, the paper 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.

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Table 1 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	197	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)	German	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 2 Average Value of Market Concentration and Innovative Activity in Taiwan's Four-digit Industries

Year	CR4 (%)	HHI (0 – 10000)	R&D (NT$ million)	technology import (NT$ million)
1997	45.180	1240.684	375.700	148.285
1998	43.607	1083.876	446.640	206.856
1999	42.758	1026.248	516.039	179.255
2000	42.468	993.336	564.059	184.141
2001	40.902	1065.184	817.144	n.a.
2002	43.213	1034.008	688.545	211.061
2003	42.579	1008.853	762.718	234.361

Note: Data for 2001 are calculated by Census data. For that year, the figure in the R&D column is the sum of R&D expenditures and technology imports.

Table 3 Concentration Ratios and Innovative Activity in Taiwan's 2-digit Manufacturing Industries

Industry	1997				2003			
	CR4	HHI	R&D (%)	TI (%)	CR4	HHI	R&D (%)	TI (%)
Food & Beverages	0.545	0.173	0.495	0.115	0.563	0.163	0.337	0.048
Tobacco	0.886	0.258	0.088	0.000	1.000	0.323	0.041	0.000
Textiles Mills	0.528	0.141	0.200	0.032	0.515	0.173	0.279	0.087
Apparel, Clothing Accessories & Other Textile Product	0.555	0.329	0.569	0.013	0.402	0.079	0.316	0.065
Leathers, Fur & Allied Products	0.224	0.026	0.616	0.004	0.300	0.044	0.795	0.039
Wood & Bamboo Products	0.316	0.048	0.069	0.010	0.381	0.071	0.088	0.089
Furniture & Fixtures	0.191	0.145	0.168	0.081	0.352	0.064	0.285	0.027
Pulp, Paper & Paper Products	0.510	0.114	0.443	0.121	0.500	0.183	0.280	0.147
Printing & Related Supported Activities	0.172	0.157	0.207	0.179	0.194	0.021	0.303	0.002
Chemical Material	0.549	0.142	0.659	0.168	0.548	0.145	0.687	0.143
Chemical Products	0.426	0.103	1.878	0.272	0.378	0.077	2.620	0.796
Petroleum & Coal Products	0.660	0.175	0.398	0.062	0.277	0.169	0.171	0.161
Rubber Products	0.289	0.039	1.009	0.097	0.332	0.049	0.865	0.155
Plastic Products	0.218	0.029	0.558	0.059	0.293	0.053	0.705	0.082
Non-metallic Mineral Products	0.417	0.094	0.929	0.063	0.423	0.091	0.574	0.059
Basic Metal	0.459	0.106	0.364	0.103	0.432	0.101	0.267	0.091
Fabricated Metal Products	0.411	0.084	0.712	0.025	0.299	0.043	0.328	0.161
Machinery & Equipment & Repairing	0.420	0.098	1.126	0.121	0.313	0.047	0.758	0.092
Computer, Communication & Video & Radio Electronic Products	0.437	0.080	2.212	1.579	0.428	0.088	2.994	0.669
Electronic Parts & Components	0.447	0.098	2.572	0.662	0.358	0.077	3.050	1.118
Electrical Machinery, Supplies & Equipment & Repairing	0.355	0.060	0.975	0.209	0.376	0.065	1.220	0.331
Transport Equipment & Repairing	0.607	0.251	0.826	0.275	0.582	0.170	1.312	0.364
Precision, Optical, Medical Equipment, Watches & Clocks	0.408	0.123	1.738	0.314	0.394	0.097	2.851	0.152
Other Industrial Products	0.395	0.111	0.444	0.054	0.395	0.084	1.339	0.344

Note: R&D and TI are ratios of R&D expenditures and technology imports, respectively, to sales.

