Competition: Missing Piece in Innovation Equation

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Abstract

Despite numerous attempts by the government to promote innovation, private R&D in Thailand has been persistently low. Literature has established that competition can—either beneficially or detrimentally—affect firm's innovative efforts. For Thailand, however, competition regulation has been missing from the innovation policy framework. In this setting, we examine the effect of competition on innovation using industry- and firm-level data in Thailand. We find that competition and innovation in manufacturing industries follows an inverted-U relationship. In contrast to the literature, the peaks in leveled and unleveled industries are not significantly different. We also reaffirm the competing escape-competition and Schumpeterian effects at a firm level.

JEL Classification Codes: L13, L50, O30

Keywords: innovation, research and development, competition

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1 Introduction

Thailand has experienced relatively sluggish economic growth in recent years despite the fact that economic stability has been largely maintained during the prolonged period of political unrest. The average GDP growth since 2008 has slipped under four percent. Still under the middle-income trap, Thailand has currently been facing alarming challenges, ranging from aging society to weak demand from its major trading partners. Thailand undeniably requires a new engine of growth.

Thailand has been undergoing an economic reform, and one of the key directions is to promote innovation. However, the country's innovation policies have so far produced limited result and, as suggested by many indicators, Thailand is still nowhere near its goal of becoming a major global innovator. Thailand's gross R&D expenditure to GDP ratio in 2014 remains lower than 0.5 percent, far below the average of upper-middle income countries of 1.6 percent. Moreover, Thailand ranks 51th in the Global Innovation Index in 2017, down from 48th in 2014. A crucial question then arises: despite unwavering attempts to encourage innovations, why innovation in Thailand remains relatively low.

One missing factor that could play a vital role in promoting innovation in Thailand is competition. The relationship between competition and innovation has been studied extensively in many academic fields. Nonetheless, it is still one of the most controversial topics in economics. On one hand, competition can incentivize firms to innovate by increasing incremental profit. On the other hand, pre-innovation market power can be a necessary condition for creating innovation because a firm with market power faces less uncertainty, possesses financial resources for innovation, and tends to retain post-innovation market power.

Arguably, the overall level of competition in Thailand remains unchanged during the past two decades, notwithstanding the fact that some Thai industries have been structurally affected by competition policies and sectoral liberalizations. Based on Aghion and Griffith (2005) who viewed a decision to carry out innovative effort as a function of the incremental profit from innovation, we propose our premise that the stagnant level of competition is a reason of low innovation effort in Thailand. Had the *ex-ante* competition varied over the years, the innovation effort could have changed over time.

In such case, Thailand should also focus on promoting healthy competitive environment instead of relying solely on innovation promotion policies. In this paper, we investigate the relationship between competition and innovation effort, which is represented by R&D intensity, in Thailand at both industry and firm levels. We derive our empirical hypotheses from the theoretical model of Aghion et al. (2005), henceforth AG. We then empirically test the hypotheses using Thailand's competition and private R&D dataset. We find an inverted-U relationship in manufacturing sectors which confirms the competing positive and negative forces of competition on innovation. In contrast to AG, the peaks in leveled and unleveled industries are not significantly different. We also found evidence of both escape-competition and Schumpeterian effects at the firm level.

This study makes the following contribution to the literature. First, this study is the first study that has drawn the relationship between competition and R&D in Thailand, an economy that relies heavily on production and export activities. Moreover, while various case-studies on Thailand, including Charoenporn (2005a), Charoenporn (2005b), Jongwanich and Kohpiboon (2011) and Srithanpong (2014), examined the linkage between innovation level and firm characteristics and found a positive relationship between the two variables, we extend the analysis by allowing the non-linear relationship between competition and innovation as suggested by the recent literature. Second, this study is among a very few studies, if any, that test the firm-level mechanism that entails an inverted-U relationship between competition, technology gap and R&D at the industry level. Sharing many similarities with our paper, Hashmi (2013) tested AG hypotheses using the US and UK data only at an industry level.

This paper is organized as follows. Section 2 provides some background on R&D and competition in Thailand. Section 3 discusses our data, hypotheses and methodology. Section 4 summarizes empirical results. Section 5 discusses the findings and concludes.

