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R&D intensity and business performance: The case of Thailand's maize seed industry

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Abstract

The seed industry has been accorded a high priority in Thailand's policies toward the fourth industrial revolution. The competitiveness of the seed sector can facilitate farmers' access to quality seeds at a reasonable price, stimulate growth in the agricultural economy and, overall, contribute to sustainable agriculture development. Developing the seed sector relies on many factors, an essential one being technology. Thus, the technological capability of seed companies is crucial as it enables a higher business performance, which increases and sustains the contribution of the seed industry to economic development. The paper's focus on the maize seed industry draws justification on its export value being the highest of all seeds exported from Thailand. The industry is dominated by multinational companies (MNCs) while local companies are at the early stage of development. This paper compares research and development (R&D) investment and the business performance between MNCs (both foreign subsidiaries and Thai-parent) and local small and medium-scale enterprises (SMEs). The results show that MNCs have higher investment in R&D, both in capital investment and human resources, and perform better. With a smaller investment in R&D, local SMEs have less technological capability and lower business performance than MNCs. On the other hand, a local research company showed an outstanding performance on return on sales. These findings suggest that Thai companies have a high potential for improvement in technological capability and business performance. To achieve this, they require support from the government and academic institutions in human resource development and enabling regulatory framework.

Keywords: Seed, Breeding, R&D, Technological capability, Business performance, Maize, Plant variety protection

1. Introduction

Seed is one of the fastest-growing industries in the agricultural sector. Thailand's seed supply indicator, which measures laws and regulations that support the timely release of seed for use by domestic farmers, was 78 out of 100, a performance that is above the regional average of around 50 points [1]. This indicates that Thailand has potentials to become a leading seed industry in the region. Among all crops, maize has the highest share of the seed exports from Thailand. In 2020, the country exported maize seed valued at around USD 70.125 million, about 30% of all its seed exports. In the past few decades, production and yield of maize have increased by more than 40% and 200%, respectively. This remarkable increase has been attributed to investments the research and development (R&D) in varietal improvement, which has helped develop a vibrant maize seed industry. The success of the maize seed industry development in Thailand became the platform for the Government and the Thai Seed Association to promote Thailand as a regional seed hub since 2006.

The Seed Hub policy set the goal for the country to be the region's hub of seed R&D, seed production and testing. Several public programs were implemented to promote this policy including investment incentives and support on the application of science and technology (S&T) to produce high quality and higher value seed [2]. Despite promising examples, most of the leading maize seed companies in Thailand are subsidiaries of multinational companies (MNCs), and only a few are capable of producing Thai brand-name seed. This may be

attributed to the limited technological capability of Thai companies. The dependence of the maize seed industry on foreign companies' technology has prompted the Government to promote and encourage more investments in R&D to enhance the technological capability of local companies. This would, among other outcomes, end their reliance on foreign companies for technology.

After the privatization of the hybrid maize seed industry in the early 1990s, adoption of hybrids increased dramatically [3]. The release of a single-cross hybrid, named CP-DK888, jointly developed by C.P. Seeds (presently Charoen Pokphand Produce) and DeKalb (presently Monsanto-Bayer) in 1991 made a significant impact on the maize seed industry. Its high yield, orange-yellow color and less susceptibility to ear rot made CP-DK88 very popular until recent years [4]. The hybrid's success opened new opportunities for seed companies; they began to focus their research programs on hybrid development. This also stimulated the establishment of more seed companies. The frequent release of single-cross hybrids and the increasing competition among seed firms gave farmers a wider choice of hybrids, each with traits that would suit their farming conditions and production objectives.