Table 4 The Relationship Between Innovation and Market Structure

Dep. variable	CR4		HHI	
1/ln(S/σ)	1.875***	1.868***	0.372	0.351
	(0.723)	(0.724)	(0.783)	(0.784)
INNO	0.025		0.047**	
	(0.021)		(0.023)	
RDR		0.020		0.029
		(0.026)		(0.029)
TIR		0.033		0.075**
		(0.033)		(0.037)
PCM	0.008***	0.008***	0.008***	0.008***
	(0.002)	(0.002)	(0.003)	(0.003)
GR	0.637E-03***	0.637E-03***	0.642E-03	0.624E-03***
	(0.103E-03)	(0.105E-03)	(0.117E-03)	(0.119E-03)
Adj. R^2	0.898	0.898	0.864	0.864
Hausman test	253.13***	256.02***	174.67***	178.85***

Note: Figures in parentheses are standard errors. *** and ** represent significance at the 1% and 5% level, respectively.

Table 5 GMM Estimates for the Innovation – Market Structure Nexus

Dep. variable	CR4		HHI	
Constant	-1.756***	-1.605***	-3.666***	-3.617***
	(0.148)	(0.056)	(0.164)	(0.063)
1/ln(S/σ)	9.004***	7.813***	4.971***	4.867***
	(1.073)	(0.343)	(1.174)	(0.364)
INNO	0.015		0.032**	
	(0.012)		(0.014)	
RDR		0.030***		0.040**
		(0.010)		(0.011)
TIR		-0.008		0.033***
		(0.005)		(0.009)
PCM	0.007***	0.007***	0.008***	0.008***
	(0.001)	(0.40E-03)	(0.001)	(0.601E-03)
GR	0.604E-03***	0.775E-03***	0.877E-03***	0.830E-03***
	(0.994E-04)	(0.513E-04)	(0.130E-03)	(0.537E-04)
Sargan test	56.639	71.220	45.977	72.912
(prob.)	(0.567)	(0.570)	(0.635)	(0.514)

Note: Figures in parentheses are standard errors. *** and ** represent significance at the 1% and 5% level, respectively.

Table 6 GMM Estimates of the Innovation – Market Structure Nexus for Low R&D and High R&D Subsamples

Dependent	CR4				HHI			
variables	High R&D		Low R&D		High R&D		Low R&D	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Constant	-1.187***	-1.283***	-2.200***	-2.333***	-3.317***	-3.329***	-4.343***	-4.347***
	(0.085)	(0.027)	(0.141)	(0.056)	(0.035)	(0.036)	(0.064)	(0.063)
1/ln(S/σ)	4.291***	5.251***	11.819***	13.339***	2.606***	2.641***	10.194***	10.252***
	(0.586)	(0.129)	(0.614)	(0.355)	(0.159)	(0.163)	(0.373)	(0.370)
INNO	0.026***		0.100***		0.038***		0.100***	
	(0.007)		(0.026)		(0.003)		(0.010)	
RDR		0.042***		0.090***		0.050***		0.101***
		(0.005)		(0.013)		(0.005)		(0.015)
TIR		0.384E-02		0.275E-02		0.022***		0.103***
		(0.236E-02)		(0.015)		(0.003)		(0.020)
PCM	0.014***	0.015***	0.006***	0.006***	0.013***	0.013***	0.008***	0.008***
	(0.001)	(0.581E-03)	(0.266E-03)	(0.217E-03)	(0.582E-03)	(0.579E-03)	(0.250E-03)	(0.250E-03)
GR	0.705E-03***	0.778E-03***	0.248E-03***	0.344E-03*	0.856E-03***	0.896E-03***	0.483E-03***	0.492E-03***
	(0.446E-04)	(0.264E-04)	(0.794E-04)	(0.414E-04)	(0.151E-04)	(0.178E-04)	(0.488E-04)	(0.491E-04)
# of industry	117	117	116	116	117	117	116	116
Sargan test	38.319	52.608	36.696	51.477	50.251	50.465	50.847	50.401
(prob.)	(0.886)	(0.972)	(0.920)	(0.979)	(0.988)	(0.984)	(0.985)	(0.984)

Note: Figures in parentheses are standard errors. ***, **, and * represent significance at the 1%, 5% and 10% level, respectively.