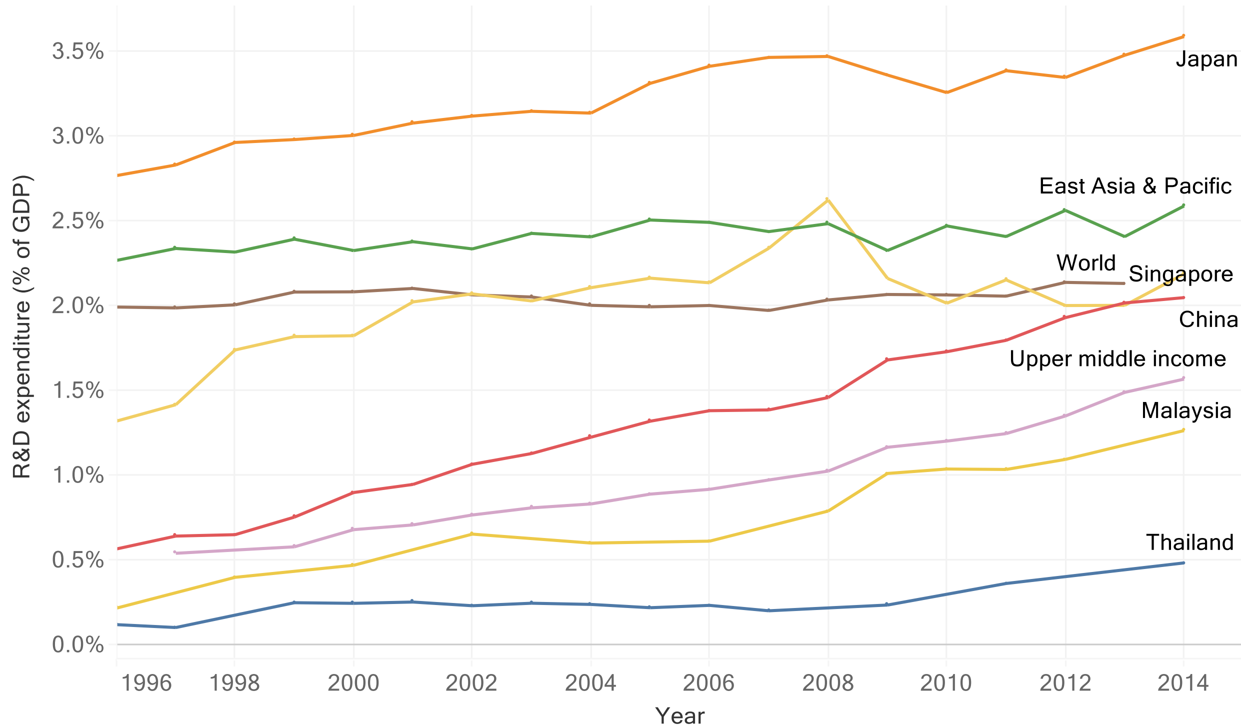

Figure 1. R&D expenditure as a percent of GDP

(Source: UNESCO Institute for Statistics)

2 Background on R&D and competition in Thailand

2.1 R&D in Thailand

The R&D expenditure in Thailand has slowly risen after 2008. It has, nevertheless, never exceeded one percent of GDP. As shown in Figure 1, the ratio is much smaller compared to other emerging counterparts, let alone more developed countries. According to Figure 2, while the gross expenditure on R&D increased from 19.5 billion Thai Baht (THB) in 2006 to 84.7 billion THB in 2015, the R&D expenditure to GDP ratio edges up from 0.25 to 0.62 during the same period. The public R&D expenditure accounts for one third of the total, down from the peak at 63 percent in 2008. Furthermore, as small as 3 percent of all companies spent on R&D activities during 2011 to 2013. The figure went up to 5 and 8 percent in 2014 and 2015, respectively.[2] Among these firms, 30 percent are large enterprises, which contribute as high as 70 percent of the total private R&D spending. To put it differently, small- and medium-size enterprises (SMEs) are also playing a minor yet still arguably significant role in creating innovation.

[2] Source: NSTI survey of firm-level R&D.

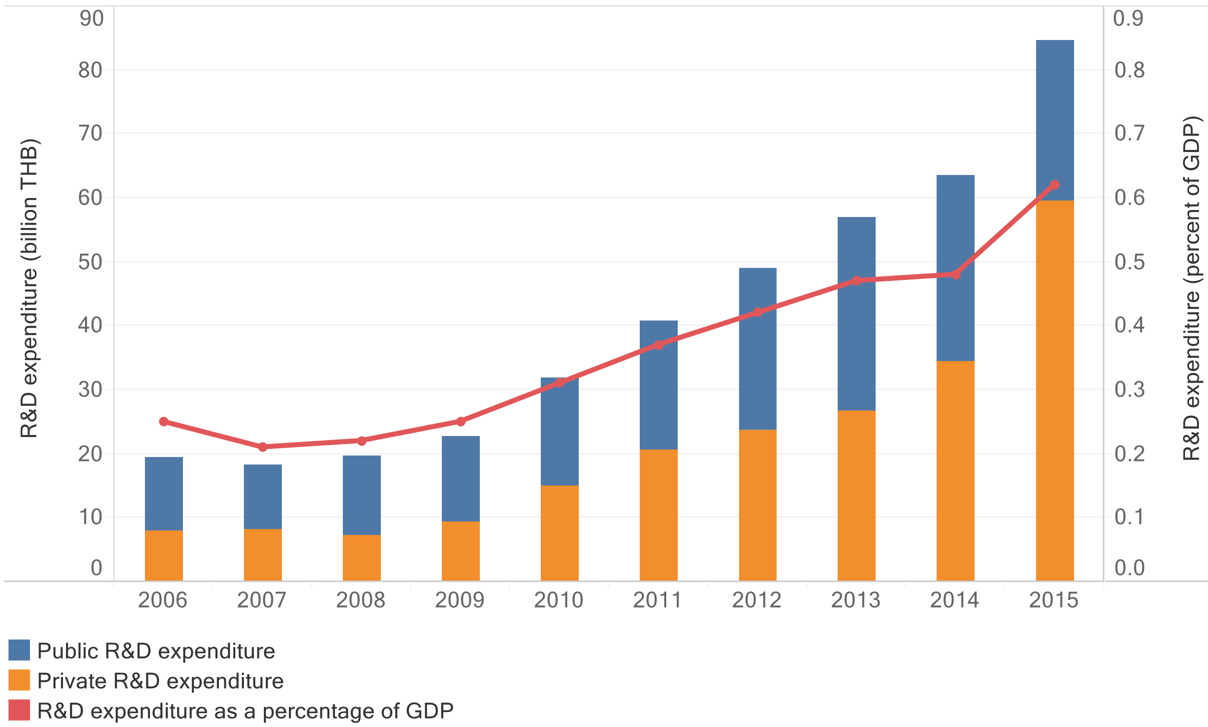

Figure 2. Gross R&D Expenditure in Thailand
(Source: National Science Technology and Innovation Policy Office)[3]

Furthermore, R&D activities are concentrated in manufacturing industries, whereas the rest is attributed to service and trade industries combined. The share of manufacturing firms conducting R&D activities is much higher at 11 percent as opposed to merely 2 percent among non-manufacturing firms.

