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The Reorientation of Thailand's National R&D Programmes - Limits and Challenges

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ABSTRACT

Since 2016 Thailand has recognised a significant transition in research and innovation policy, with government increasingly acknowledging the importance of national R&D programmes and favourable institutional conditions as determinants to overcome 'middle-income trap'. Drawing the lessons learned from successful experiences of South Korea and Japan, the Thai government decided to experiment with the national large-scaled mission-oriented R&D programme, known as 'Spearhead R&D Programme'. This novel innovation financing scheme was designed to accelerate the commercialisation and economic impact of R&D outputs. From the outset, it is clear that the outcome and impact of Spearhead R&D Programme has yet to be realised. The purpose of this paper is to investigate the reorientation of Thailand's research and innovation landscape with the focus on the efficiency of operation in relation to the objective of Spearhead R&D Programme. It is found that the Spearhead R&D Programme is equipped with four novel conceptual and operational features including strategic national STI agenda, R&D commercialisation, multi-year budget allocation and proactive research management. Yet, there are also potential limits and challenges that need to be addressed to move the Programme towards greater sectoral contribution with open innovation and flexibility in policy learning.

I. INTRODUCTION

Thailand has made notable socio-economic progress over the past four decades from 1957 to 1996 (with average annual GDP growth rates of more than seven percent) and attained middle-income status. Sadly, Thailand is stuck in the 'middle-income trap' as the country fails to produce differentiated and sophisticated products and climb up the global value chain. Although Thailand is now well integrated into regional and global production networks, moving up the global value chain demands greater efforts of local firms to absorb imported technology and develop indigenous technological capabilities.

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Yet, technological capabilities of Thai firms remain low and exhibit more 'passive' learning patterns. These phenomena could be seen in many high performing industries. For example, Thailand ranks the 12th top automobile producer in the world and became a major exporter of hard disk drives. Much of the technology owned by multinational firms has not spilled over into domestic firms. Tier 1 suppliers or finished goods assemblers are mainly foreign firms. By contrast, the large majority of local firms remain Tier 2 and Tier 3 suppliers of which processes and products show relatively low industrial sophistication. According to the R&D survey conducted by national science technology and innovation policy office in 2017, it was found that only 15 large Thai firms contributed to the majority of the country's R&D spending, accounting for 51%. Considering innovative products and services development, the majority of Thai businesses tended to be followers rather than leaders.

The national innovation system of Thailand has remained fragmented (Intarakumnerd, et al. 2002; Chaminade, Intarakumnerd and Sapprasert 2012; Intarakumnerd, 2017). The innovation financing schemes in the country has not co-evolved as much with the development of technological capabilities of firms and national innovation systems. Thailand has been unable to quickly modify its policy instruments to address the need of firms at different development stages. Such financing schemes are limited mostly to passive tax incentives and the activities narrowly focus on R&D rather than the broader scope of innovation. The effectiveness and efficiency of such innovation financing schemes are hampered by not only fragmented and overlapping policies but also government agencies' incapacity to monitor, evaluate and learn from implementation (Intarakumnerd and Wonglimpiyarat, 2012).

Even though R&D spending in Thailand has been low and stable, over 0.25% during the past decade (2001-2009), the gross R&D spending from both government and business enterprises has sharply increased from 0.37% of GDP in 2010 to 1.0% of GDP in 2017. The intense market competition caused big corporations to innovate for the sake of business differentiation and high value-added products (Bangkok Post, 2019). Within the total R&D spending of THB 155 billion, the R&D expenditure from business sector accounts for 80% of gross R&D investment. Food, automotive, and petroleum are among the top three investment sectors for R&D.

Until now, the Thai government provided policy measures to encourage private sectors to invest more in research and development, such as 300% tax deduction for R&D and the promotion of talent mobility between universities and private companies. The growth of R&D expenditure had urged the Thai government and public funding bodies to seek increased efficiency in the use of funds. The Thai government has demonstrated an effort to develop systemic capability to channel resources towards national urgent agenda and create favourable Research & Innovation (R&I) governance.

Considering the capabilties to orchestrate public and private resources towards national strategic goals, it is evident that South Korea and Japan have demonstrated remarkable experiences in utilising their national large-scaled mission-oriented R&D programmes to pursue catch-up, leapfrog and sustained growth. Such government-sponsored R&D programmes had showed a significant transition from primarily assimilating foreign technology at first to advancing global frontier research. Due to the fact that the R&D funding will consume a great portion of the public budget, those governments have made significant efforts in aligning the concept and operational features of their R&D programmes to serve their strategic goals. The effectiveness and efficiency in implementing such national R&D programmes offer some useful frameworks for Thailand to learn from.