Today Thailand's maize seed industry is host to several MNCs with access to proprietary breeding lines and advanced technologies developed in their global operations. These companies operate alongside local small- and medium-sized enterprises (SMEs) that rely primarily on improved germplasm from public research programs for their multiplication and distribution operations. The mergers and acquisitions of multinational seed companies in recent years led to Thailad's maize seed industry becoming moderately concentrated on a few MNCs and several SMEs [2]. Nearly all maize production in Thailand use hybrids from private companies; less than 3% are public or local varieties [3]. Market concentration of the country's maize seed industry, estimated by HHI and CR4 in 2012, yields 1,700 and 76%, respectively [2]. Similarly, a study by OECD (2018), using 2016 data to estimate Thailand's maize seed industry concentration found that HHI and CR4 were 2,346 and 94%, respectively, in terms of value [5]. This implies an increasing concentration in the maize seed market during the past decades and the structure getting closer to oligopolistic competition.

A recent study showed that maize seed companies tend to develop varieties suitable to their specific market segments characterized by climatic condition, geographical area, season and harvesting technique, and offer farmers with a range of products differentiated by price, yield performance, standing ability, resistance to disease, and other traits [2]. Public breeding programs, primarily by the Department of Agriculture (DOA) and National Corn and Sorghum Research Center (NCSRC) have also contributed to the seed market by providing small local companies public varieties without property rights protection and non-exclusive licensing. Large MNCs have access to their proprietary breeding lines and advanced technologies while several small local SMEs can only rely on improved germplasm from public research programs. It was found that the R&D investment and seed production technologies in the corn seed industry (most are also players in the maize seed market) differ significantly between MNCs and the local companies, which gives rise within the industry to different levels of technological capacity [6]. In addition, Reichert and Zawislak asserted that in emerging economies where most businesses are primarily based on low and medium-low technology industries [7], it is impossible to verify a positive relation between technological capability and firm's performance. To support the Seed Hub policy goal of Thailand becoming the center for seed business in the region, it is important to ensure that along with developing an enabling environment. Thai local companies have the strength and resources to build their technological capability and perform well in the industry. Since the relationship between technological capability and corporate performance is not clear [8,9], this paper aims to compare investment in R&D, technology used, human capacity and business performance of maize seed companies in Thailand across different groups, namely, MNCs, local seed companies, and local research companies. The results would give useful implications for strengthening local companies' technological capability and enhancing their business performance.

In Thailand, the intensity of public R&D spending relative to agricultural gross domestic product (GDP) grew from 0.75 in 2000 to 0.94 in 2017 [10]. Although public investment was found to be mostly on crop improvement, the public sector only released two maize varieties during 2013/14-2017/18. Agricultural R&D investment by the private sector has not been well-documented but over several years, it had been concentrated around fast-growing industries, including livestock and seed [11]. By using expert elicitation method to assess the adoption of maize varieties, it found that the public varieties were adopted at only 2.2% [4]. This implies that the private sector contributes significantly to the release of new maize hybrids and dominates the maize seed industry in Thailand.

If the country's maize seed industry becomes more concentrated over time, increasing market power could negatively influence market efficiency and the benefits to farmers and consumers. On the other hand, it also implies economies of scale in R&D [12]. The role of market concentration (as measured by concentration ratio (CR4) and the Herfindahl Hirschman Index (HII)) on the rate of innovation (as determined by newly released varieties) in plant breeding was nevertheless unclear [2]. In the EU, depending on the model specifications, market concentration was found to negatively affect the rate of innovation although not statistically significant. However, increasing market concentration was also found to first reduce, then increase the innovation implying

an inverse U-shaped pattern [13]. Thus, the relationship between market concentration and innovation in plant breeding is ambiguous.