In response to the sluggish growth in private R&D spending, the government have devised several incentive schemes to promote R&D activities. For instance, Thailand Board of Investment grants an 8-year tax holiday for research-intensive investment activities. In selected industries, National Science and Technology Development Agency also offers a corporate income tax deduction of up to 300 percent of R&D expenses, either in-house or outsourced. National Innovation Agency also provides funding for commercialized research via innovation coupon and technology capitalization. In addition to monetary incentives, Thailand Science Park has implemented a policy to address the skilled-labor shortage and inadequacy of research facilities in small companies by encouraging collaboration between researchers in the public and private sectors to create innovation, and providing working environment where they can work closely together.

[3] The official 2010 and 2012 data are unavailable. They are interpolated using piece-wise linear function.

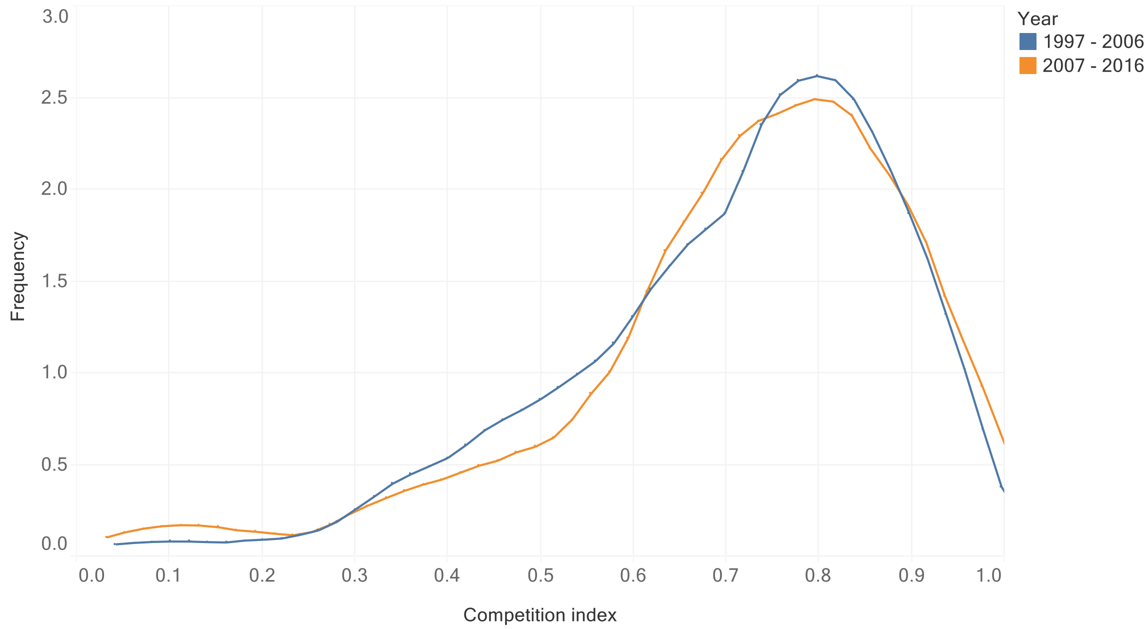

Figure 3. Kernel density of the competition index
(Source: Stock Exchange of Thailand, computed by authors)

2.2 State of competition in Thailand

In Thailand, business competition has not improved in the past 20 years. Figure 3 compares the distribution of competition index in ISIC 2-digit level for 1997-2006 and 2007-2016 periods. Apparently, the overall competition changed only slightly across the two decades.[4] This coincides with the relative modest increase in the ratio of R&D expenditure to GDP.

There are two explanations for this phenomenon. First, the competition law has never been fully enforced even though it has been enacted since 1999. According to Nikomborirak (2006), major reasons for that include the conflict of interest in institutional design, lack of transparency and effective monitoring process. Moreover, the law was not enforceable in itself since it required, as per provision, a further regulation guideline, which had been announced by the concerned authority much later on.[5] Second, there were no significant free trade agreements during the last decade. According to the World Bank, the applied weighted mean tariff rate for imports has dropped to about 5 percent since 2005. However, the agricultural products remain heavily protected as the

[4] Epps-Singleton two-sample test cannot reject the null hypothesis that the competition indices of the two decades are drawn from the same distribution ($W_2 = 1.104, p = 0.89$).
[5] For an illustrative example, the first guideline was published in 2009, 10 years after the enactment of the law. It provided the criteria to determine whether enterprises are dominant; however, none have been charged with such accusation due to other mentioned problems.

rates still stand at 26, 22 and 17 percent in 2015 for food, vegetable, and animal products, respectively. The service sector in Thailand has also been very restrictive for foreigners who want to either establish companies in Thailand or provide services as foreign affiliates (see World Bank, 2016).

Nevertheless, there are still significant improvements in the state of competition in some industries due to industry-specific events that alter market structure. For instance, air transportation has seen a sharp increase in the competition level since 2008 following the Open Sky policy. Incumbent broadcasters have also been under serious competitive pressure from new entrants owing to digital switchover and over-the-top content platforms.

2.3 Competition: Missing Piece in Innovation Equation

Although no consensus has emerged, the linkage between competition and innovation has long been established, both theoretically and empirically, in economic literature. Several theoretical studies argue that competition leads to lower level of innovative activity *à la* Schumpeter (1942). Several authors have been credited for advancing the analysis in this direction. Dasgupta and Stiglitz (1980) endogenized market structure into game theoretic model and found a negative relationship between competition and R&D. Gilbert and Newberry (1982) stated that the monopolist might have more incentive to innovate in order to preempt possible competition from potentially more innovative new entrants. Opposition to the Schumpeterian hypothesis is led by Arrow (1962) who asserted that the displacement effect—a new technology partly replaces *ex ante* monopoly rents—deters a monopolist from innovating whereas a firm in competitive environment faces no such effect. Aghion et al. (2001) argued that firms in more competitive market have an incentive to innovate to escape competition.