Table 7 GMM Estimates for the Innovation – Market Structure Dynamics Nexus

Dep. variables	CR4		HHI	
Constant	-0.639***	-0.554***	-3.264***	-1.254***
	(0.112)	(0.052)	(0.140)	(0.058)
H(t-1)	0.724***	0.758***	0.539***	0.599***
	(0.023)	(0.014)	(0.024)	(0.020)
1/ln(S/σ)	3.405***	2.866***	3.787***	0.007
	(0.809)	(0.365)	(0.980)	(0.008)
INNO	-0.001		0.023**	
	(0.006)		(0.009)	
RDR		-0.006		0.018**
		(0.005)		(0.007)
TIR		-0.002		0.033***
		(0.005)		(0.006)
PCM	0.004***	0.005***	0.007***	0.007***
	(0.805E-03)	(0.439E-03)	(0.001)	(0.502E-03)
GR	0.001***	0.001***	0.001***	0.001***
	(0.125E-03)	(0.768E-04)	(0.137E-03)	(0.660E-04)
Sargan test	42.982	59.915	46.002	68.197
(prob.)	(0.715)	(0.863)	(0.595)	(0.637)

Note: Figures in parentheses are standard errors. ***, ** and ** represent significance at the 1%, 5% and 10% level, respectively

Table 8 GMM Estimates of the Innovation – Market Structure Dynamics Nexus for Low R&D and High R&D Subsamples

Dependent variables	CR4				HHI			
	High R&D		Low R&D		High R&D		Low R&D	
Constant	-0.422***	-0.496***	-0.614***	-0.849***	-3.039***	-0.833***	-3.042***	-0.767***
	(0.076)	(0.019)	(0.069)	(0.040)	(0.086)	(0.030)	(0.077)	(0.018)
H(t-1)	0.814***	0.823***	0.829***	0.799***	0.621***	0.770***	0.825***	0.792***
	(0.015)	(0.005)	(0.101)	(0.008)	(0.030)	(0.012)	(0.016)	(0.007)
1/ln(S/σ)	1.599***	2.232***	3.468***	4.556***	1.707**	-0.001	3.058***	0.084***
	(0.627)	(0.122)	(0.435)	(0.272)	(0.663)	(0.003)	(0.517)	(0.008)
INNO	-0.004		0.072***		0.021***		0.119***	
	(0.006)		(0.014)		(0.007)		(0.019)	
RDR		-0.013***		0.144***		0.012***		0.169***
		(0.002)		(0.010)		(0.004)		(0.015)
TIR		-0.003*		0.112***		0.024***		0.258***
		(0.167E-02)		(0.018)		(0.003)		(0.022)
PCM	0.012***	0.013***	0.005***	0.005***	0.105***	0.016***	0.008***	0.007***
	(0.001)	(0.437E-03)	(0.225E-03)	(0.222E-03)	(0.002)	(0.001)	(0.252E-03)	(0.228E-03)
GR	0.001***	0.001***	0.193E-04	0.422E-03***	0.001***	0.001***	0.451E-03***	0.252E-03
	(0.855E-04)	(0.261E-04)	(0.136E-03)	(0.853E-04)	(0.894E-04)	(0.341E-04)	(0.164E-03)	(0.814E-04)
#of industry	117	117	116	116	117	117	116	116
Sargan test	31.771	36.061	37.286	48.068	32.193	47.474	41.624	48.210
(prob.)	(0.973)	(0.999)	(0.890)	(0.968)	(0.970)	(0.972)	(0.764)	(0.976)

Note: Figures in parentheses are standard errors. *** and ** represent significance at the 1% and 5% level, respectively.

Appendix Table   Variable Definitions and Summary Statistics

Variable	Definition
CR4 (43.063 16.815)	The four-firm concentration ratio (%)
CR8 (55.607 24.475)	The eight-firm concentration ratio (%)
HHI (10.499 13.475)	Herfindahl-Hischman Index (%)
SIZE (39.928 75.942)	Industry size: it is measured by industry sales (NT$ billion)
MESS (3.386 7.441)	Minimum efficient scale to sales: The average size of the largest firms accounting for the 50% of industry sales divided by industry sales (%)
K (3.078 14.229)	Capital stock of the industry (NT$ billion)
RDR (0.879 1.227)	R&D expenditure to sales ratio (%)
TIR (0.206 0.640)	Technology imports to sales ratio (%)
PROFIT (6.744 8.536)	Profitability: the ratio of industry sales minus operation outlays to industry sales. (%)
GR (31.284 143.733)	The growth rate of industry sales for each period (%)

Note: The mean is calculated as the overall average during 1997-2003. Figures in parentheses are the means and standard errors.