Reichert et al [7] and Coombs et al [8] suggested that R&D is one of the determinants for technological capability. Technology capability is the ability of a firm to innovate, execute any relevant technical function, including the ability to develop new products, processes, and technological knowledge. This will bring in higher levels of organizational efficiency, generate competitive advantage, expedite the speed of innovation, facilitate company internationalization, and stimulate economic growth [8,14]. Measuring technological capability is, however, challenging. Patent is often used to measure technological capability, but it is restricted to patent-intensive sectors. In the case of plant breeding, the plant variety protection (PVP) law plays an important role in determining the benefit of property rights protection of new varieties. The principles of PVP follow the distinctiveness, uniformity, and stability (DUS) testing under the International Union for the Protection of New Varieties of Plants (UPOV). It shows that there are only a small number of commercial maize varieties registered for plant variety protection in Thailand [6]. This could be attributed to shortcomings in the seed regulations of Thailand. For example, the registration of PVP is weakly enforced, the process of registration i.e. the submission for DUS trials imposes a large transaction cost, it takes 358 days to register a new cereal variety, if a variety is already registered in another country, the law does not allow it to be automatically approved for commercialization, and DUS testing data from foreign authorities are not accepted [1].

Nevertheless, some provisions of the seed regulation support R&D and breeding program. For instance, private seed companies or third parties can produce early generation seed from public varieties, the seed law prescribes the procedural requirements to access plant genetic materials, plant breeder's rights can be licensed to third parties for production and sale, public research institutes can license public varieties to companies for domestic production and sale, and companies can access plant genetic materials from the gene bank [1]. In addition, the government offers several incentives to investments in R&D and biotechnology in seed including a five-year corporate income tax exemption for plant breeding business, import tax exemption on goods for R&D purposes and/or manufacturing in the seed industry [6].

2. Materials and methods

Building upon the concept of the relationship between technological capability and business performance by Coombs et al. [8], this study focuses on R&D intensity, as the information is completely accessible through a survey of seed firms and has been used to approximate technological capability of seed companies [15]. Number of patents and registration of new plant variety protection have been used in previous studies to indicate technological capability [8,16,17], but because of the intellectual property right protection regulations of Thailand (as discussed above), it is inappropriate for this study. Other indicators such as technology cycle time [8] are also important but determining and measuring them is rather difficult given the diverse seed products of the same companies. R&D intensity includes R&D expenditures, technology used in plant breeding program, human capacity, and proprietary and public support activities. To evaluate business performance, this study uses accounting performance because data on market performance such as market value and seed quality as suggested by other studies [6,18] are difficult to evaluate. Since there is no consensus on what an appropriate measure of financial performance is, Return on Sales (ROS), Return on Equity (ROE), and Return on Asset (ROA) are calculated.

$$\mathrm{ROS} = \mathrm{Operating\ profit}/\mathrm{Net\ sales} \tag{1}$$

where Operating profit = Earnings before Tax = Total Revenue - expenses - operating costs, Net sales = Total Revenue – returns – allowances - discounts

$$\mathrm{ROA} = \mathrm{Net\ income}/\mathrm{Total\ assets} \tag{2}$$

where Net income = Profit before common stock dividends (none of these companies are listed on the stock market), Total Assets = Equity + Liabilities

$$\mathrm{ROE} = \mathrm{Net\ income}/\mathrm{Equity} \tag{3}$$

where Net income = Profit before common stock dividends (none of these companies are listed on the stock market), Equity = Assets − Liabilities

Furthermore, the performance of a seed firm is evaluated by its market power [2]. A firm that has higher technological capability should have higher market power as it can generate new products differentiated from its competitor's. Lerner index is conceptually used to measure the monopolistic power. Assuming that the average

costs are constant, the price-cost margin (PCM) is equal to the Lerner index [18]. The larger the PCM, the greater the company's ability to raise prices above average costs, which implies higher monopoly power. PCM is defined as the ratio of profit after interest and tax to sales revenue and can be expressed as

$$\mathrm{PCM} = \frac{\mathrm{P}-\mathrm{AC}}{\mathrm{P}} = \frac{\mathrm{P}\cdot\mathrm{Q}-\mathrm{AC}\cdot\mathrm{Q}}{\mathrm{P}\cdot\mathrm{Q}} \quad (4)$$

where P is price, Q is quantity and AC is average cost. Firm's financial data are obtained from [19]