Several empirical studies that one-directionally examined the effect of competition on innovation offered conflicting evidence (see Cohen, 2010, for a survey of literature). Scherer (1967) is the first that has found evidence for an inverted-U relationship between R&D activities and industry concentration. Leven et al. (1985) also observed similar finding. To reconcile the inverted-U relationship, AG developed a theoretical model and empirically tested it using the UK data. According to AG, if the competition is low, laggard firms innovate to catch up with the leader, creating a neck-and-neck situation. At the same time, neck-and-neck firms innovate less when competition is low. At the end, there are more neck-and-neck firms which innovate less under low level of competition. But if competition is high, neck-and-neck firms innovate more while laggards innovate less. Neck-and-neck firms become leader-laggards as a result of innovation. In this case, there are more leader-laggard industries which innovate less if competition is high. This disparity in effects of competition yields that too low and too high level of competition yields lower total innovative efforts and outputs than the intermediate level of competition.

Nevertheless, several authors that subsequently attempted to replicate AG analysis still found conflicting results. Hashmi (2013) and Correa and Ornaghi (2014) analyzes US industries and found, respectively, negative and positive relationships between competition and innovation. Due to the lack of consensus, this study aims to fill the gap by analyzing the interrelationship between competition and innovation using Thailand as a case study.

3 Data, hypothesis and methodology

3.1 Data

Our measure of competition is equal to one minus the weighted average Lerner index in the industry. We weight the firm-level Lerner index by sales to capture stronger competitive impact of larger firms. Alternative measures such as Herfindahl-Hirschman Index and concentration ratio are inferior to the Lerner index because of their sensitivity to market definition. The Lerner index of a company i at time t is defined as follows:

$$L_{it} = \max\left\{0, \frac{s_{it} - c_{it}}{s_{it}}\right\}$$

where s_{it} is company i's revenue and c_{it} is its cost at time t. The industry-level Lerner index is the sales-weighted average Lerner index across all companies in an industry defined by two-digit ISIC code.

To calculate the Lerner index, we obtain annual income statements of all listed companies in the Stock Exchange of Thailand from the Stock Exchange of Thailand Market Analysis and Reporting Tool (SETSMART). We collect the data from consolidated income statements whenever available and standalone income statements otherwise. There was a total of 657 companies listed during the study period of 2011 to 2015, and 66 companies are in financial sectors[6]. The Lerner index for non-financial and financial companies are defined differently to reflect dissimilar sources of revenue and cost structures. For non-financial companies, r_{it} and c_{it} are the revenue from sales and cost of sales, respectively. For financial companies, the revenue is the sum of interest incomes and fee incomes whereas the cost is the sum of interest expenses and fee expenses.

Then, we map each company's Lerner index to 2-digit ISIC code using Department of Business Development (DBD) database, and manually reassign an appropriate ISIC code to companies whose ISICs reported in DBD database are inconsistent with their main business activities. Thus, we can define the competition index of industry j at time t as follows.

$$c_{jt} = 1 - \frac{\sum_{i \in I^j} s_{it} L_{it}}{\sum_{i \in I^j} s_{it}}$$

where I^j is the set of companies in industry j.

Our main measure of R&D activity is the R&D intensity—the ratio between total R&D expenditure plus one to total sales. We obtain the firm-level R&D expenditure[7], sales at 2-digit ISIC code from the private sector R&D survey conducted by National Science Technology and Innovation Policy Office (NSTI)[8]. NSTI has administered the survey annually since 2011 with an exception of 2012 and 2013 during which NSTI collected data for both years in a single survey. The industry R&D expenditure and sales are aggregated from firm-level data and weighted by group ratios.

One of the main problems in analyzing the relationship between competition and R&D intensity is a potential endogeneity between them. If R&D is a significant source of market power, the estimated relationship between competition and R&D intensity will be biased towards negativity. We address the endogeneity problem by using a control function approach. In our study, we

[6] The dataset excludes 67 infrastructure funds, real estate investment trusts and infrastructure trusts listed in SET.
[7] As the purpose of measuring innovative efforts, we combine both in-house and outsourcing R&D expenditures.
[8] The definition of R&D in NSTI survey follows the standardized measurement in Frascati Manual (2002). NSTI uses stratified sampling which reflects firm size and industry defined by four-digit ISIC code.

propose an industry exchange rate, as in Hashmi (2013), and industry import values as instrument variables of competition[9].

The industry-level technology gap is the average of the firm-level industry gaps weighted by group ratio. Similar to AG, we define the firm i's technology gap at time t as follows:

$$m_{it} = \frac{TFP_{Ft} - TFP_{it}}{TFP_{Ft}}$$

where TFP is the firm's total factor productivity and F denotes the firm with the highest TFP in the industry. The total factor productivity of firm i at time t is calculated as

$$TFP_{it} = \frac{y_{it}/L_{it}}{\left(k_{it}/L_{it}\right)^{1/3}}$$

where y_{it}, k_{it} and L_{it} are sales, capital and the number of employees, respectively. We obtain all data for TFP calculation from the NSTI surveys.

Combining all of the data, our dataset consists of 47 sectors spanning over a period between 2011 and 2015. Table 1 shows descriptive statistics of all industries and of manufacturing industries. It is evident that competition level in manufacturing industries is relatively higher, while its R&D intensity is lower. Moreover, despite very different nature of innovation, the technology gap in manufacturing industries is on par with that of the other industries.

The firm-level statistics give rather different picture. More firms in manufacturing industries conduct R&D, and their R&D intensity is higher on average. This contrast arises because the R&D activities are decreasing in the group ratio used as the weight to aggregate firm-level data up to industry level. The large average technology gap reflects that the leading firm is by far

[9] Import values are obtained from Trade Map in HS 6-digit level, which are later transformed into ISIC 2-digit data using correspondence table provided by the United Nations. As for industry exchange rate, we use weighted average exchange rate of 22 major countries. For each industry, the shares of imports from each country in the year 2011 are used as weights. The countries included in the construction of the instrument are Australia, China, France, Germany, Hong Kong, India, Indonesia, Japan, Korea, Malaysia, Myanmar, Oman, Philippines, Qatar, Russia, Saudi Arabia, Singapore, Switzerland, Taiwan, United Arab Emirates, United States of America and Vietnam. These countries account for 80% to 90% of imports in each industry on average. The industry exchange rates are indexed with the value of 2011 for each industry equals to one.

technologically ahead of the rest. This is consistent with the fact that R&D activities are concentrated in only a small portion of firms.