This research aimed to investigate the recent transition in Thailand's research and innovation policies. Not only to outline key features and drawbacks from the experimentation of national large-scaled mission-oriented R&D programme, but also to identify room for improvement. In section two, we explained the methodology. In section three, we articulated how relevant research and innovation policies and systems were needed for different phases of economic development. The lessons learned were from the mission-oriented

R&D experiences of South Korea and Japan in their different stages of development. Section four illustrated the reorientation of Thailand's R&I system. In section five, we analysed the concept and operational features of national large-scaled mission-oriented R&D programme known as 'Spearhead R&D Programme', that was designed to accelerate the commercialisation and economic impact of R&D outputs. Section six examined the limitations of the Spearhead R&D Programme and section seven drew conclusions for improvement.

II. METHODOLOGY

From the outset, it is clear that the outcome and impact of Spearhead R&D programme was not realised. The analysis of this study focused on the efficiency of operation in relation to the objective of Spearhead Programme. There was increased debate about justification for allocating resources to the Spearhead R&D Programme as well as questions about their efficiency and effectiveness of mechanism.

The research was conducted through a series of interviews and focus groups with relevant stakeholders during January-May 2019. The key informants were from National Science Technology and Innovation Policy Office that was designated as the funding body and three funding agencies that performed as the Outcome Delivery Units (ODUs) to handle project administration and management.

The interviews were conducted to obtain information on specific issues according to OECD (2018):

- The purpose of scheme and eligibility criteria (objective, recipient);
- Nature of the funding awards (grant duration, grant size and co-funding);
- Request for proposal process (proposal frequency, reviewing approach and evaluation criteria);
- Proposal evaluation process (initial screening, reviewing panel's role and composition);
- Monitoring and evaluation of the impact;
- Perceived challenges in the system and proposed solutions.

The research findings were also presented to the focus group among the Programme Chair and the Steering Committee for discussion and recommendations.

III. MISSION-ORIENTED R&D PROGRAMMES FOR TECHNOLOGICAL DEVELOPMENT: CASES OF SOUTH KOREA AND JAPAN

This section captured the experiences of South Korea in utilising its national mission-oriented R&D programme to pursue catch-up and leapfrog and those of Japan in sustaining economic growth under the arrival of disruptive technologies. The conceptual and operational features of mission-oriented R&D programmes were highlighted to articulate how those mission-oriented R&D programmes were designed to suit the country's needs under different contextual constraints. The catch-up strategies were dynamic; the efficiency then depended on the country's endowment, economic stage, institutions, and policy orientation (Wong,1999; Chaminade and Padilla-Perez, 2017).

In their catch-up phases, Japan and South Korea demonstrated similar catch-up strategies. Japanese and Korean governments were very interventionist, using industrial policies and national S&T programmes as well as strong government research institutes as key instruments. In the catch-up phase, the national priorities were determinedly targeted in terms of technologies and industrial sectors. Selected industries and firms benefited from preferential treatments, such as subsidies, privileged access to government contracts and tax concessions. More importantly, the success of South Korea and Japan in innovation came as a result of the active role of governments in R&D investment accompanied by strategic changes in institutional setting and framework conditions. Their government-sponsored R&D programmes had showed a distinct transition from primarily assimilating foreign technology at first persued global frontier research with the substantial amount of mission-oriented R&D

funding that consumed a significant portion of the government fund in the later stage.

It is worth noting that the capabilities of government research institutes along with the operations of mission-oriented R&D programmes had been well established in Research and Innovation (R&I) system in both South Korea and Japan before the governments decided to invest a substantial amount of national R&D spending. We believed that the experiences of Japan and South Korea in designing and implementing national large-scaled mission-oriented R&D programmes offered us some references to Thailand.

A. The Design of National R&D Programmes in South Korea for Catch-Up and Leapfrog

Concept and Operational Design

Since the early 1980s, the Korean government had recognised the need for a national R&D programme. The government intended to both deepen technological innovations needed in advancing the existing heavy and chemical industries and broaden priorities into other future industries including information, mechatronics, new materials/energy, medical/environmental and bioengineering technologies. As Korean firms had an intention to compete in the global product market under their own brands, other industrialised countries became reluctant to transfer and share key technologies with Korean firms. This led to the growing need for Korea to conduct the in-house development of such key technologies. However, during the catch-up period Korean local firms were not yet equipped with the ability to lead technological innovations. Due to the contextual constraints for catch-up, the government purposely initiated collaborative R&D programmes between government and industry to induce industrial investment for the technological advancement. As a result, the public research institutes played a very dominant role in leading research activities for the country (Bartzokas, 2017).