To compare the R&D investment and the business performance between MNCs and local companies, the scope of maize seed companies comprises all companies that are engaged in R&D or have some research programs and/or participating in technology development (i.e. technology firms). The level of research could range from participating in field trials of public varieties to being fully engaged in breeding, varietal improvement, and seed technology development. The list of MNCs was obtained from Napasintuwong [2], which identified four foreign subsidiaries and one Thai-parent MNC. Three out of four foreign subsidiaries were randomly selected and the only one Thai-parent MNC is included. For local companies, the list was obtained from registered seeds [20] and companies were randomly selected from a list of those Thai owned companies engaged in R&D. The identification of R&D local companies was made through a consultation with experts from DOA and NCSRC who have conducted the multilocation public-private yield trial program. There are very few local companies engaged in R&D and four were selected based on their willingness to respond to the questionnaire; among them, one is the research company. The research company is a local company engaged primarily in R&D of maize varieties and less focused on production and sales. The corporate survey was conducted in 2016, and the scope of research on seed business covers data in 2015 and 2016 both in Thailand and other countries (if MNCs). As evidence has shown, R&D investment in breeding can have as long as decades of time-lag effect in agriculture [21,22]. As this study focuses on the private sector that typically has a continuous investment over several years, the R&D investment effect on a firm's performance is presumed to have a 5-year time-lag effect (corporate accounting information in 2020 and the most recent available data across selected companies). It should also be noted that MNCs have other related businesses such as agrochemicals; thus, the company's financial data represent all businesses although seed is one of their key businesses.

3. Results and discussion

The survey information on R&D provided by the seed companies is confidential. To reveal this information, the companies are grouped into four rather than mentioning each one's identity. Their business ownership and operation is summarized in Table 1. Table 2 shows the profile of activities that selected maize seed companies engage in. All groups of companies are involved in key activities: genetic resource collection and/or maintenance, R&D, seed multiplication of parental seeds or early generation seeds and F1 hybrid seeds, marketing and sales. The exceptions are local SMEs that are not involved in genetic resource collection and/or maintenance. Not all local SMEs are involved in breeding but they all participate in the multi-location yield trial, which is a cooperative program organized by DOA and NCSRC to bring both public and private sectors together in testing their elite lines.

Table 1 Samples of maize seed companies in Thailand, 2016.

Company group	MNC		Local company	Local research company
	Foreign subsidiary	Thai-parent		
Locally headquartered with a majority of local ownership	No	Yes	Yes	Yes
Listed on the local stock market	No	No	No	No
Headquartered locally with foreign subsidiaries	No	Yes	No	No
Affiliated with a foreign company headquartered elsewhere	Yes	No	No	No
N	3	1	3	1

Table 2 Thailand's maize seed companies' profile, 2016.

Company group	Genetic resource collection/ maintenance	R&D		Seed multiplication		Marketing/ sales
		Breeding	Multi-location yield trial	Parental seed (Early generation seed)	F1 Hybrid seed	
MNC (Foreign subsidiaries)	Yes	Yes	Yes	Yes	Yes	Yes
MNC (Thai-parent)	Yes	Yes	Yes	Yes	Yes	Yes
Local company	No	Yes/No	Yes/No	Yes	Yes	Yes
Local research company	Yes	Yes	Yes	Yes	Yes	Yes

Table 3 reveals the financial investment in R&D and the information on human capacity. As would have been expected, financial investment intensity in R&D by MNCs is much larger than the local companies. The local research company also invests much more than the local seed companies. Overall, MNCs have significantly higher number of employees than the local companies, reflecting the scale of operation. The total number of R&D staff of MNCs is also apparently higher than those of local companies. The share of R&D staff and technology development staff of the MNCs who have Ph.D. and Master's degree is also higher than the local companies. The local research company invests significantly higher in employing R&D staff than local companies. As the competency or education of employees [23] and employees engaged in research activities [24,25] has been suggested to be associated with the performance of knowledge-based firms, MNCs would likewise have higher technological capability and performance than local companies. Specific to SMEs, [26] it is also suggested that human resource is indeed associated with product innovation capabilities.