Table 1. Descriptive statistics

	All industries	Manufacturing industries
Industry level		
Competition	0.76	0.83
	(0.16)	(0.09)
R&D intensity (percent)	0.22	0.15
	(1.27)	(0.13)
Technology gap	0.92	0.93
	(0.05)	(0.04)
Industries	47	21
Observations	179	95
Firm level		
Conduct R&D	0.26	0.31
	(0.44)	(0.46)
R&D intensity (percent)	0.25	0.29
	(0.81)	(0.86)
Technological advance	0.14	0.13
	(0.62)	(0.56)
Size[10]		
Large firm	0.32	0.32
	(0.47)	(0.47)
Medium firm	0.30	0.30
	(0.46)	(0.46)
Small firm	0.38	0.38
	(0.49)	(0.47)
MNC dummy	0.13	0.15
	(0.33)	(0.36)
Share of export revenue	0.20	0.25
	(0.32)	(0.34)
Industries	47	21
Observations	19,422	14,340

Note: The numbers in the parentheses are standard deviations.

Since a large body of studies suggests that firm characteristics are important determinants of R&D activities, we consider additional control variables, including firm size and multinational cooperation dummy variables. Moreover, firms that export their products or services are likely to conduct more R&D since they need to compete at international level in addition to facing

[10] We define small, medium and large firms according to the Thai law, Small and Medium Enterprises Promotion Act, B.E. 2543 (A.D. 2000).

competitive pressure in the domestic market. The data show that about 43 percent of exporting firms conduct R&D, while only 12 percent of non-exporting firms do.

In addition, time variation in competition within each industry is small in our particular dataset. Despite this, our hypotheses regarding the relationship between competition and innovation can still be tested by using between-industry variation in competition level.

3.2 Hypotheses and methodology

We form four hypotheses on the relationship between competition, innovation, and technology gap, according to the theoretical framework in AG and outline empirical methodology for testing the hypotheses. Hypotheses 1 to 3 pertain to the industry-level relationship whereas Hypothesis 4 concerns the effect of competition on firm-level behavior. Our regression models for Hypotheses 1 to 3 are similar to those in AG and Hashmi (2013). Hypothesis 4, which is based on Proposition 1 in AG, has not been tested by the two studies, however. The four hypotheses are as follows:

Hypothesis 1. *The relationship between competition and R&D intensity is inverted-U shaped.*

The inverted-U relationship between competition and innovation is a result of the two opposing forces: *escape-competition effect* and *Schumpeterian effect*. At a low level of competition, the escape-competition effect—i.e. competition motivates firms to innovate by raising incremental profits of R&D—dominates the Schumpeterian effect—i.e. more competition discourages a firm to innovate by reducing post-innovation rents. On the contrary, the Schumpeterian effect dominates the escape-competition effect when competition is high.

To test this hypothesis, we estimate the relationship between competition and R&D using the log-quadratic specification. That is, for industry j at time t,

$$\log r_{jt} = \beta_0 + \beta_1 c_{jt} + \beta_2 c_{jt}^2 + \gamma' z_{jt} + \varepsilon_{jt} \tag{1}$$

where r_{jt} is the R&D intensity, c_{jt} is the competition, γ is a vector of parameters, z_{jt} is a vector of control variables and ε_{jt} is a random disturbance.

Hypothesis 2. *The technology gap is larger as the competition increases.*

As the competition increases, R&D increases in *leveled* industries where the technology gap is small and decreases in *unleveled* industries where the technology gap is large. The net result is that more leveled industries become unleveled, and thereby constituting an increase in the average technology gap.

To test this hypothesis, we estimate the relationship between the technology gap and competition using the following specification:

$$m_{jt} = \beta_0 + \beta_1 c_{jt} + \gamma' z_{jt} + \varepsilon_{jt} \tag{2}$$

where m_{jt} is the industry-level technology gap.

Hypothesis 3. *In more leveled industries, the peak of inverted-U relationship between competition and R&D intensity is larger and occurs at a higher level of competition.*

In a leveled industry, the escape-competition effect is more dominant. Therefore, the inverted-U relationship peaks at higher level of competition and the peak appears at higher level of competition.

To test this hypothesis, we estimate the following model:

$$\log r_{jt} = \beta_0 + \beta_1 c_{jt} + \beta_2 c_{jt}^2 + \beta_3 d_{jt} \cdot c_{jt} + \beta_4 d_{jt} \cdot c_{jt}^2 + \gamma' z_{jt} + \varepsilon_{jt} \tag{3}$$

where d_{jt} is a dummy variable equal to one if the average technology gap is lower than the median of the technology gap across industries. This specification is similar to equation (1) except that it allows different marginal effect between industries with low and high technology gap.

Hypothesis 4. *The firm's R&D intensity increases with competition. Moreover, as the firm becomes more technologically laggard, the marginal effect of competition on the R&D intensity is smaller.*

Proposition 1 in AG states that competition increases the R&D intensity of a neck-to-neck firm and decreases the R&D intensity of a laggard firm. By construction, the leading firm does not conduct R&D. Since the technologically advanced firm is expected to keep innovating in the real world, our practical interpretation of this proposition is that competition increases the R&D

intensity regardless of the width of the technology gap, but the marginal effect of competition on the R&D intensity is greater for firms with smaller technology gap. In other words, the Schumpeterian effect implies a smaller marginal effect, rather than a negative one.