Molecular breeding technology is considered superior in plant breeding to conventional methods. However, Thailand's regulation does not authorize Genetically Modified (GM) crop production, and open field trials of GM seed need government approval since 2007 (cabinet approval is on a case-by-case basis). This has limited the choices of technology used for varietal development, and seed companies, specifically MNCs, have raised the concern as to whether the limitation of breeding technologies would undermine Thailand's capability to lead the seed industries and become the seed hub in the region. Nevertheless, Marker Assisted Selection (MAS) that can increase the precision and predictability of conventional breeding and reduce time to develop new cultivars is permitted. This implies that firms that employ molecular breeding technology, namely MAS would have more technological capability that those that do not. Table 4 shows the status of R&D in breeding technology. The more advanced technology i.e. MAS and double haploid is only employed by the MNCs while the local companies still primarily use selfing technology. Although none of the companies conduct research on GM technology in Thailand, some MNCs carry out research on GM in other countries. Furthermore, as foreign MNCs operate in other countries, it can be assumed that they have more access to genetic resources and apply more advanced technologies, such as genetic engineering and genome editing in their breeding programs in other countries.

Once the Thai regulation allows these technologies, MNCs would be able to rapidly expedite their R&D in Thailand with the same technology available from other countries, assuming that legislation is passed that authorizes such transfer. As to support for breeding, although the government has provided several incentives to promote R&D in the seed industry [6], the local companies still have not benefited much from such incentives as tax credit and tax exemption. However, some local companies engage in collaborative research with the public institutes and other private companies while the MNCs have no collaborative research with any other companies.

The seed products of most companies include field maize, sweet corn, waxy corn and baby corn (Table 5). Foreign subsidiaries of MNCs also have businesses in crop protection products. Thai companies have none. The products, specifically maize seeds, developed by all companies are primarily single cross hybrids. Some local companies, however, still sell double cross hybrids and modified single cross hybrids, which require less advanced technology to develop. One important difference is that MNCs and the Thai research company developed the new varieties with their own research and not licensed by a local public institute (Table 5). The products of some local companies, on the other hand, were licensed from the local public institute or individuals. Varieties licensed from other private companies are also observed from Thai-parent MNC and local companies.

Table 3 Thailand's maize seed companies' R&D investment, 2016.

Company	MNC		Local company	Local research company
	Foreign subsidiary	Thai-parent		
Research expenditures (million THB)*				
2016	30-120.6	66.5	2.0-10.0	n/a
2015	30-121.8	70.2	0.5-5.0	10
Human capacity				
Research staff (including manager and consultants)				
PhD	0-2	3	0	1
MSc	3-9	10	1-2	4
BSc	0-9	11	0-5	3
Other diploma/degree	0-49	6	0-1	15
Technology Development staff				
PhD	1-3	0	0	0
MSc	0-4	4	0	0
BSc	5-7	9	0-3	0
Other diploma/degree	0-4	0	0	0
Sales/Marketing staff				
PhD	0	0	0	0
MSc	2-8	4	0-2	0
BSc	27-34	57	5-30	0
Other diploma/degree	0	7	0	0
Total number of local employees	163-1100	n/a	15-24	23
Total number of local R&D employees	18-61	89	1-3	23
Total number of local foundation seed employees	4-48	74	0-4	0
Total number of local field production extension employees	22-23	40	2-4	0
Total number of processing plant employees	16-70	372	0-50	0
Total number of quality assurance employees	12-16	14	0-1	0

*Note: 1 USD = 35.298 THB in 2016, Bank of Thailand.

Table 4 Thailand's maize seed companies' breeding technology, 2016.

Company	MNC		Local company	Local research company
	Foreign subsidiary	Thai-parent		
Current breeding technology used in Thailand				
Selfing	Yes	Yes	Yes	Yes
Back crossing	Yes	Yes	Yes	No
Marker Assisted Selection (MAS)	Yes	No	No	No
Double haploid	Yes	Yes	No	No
Genetically modified	No	No	No	No
Multi-location yield trial	Yes	Yes	Yes/No	Yes
Current breeding technology used in other countries				
Selfing	No	Yes	No	No
Back crossing	No	Yes	No	No
MAS	Yes	No	No	No
Double haploid	Yes/No	Yes	No	No
Genetically modified	Yes/No	No	No	No
Multi-location yield trial	Yes/No	Yes	Yes/No	Yes
R&D breeding activity				
Did your firm carry-out any in-house R&D?	Yes	Yes	Yes/No	Yes
Did your firm use any public R&D?	Yes/No	No	Yes	No
Did your firm sell licenses on varieties?	Yes/No	No	No	Yes
Did your firm buy licenses on varieties?	Yes/No	Yes	Yes/No	No
Public support activities				
Tax credits for R&D expenditures	Yes/No	No	No	No

Table 4 (Continued) Thailand's maize seed companies' breeding technology, 2016.

Company	MNC		Local company	Local research company
	Foreign subsidiary	Thai-parent		
Government financial support for your firm's research	No	No	No	No
Other government support for your firm's research	Yes/No	No	Yes/No	No
Collaborative research with government research institutes	Yes/No	No	Yes/No	No
Use government research pedigree or germplasm	Yes/No	Yes	Yes	No
Collaborative yield trial with government research institutes	Yes	Yes	Yes/No	Yes
Collaborative research with international research institutes (not private companies)	No	No	No	No
Collaborative research with other private firms	No	No	Yes/No	Yes

It is worth noting that the new varieties of Thai companies are not protected under the PVP and only some of the foreign MNCs' varieties are PVP protected. In addition, only the new varieties of some foreign MNCs are registered and approved by the DOA. The registered varieties do not have DUS characteristics like the PVP, but the company needs to declare the source of genetic materials, history of development and characteristics with the DOA.

The quality of seed products may be determined from two aspects: traits of the varieties and seed quality. Under the "Plant Variety Act" in Thailand, (The seed law) it is required that the purity and germination rates of maize be at least 98 percent and 75 percent, respectively. The specifications of seeds produced by MNCs and local companies are nearly the same, but their shelf life is different. The characteristics of varieties, however, are somewhat different. As shown in [2] and [4], maize seed products are developed to be competitive in the segmented markets.

The result of the assessment of business performance is shown in Table 6. Generally, the foreign MNCs have a higher performance than the Thai companies. The ROA represents the efficiency by which a firm can generate profit on its investment in capital. Among Thai companies, the performance of the local research company is higher than Thai-parent MNCs and some local SMEs. The ROE also shows similar trends. The major difference is that the ROE does not take into account the liabilities of the firm, which can make this indicator much larger than the ROA when a firm has large liabilities. One local company has a good performance on ROA, but its ROE is almost 48 which suggest that its liabilities to profits are significantly larger than those of other firms. The ROS also shows that foreign MNCs outperform Thai companies but not the local research company. The ROS of the research company is far larger than all the other firms including MNCs. This suggests that a local research company that focuses on R&D, has built up its technological capability and becomes well-recognized in the industry is able to generate good returns by licensing its products and collecting royalty fee. Such capability is not possessed by local seed companies that have lower technological capability and depend largely on sales. The PCM, which represents market power, shows that foreign MNCs have higher market power than local companies, including the Thai-parent MNC. However, the market power of the research company is larger than all representative firms. This result affirms that by investing and focusing on research, a company can build technological capability, innovate new products, and gain more power to control the market compared to a company that invests less in R&D.

Table 5 Thailand's maize seed companies' products, 2016.