To test this hypothesis, we estimate the following two regressions: for firm i at time t,

$$r_{it} = \beta_0 + \beta_1 c_{it} + \beta_2 d_{it} + \beta_3 d_{it} \cdot c_{it} + \gamma' z_{it} + \varepsilon_{jt} \tag{4}$$

where d_{it} is the technological advance defined as the difference between firm i's total factor productivity and the industry average. We choose not to use the firm-level technology gap defined earlier because it is one-sided. More precisely, the technological advance is superior to the technology gap since the former can be interpreted as follows: (1) a firm with positive technology difference is an industry technological leader, (2) a firm with negative technology difference is an industry technological laggard, (3) a firm with technology difference approaching zero is neck-and-neck firm.

Although AG theoretical models the innovation intensity as R&D intensity, they make use of citation-weighted patent counts in empirical study. Nevertheless, our study uses R&D intensity as a proxy for the innovation intensity as in the original theoretical model. Moreover, the available patent count data in Thailand are reputedly unreliable[11] since many firms that engage in innovative activities never filed patent applications.

Due to the small industry-level dataset which covers 47 industries and spans over a period of, at most, five years, we prefer more parsimonious estimation models to test Hypothesis 1 to 3. We, therefore, estimate equation (1) to (3) using OLS as well as random effect models to capture time invariant heterogeneity across industries[12]. We avoid using fixed effect model since the panel is short and many industries have only one data point. In contrast, while the firm-level dataset is quite

[11] More than 90% of patents were awarded to non-resident or international applicants as reported by WIPO World Intellectual Property Indicators. The NSTI R&D surveys also ask respondents about patents. However, in each year only 1 to 4% of the respondents received patent grants and the number of patents vary greatly year-to-year depending on sampled firms.
[12] In all random effect models, the Breusch and Pagan Lagrange multiplier test for random effects reject the null hypothesis at 1% significance level.

large, only a quarter of the firms are found to conduct R&D. As a result, we estimate equation (4) using OLS and Tobit model where the R&D intensity is censored from below at zero.

To address possible endogeneity between competition and innovation, we employ a control function approach to capture a correlation between their random components. The industry-level and firm-level analyses estimate control functions with different sets of instrument variables. We select instrument variables that can better explain the variation of competition level. That is, we use only the import value in industry-level analysis, while using both log of the industry import value and the industry exchange rate in the firm-level analysis.

4 Empirical results

We test Hypotheses 1 to 4 by estimating equation (1) to (4) with two sets of samples: all industries and only manufacturing industries. Our findings can be summarized as follows.

Finding 1. *There is an inverted-U relationship between competition and R&D intensity in manufacturing industries.*

We find that Hypothesis 1 is true only for manufacturing industries. Table 2 shows the OLS and random effect model estimation results of equation (1) with full and manufacturing-industry samples. All regressions include year fixed effects and control functions. The estimates in column 1 and 2 give us a hint of an inverted-U relationship in all-industry sample, but the competition variables are collectively insignificant. Nevertheless, we observe a significant inverted-U relationship in manufacturing industries. As shown in column 3 and 4, the coefficients of competition and competition squared are both statistically significant and thereby constitute an inverted-U shape relationship. In the first stage of all regressions, the instrument variable is statistically significant at 1% level. Although the coefficient estimates and the statistical significance of OLS and random effect models are similar, the Hausman test suggests that the random effect model is preferred.

Figure 2 shows the inverted-U relationships estimated using the random effect model. The relationship clearly indicates that the escape competition effect dominates up to a competition level of approximately 0.82, and the Schumpeterian effect then takes effect after that point.

Table 2. Hypothesis 1 testing results

	(1)	(2)	(3)	(4)
Industries	All	All	Manufacturing	Manufacturing
Model	OLS	Random effect	All	Random effect
Competition	8.99	6.72	32.98**	26.99*
	(18.15)	(12.17)	(11.87)	(12.53)
Competition squared	-5.23	-4.84	-19.97**	-16.48*
	(10.60)	(9.68)	(7.40)	(8.43)
Control function	-7.27	-1.47	-0.61	0.71
	(5.90)	(3.55)	(1.79)	(5.62)
Constant	-13.97	-10.80**	-20.60**	-18.08**
	(7.41)	(3.97)	(4.70)	(4.42)
Manufacturing and financial industry fixed effects	Yes	No	No	No
Joint significance of competition and its square	0.12	0.38	3.94	10.51
	(0.88)	(0.83)	(0.02)	(0.01)
Hausman test of random effect model		1.72		0.17
		(0.42)		(0.92)
Estimate of instrument in reduced form	4.99**	4.91**	5.08**	2.24**
	(1.20)	(1.90)	(0.65)	(0.85)
R-squared of reduced form	0.36	0.20	0.42	0.39
Number of industries	47	47	21	21
Observations	179	179	95	95

Note: The dependent variable is log of the R&D intensity. The estimates of year fixed effects are omitted. Numbers in the parentheses under respective coefficient estimates are Huber-White standard errors. Asterisks * and ** indicate significance at 5% and 1% level, respectively. The numbers for the test of joint significance are Wald test statistics and the numbers in the parentheses underneath are p-values. The numbers for Hausman test are Hausman test statistics and the numbers in the parentheses underneath are p-values.