Company	MNC		Local company	Local research company
	Foreign subsidiary	Thai-parent		
Product lines				
Seed (field maize)	Yes	Yes	Yes	Yes
Seed (sweet corn)	Yes/No	Yes	Yes/No	Yes
Seed (waxy corn)	Yes/No	Yes	Yes/No	Yes
Seed (baby corn)	Yes/No	Yes	No	No
Pesticides/Herbicides	Yes/No	No	No	No
Fertilizers	No	Yes	Yes/No	No
Are there any new maize seed products in the past five years? (2011-2016)				
Single cross hybrid	Yes	Yes	Yes	Yes

Table 5 (Continued) Thailand's maize seed companies' products, 2016.

Company	MNC		Local company	Local research company
	Foreign subsidiary	Thai-parent		
Modified single cross hybrid	Yes/No	No	Yes/No	No
Double cross hybrid	No	No	Yes/No	No
Are the new varieties from company's own R&D	Yes	Yes	Yes/No	Yes
Are the new varieties licensed by local public institutes?	No	No	Yes/No	No
Are the new varieties licensed by private companies?	No	Yes	Yes/No	No
Are the new varieties licensed by individuals?	No	No	Yes/No	No
Are the new varieties protected under Plant Variety Protection in Thailand?	Yes/No	No	No	No
Are the new varieties protected under Plant Variety Protection in Other countries?	Yes/No	No	No	No
Are the new varieties registered?	Yes/No	Yes	No	No
Field maize seed product characteristics				
Shelf life (months)	12-24	12	12-24	6-12
Germination rate (%)	90	90	90	85
Genetic purity (%)	98	98	98	n/a

Table 6 Thailand's maize seed companies' performance, 2020.

Company	MNC		Local company	Local research company
	Foreign subsidiary	Thai-parent		
ROA	5.62-13.6	2.80	0.03-4.88	3.24
ROE	10.20-18.40	13.01	0.21-47.92	3.26
ROS	13.34-24.03	2.92	0.26-8.63	33.69
PCM	0.129-0.195	0.029	0.01-0.072	0.269

Source: Calculated from Thailand Department of Business Promotion, 2020. [19]

Figure 1 illustrates three performance indicators, namely PCM, ROA and ROS represented by the size of the bubbles. The figure clearly shows that foreign MNCs have higher market power and are more profitable than local companies but not more than the local research company. One Thai-parent MNC does not perform as well as foreign MNCs and even more poorly than some local companies in some indicators. This implies that the Thai MNC has been unable to exploit the opportunities offered by government support and may need to engage in collaborative research programs with public institutes and research companies to strengthen its technological capability.

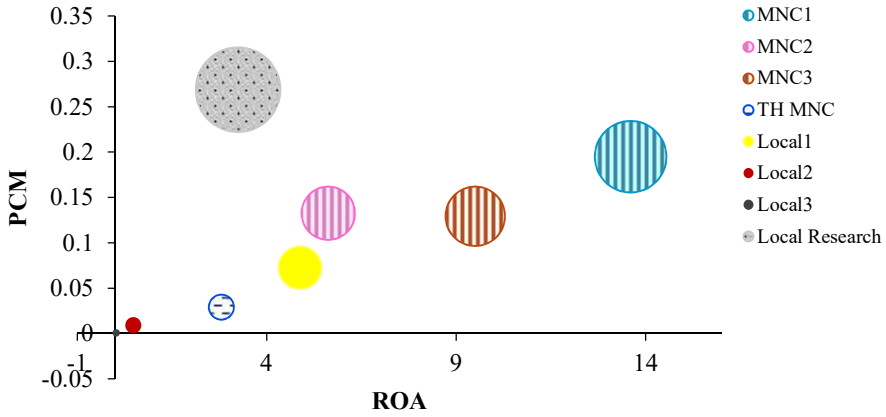

Figure 1 Business performance of maize seed companies, 2020.
Source: Calculated from Thailand Department of Business Promotion, 2020. [19]
Note: Size of the bubbles represents Return on Sales.