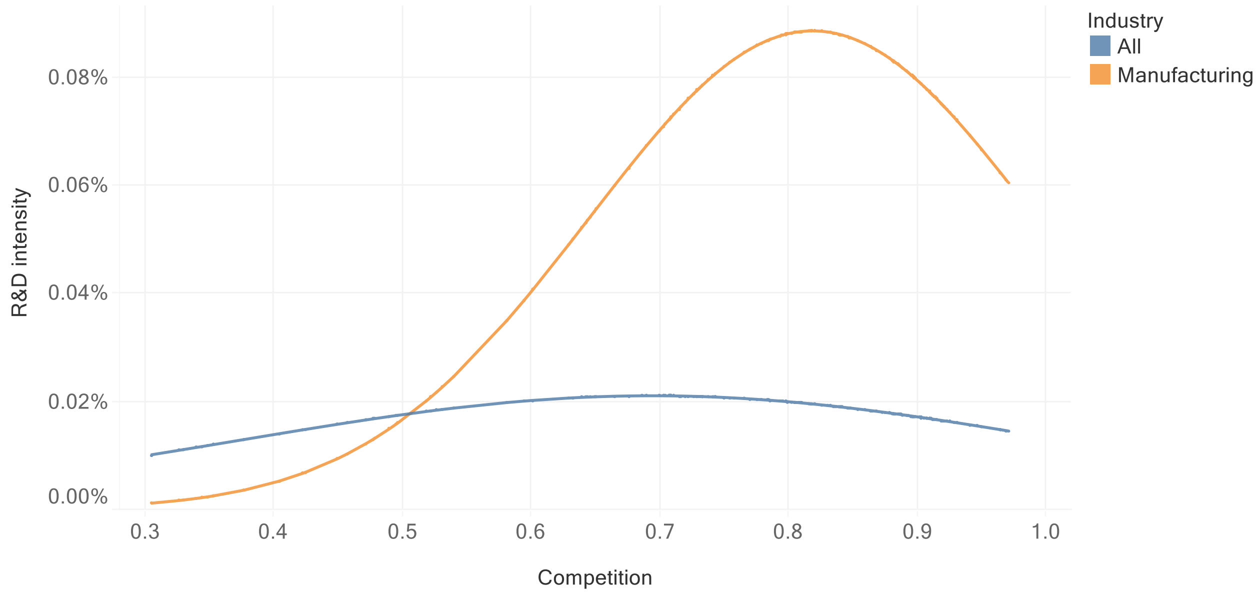

Figure 2. Estimated inverted-U relationship between competition and R&D

Table 3. Estimation results on test of Hypothesis 2

	(1)	(2)	(3)	(3)
Industries	All	All	Manufacturing	Manufacturing
Model	OLS	Random effect	OLS	Random effect
Competition	0.15^{*}	0.07	0.14^{**}	0.27^{**}
	(0.06)	(0.06)	(0.06)	(0.08)
Control function	-0.16^{*}	-0.11	0.18^{**}	-0.20
	(0.08)	(0.08)	(0.07)	(0.12)
Manufacturing and financial industry fixed effects	Yes	No	No	No
Hausman test of random effect model		30.64		1.26
		(0.00)		(0.94)
Estimate of instrument in reduced form	4.99^{**}	4.91^{**}	5.08^{**}	2.24^{**}
	(1.20)	(1.90)	(0.65)	(0.85)
R-squared of reduced form	0.36	0.20	0.42	0.39
Number of industries	47	47	21	21
Observations	179	179	95	95

Note: The dependent variable is technology gap. The estimates of intercepts and year fixed effects are omitted. The numbers in the parentheses are bootstrapped standard errors with 1,000 replications. Asterisks * and ** indicate significance at 5% and 1% level, respectively. The numbers for Hausman test are Hausman test statistics and the numbers in the parentheses underneath are p-values.

Finding 2. *Competition increases the technology gap in manufacturing industries.*

As in Finding 1, Hypothesis 2 is true only for manufacturing industries. Table 3 reports estimation results of equation (2). The exogeneous variables are the same as those in Table 2. Since the control functions in the regressions are significant, we correct the standard errors by bootstrap. The coefficients of competition are positive in all regressions, although not statistically significant in the random effect model with all-industry sample. Hausman test suggests that the results from the random effect model for all-industry sample are preferred. Thus, the estimation fails to conclude that competition increases the technology gap in all samples.

Finding 3. *The inverted-U relationships between competition and the R&D intensity in leveled and unleveled manufacturing industries are not significantly different.*

Our finding contradicts Hypothesis 3. Table 4 reports the estimation results of equation (3). Contrary to our hypothesis, we do not observe an inverted-U relationship in all-industry sample. For manufacturing industries, the OLS and random effect models yield different results as shown in column 3 and 4. While the OLS estimation indicates that the peak of the inverted-U relationship in unleveled manufacturing industries is higher and occurs at a lower level of competition, the random effect model suggests that there is no difference between the relationship in leveled and unleveled manufacturing industries. We agree with the result from random effect since the Hausman test of random effect model cannot reject the null hypothesis.

Table 4. Estimation results on test of Hypothesis 3

	(1)	(2)	(3)	(4)
Industries	All OLS	All Random effect	Manufacturing OLS	Manufacturing Random effect
Competition	18.05	11.64	28.38**	22.62*
	(17.04)	(10.41)	(10.58)	(11.47)
Competition squared	-13.67	-8.62	-18.95**	-15.51*
	(9.91)	(7.66)	(6.54)	(7.57)
Competition × Low technology gap	-9.54*	-4.21	-5.89*	-4.88
	(4.42)	(4.96)	(2.78)	(3.66)
Competition squared × Low technology gap	9.55	2.00	6.49*	5.25
	(5.54)	(6.30)	(3.20)	(4.14)
Control function	-6.37	0.16	-1.02	2.92
	(5.42)	(3.60)	(1.92)	(5.62)
Constant	-15.06*	-11.39**	-17.20**	-14.87**
	(7.09)	(3.72)	(4.32)	(4.35)
Manufacturing and financial industry fixed effects	Yes	No	No	No
Joint significance of competition and its square	2.44 (0.09)	1.27 (0.53)	4.47 (0.01)	4.23 (0.12)
Joint significance of competition and competition-squared interaction terms	6.10 (0.00)	8.98 (0.01)	2.96 (0.06)	2.45 (0.29)
Hausman test of random effect model		6.63 (0.25)		2.73 (0.95)

Estimate of instrument in	4.99**	4.91**	5.08**	2.24**
reduced form	(1.20)	(1.90)	(0.65)	(0.85)
R-squared of reduced form	0.36	0.20	0.42	0.39
Number of industries	47	47	21	21
Observations	179	179	95	95

Note: The dependent variable is the log of the R&D intensity. The estimates of year fixed effects are omitted. the numbers in the parentheses under the coefficient estimates are Huber-White standard errors. Asterisks * and ** indicate significance at 5% and 1% level, respectively. The numbers for the test of joint significance in OLS models and random effect models are F test and Chi-square test statistics, respectively, and the numbers in the parentheses are p-values. The numbers for Hausman test are Hausman test statistics and the numbers in the parentheses underneath are p-values.