During 2010-2019, the investment towards achieving a sustainable seed system (defined as improved productivity, improved resilience, improved input efficiency, reduced environmental footprint, improved nutrition goals, and improved affordability and income for farmers) in the Global South was marked by private companies investing primarily in S&T, product development and marketing and government investing more broadly and almost equally on S&T, product development, marketing and extension, and infrastructure development. The institutes receiving grants from philanthropic foundations, on the other hand, invested more on S&T, specifically breeding [27]. Our study, however, shows that maize seed companies in Thailand have the technological capability to invest in S&T, and develop the market and carry out extension. This suggests that some basic research on more advanced technology such as genome editing that require a high level of technological capability and resources may still need to be done by academic institutions or public research institutions. This would build up the S&T support for the private sector, particularly local companies that have limited resources, to strengthen their technological capability.

MNCs and local companies have benefited from public support i.e. by accessing genetic resources, engaging in collaborative yield trials and participating in collaborative research projects. The result of this study points out an important situation: local SMEs still have less technological capabilities despite the R&D investments. Government support in strengthening the technological capability of companies is essential for a sustainable seed industry. Potential support may include facilitating the accessibility of the scientific expertise of academic and research institutions to the local companies by creating partnerships in research and technology development and working out a benefit-sharing scheme. This would increase the competency of the small local companies.

Furthermore, the policy and implementing regulations that enable seed industry innovation might need further improvement. As discussed by Srinivasan [28] and Spielman et al [29], private companies' incentive in R&D depend on the PVP legislation. Although most seed companies would invest more in R&D with PVP, an effective regulation on breeders' rights would assure companies protection of their rights to any innovation that they develop. One piece of legislation that may need some reform or updating is the current Thailand's PVP law. The current PVP was designed to balance the plant breeders' rights and the farmers' rights under the Convention on Biological Diversity (CBD). The Thai PVP which came into force in 1999 is closer to UPOV 1978 while other UPOV members have adopted UPOV 1991 [6]. UPOV 1991 would provide benefits to MNCs that operate in several countries by reducing transaction cost of DUS testing as it would be automatically approved for commercialization if the same variety is already registered in another UPOV country. At present, local companies may appear to benefit less from UPOV 1991 than foreign MNCs. Nevertheless, as their technological capability strengthens, Thai-parent MNCs would grow and benefit from UPOV 1991 as well.

4. Conclusion

This paper investigates the technological capability and business performance of maize seed companies in Thailand using primary data collected from a corporate survey. Due to the regulation of property rights protection of plants in Thailand, the number of patents and the number of registrations of the new PVP are not appropriate for measuring technological capability. As an alternative, the R&D intensity including R&D expenditures, technology used in plant breeding program, human capacity, proprietary and public support activities are used to represent the technological capability of seed firms. The indicators of financial performance, ROS, ROE and ROA, and of monopolistic power, PCM, are used to measure the business performance. The information on R&D intensity and business performance of maize seed companies reveals that foreign MNCs engage in germplasm collection, maintenance, conduct in-house R&D, and invest much more in R&D than local companies. The information on technology used in breeding and types of hybrids suggest that MNCs have a higher technological capability than local firms. The local research company that established its technological capability by focusing on research and licensing rather than on production and sale of seeds, however, performed relatively better than the local seed SMEs, especially in terms of return on sales and market power. This implies the need to strengthen local companies and incentivize them to improve their technological capability. Local companies do not utilize government support on tax credit for R&D activities, but engage in collaborative yield trials and collaborative research with public institutions. These support mechanisms might not be sufficient to build up their technological capability. The government could explore opportunities to strengthen local companies through human capacity development particularly breeding technology and seed technology and revisit PVP regulations to provide incentives for R&D investment. The results and implications of the paper are constrained by the information provided by the companies. There could be important information that companies cannot divulge because they are deemed trade secret or their being revealed is seen to negatively affect the company's commercial interest. The results could be improved if the information is verified. Furthermore, the number and variety of selected companies can be increased if more companies are willing to reveal corporate data.

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