Finding 4. *The firm's R&D intensity increases with competition. Moreover, in manufacturing industries, the marginal effect of competition on the R&D intensity is larger as the firm becomes more technologically advanced.*

This finding is consistent with Hypothesis 4. Table 5 reports the estimation results of equation (4). As the OLS and Tobit model estimations yield rather different estimates with respect to the coefficient signs and statistical significance, the censoring of the R&D intensity is non-trivial. We, therefore, prefer the results obtained from the Tobit model estimation.

There are several interesting observations, however. First, the escape-competition effect exists. The effect of competition on the R&D intensity in all columns except column 1 is positive and statistically significant. Second, the positive effect of the technological advance on the slope of competition suggests that the Schumpeterian effect applies on laggards. Third, in manufacturing industries, the negative coefficients of technological advance imply that laggards in unleveled industries try to catch up with other firms by asserting more innovative efforts. This is consistent with Finding 3 in that the higher R&D intensity from laggards raises the peak of inverted-U relationship of unleveled industries. Finally, competition has significant effect on the R&D intensity at a firm level in all-industry sample, but the magnitude is so small that it could translate into a negligible effect at the industry level as pointed out in Finding 1.

The signs of the firm size dummy variables and the share of export revenue are consistent with our expectation: larger or exporting firms conduct more R&D. However, the coefficient of the MNC dummy variable is negative and significant. That is, as Thailand historically attracts large inward FDI and serves as a production base of many MNCs, the MNC firms in Thailand may adopt technologies from the MNC units located elsewhere instead of conducting R&D domestically.

Table 5. Estimation results on test of Hypothesis 4

	(1)	(2)	(3)	(4)
Industries	All OLS	All Tobit	Manufacturing OLS	Manufacturing Tobit
Competition	1.97	11.85**	39.22**	204.06**
	(1.21)	(4.41)	(10.57)	(34.79)
Technological advance	0.06	0.32	-0.44**	-2.71**
	(0.03)	(0.55)	(0.13)	(0.72)
Competition × Technological advance	-0.18**	-0.68	0.36*	2.63**
	(0.05)	(0.63)	(0.14)	(0.80)
Large firm	-0.07**	0.70**	-0.06**	0.76**
	(0.01)	(0.05)	(0.02)	(0.05)
Medium firm	-0.05**	0.31**	-0.05**	0.38**
	(0.01)	(0.05)	(0.02)	(0.05)
MNC dummy	-0.11**	-0.38**	-0.12**	-0.39**
	(0.02)	(0.06)	(0.02)	(0.05)
Share of export revenue	0.10**	0.70**	0.10**	0.55**
	(0.02)	(0.06)	(0.02)	(0.06)
Control function	-1.90	-11.06*	-39.50**	-201.54**
	(1.24)	(4.42)	(10.62)	(34.69)
Joint significance of instruments in reduced form	172.15 (0.00)		16.02 (0.00)	
R-squared of reduced form	0.94		0.98	
Number of industries	47		21	
Observations	19,422		14,340	

Note: The dependent variable is the R&D intensity in percent. The estimates of intercept, year fixed effects and industry fixed effects are omitted. The numbers in the parentheses under the coefficient estimates are bootstrapped standard errors with 1,000 replications. Asterisks * and ** indicate significance at 5% and 1% level, respectively. The numbers for the test of joint significance are F-test statistics, and the numbers in the parentheses underneath are p-values.

5 Discussion and conclusion

Pressured by the looming loss of competitive advantage, the Thai government has adopted generous incentive schemes to promote innovation in the private sector. As fruitless as it may seem, the stubbornly low R&D intensity is indeed a puzzle for policymakers. Since overall competition level has been unaltered for the past two decades, our main argument in this paper is that the effect of competition is somehow missing from the necessary condition for innovation promotion.

We, therefore, study the relationship between competition and innovation effort. The results of the study indicate that the relationship follows an inverted-U shape in manufacturing industries and that the peak of the inverted-U relationship is higher in unleveled industries. In addition, to supplement the industry-level findings, we further investigate the R&D behavior at a firm level and could confirm that firm-level sources of the inverted-U relationship are the opposing escape-competition and Schumpeterian effects on the firm R&D intensity.

It is clear from the empirical results that competition plays a key role in determining innovative efforts in manufacturing industries. We can provide further interpretations of our findings as follows. First, to encourage private sector innovation, we need to create a healthy competitive landscape by effectively enforcing competition law. Second, excessive competition may be undesirable due to the dominance of Schumpeterian effect over beneficial escape-competition effect. This means that the presence of market power does not equate lower total consumer welfare as monopoly rents are good incentives to induce innovations. Higher consumer welfare as a result of innovations can potentially outweigh the short-term loss. Thus, competition regulation should emphasize an objective of maximizing dynamic efficiency where innovation is a main concern, rather than focusing solely on static efficiency that aims to reduce market power and hence an incentive to innovate. This, in effect, argues that ex-post enforcement where investigation whether consumers are harmed by monopolistic behavior should be conducted on a case-by-case basis. Lastly, since we cannot find significant linkage between competition and innovation in non-manufacturing industries, better understanding into the nature of innovation practices in the industries is needed in order to draw policy recommendations.

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