These mission-oriented R&D programmes during the catch-up phase aimed for ready-to-commercialisation outcomes. This type of R&D programmes directly served the real demand of industrial players and the advance of technology outcome was benchmarked beforehand with those of global competitors. Launched by the Ministry of Commerce and Industry in 1987, the special R&D programme, named Generic Technology Development Programme, gave priority to technologies urgently required by small- and medium-sized firms (Lee, Son and Om, 1996). Technologies to be developed through this programme were identified through the annual industrial technology demand survey. Each R&D project required outcomes to be commercialised within three years after the project was completed. The operation mechanism to ensure that such missions were achieved was neatly designed. The programme sponsored up to 80% of the total budget until a prototype was developed; however, the commercialisation and production were to be funded by other sources. Even though a project is undertaken by a supervising research institute, paired with participating firms, a supervising research institute was given full accountability for administration, execution, and reporting results of the project. On the other hand, to activate the commercialisation of the research outcomes, there was a rule for participating firms to pay back the entire or a part of the governmental fund in the form of royalties for five years from the project completion time.

B. The Design of Mission-oriented R&D Programmes in Japan for Frontier and Disruptive Technology

Concept and Operational Design

Since 2000, global business landscape had experienced the disruption in both technologies and business models. Recognised the difficulties of Japanese manufacturers in maintaining their competitiveness and the delay in acquiring new customer value in the global landscape, the Japanese government has acknowledged that the strategic outcomes of national R&D programmes cannot perform as the extension of the technologies developed so far. The new concept and operational design for conducting creative R&D Programmes was needed to cope with such level of complexity and uncertainty.

Apparently, Apple and Google, the global companies equipped with a platform business model, have risen to rank the first and second top of global market value and outpaced the traditional supply chain business model. In 2015, the aggregate market value of supply-chain businesses for all big Japanese companies in automotive and electronic industries was just equivalent to the total market value of Google, one platform-based company. Under this situation, it was extremely difficult for any single Japanese company to independently create innovation and add value to the customers in a short time (Wongnapapan, 2017).

In 2015, Japan was amongst the world's largest investors in science and innovation, spending almost 3.5% of GDP on research and development (R&D) (OECD, 2017). However, such investment in innovation had not been translated into productivity growth. According to the Industrial Technology Survey conducted by Ministry of Economy, Trade and Industry in 2015, 61% of R&D activities were independently conducted within firms and 63% of R&D results were kept idle without commercialisation. In addition, the government recognised that there was little cooperation between universities and industries. According to the breakdown of Japanese companies' R&D activities, about 90% of business R&D budget was spent on short-term research. Only 8% of private expenditure on R&D was put into research that requires 5-10 years for commercialisation, e. g. self-driving system. Less than 2% was invested in research of which future market needs cannot be estimated at the time, e.g. quantum dot solar cells. Thus, this provided strong justification for the government to support mid- and long-term R&D projects that had the commercial viability of future solutions (Wongnapapan, 2017).

This became a key challenge for the 5th S&T Basic Plan (2016-20), if Japan aimed not only to develop research fields at the knowledge frontier, but also to realise more and better innovation from government-sponsored Science Tehcnology and Innovation (STI) investment. Under this environment, the Cross-Ministerial Strategic Innovation Promotion Programme (SIP) and Impulsing Paradigm Change through disruptive Technologies Programme (ImPACT) were initiated. These special designed features of those two mission-oriented R&D programmes aimed to promote innovation along the entire path from basic research toward commercialisation with effective exit strategies. This was to push fundamental researches of academia into practical applications. SIP targeted R&D programmes aiming to sustain and revitalise the existing industries and to strengthen Japan's industrial position in the world (Cabinet office, 2017b); meanwhile, the ImPACT focused on high risk and high impact innovations for future industry (Cabinet office, 2017a).

Under these two R&D programmes, the key operational features highlighted the great authority and strong leadership of programme managers or programme directors to plan, act and manage researchers to collaborate or even compete. Programme managers and directors also constantly adjusted their course where necessary to ensure the desired results. Another factor underpinning the success of the mission-oriented programmes was the rigorous evaluations carried out based on the practical applications and commercialsation of R&D outcomes. The key evaluation criteria were whether programmes resulted in creating new businesses or strengthening the nation's industrial competitiveness. A repayment plan for public R&D investments through the creation of new markets was considered in evaluations from the beginning.

After we highlighted the concept and operation design of large-scaled mission-oriented R&D programmes in South Korea and Japan, in the next section, we investigated Thailand's R&I funding landscape and the gaps in research and innovation policy implementation. In particular, this was the first time that the Thai government had introduced the Spearhead R&D Programme as a selective intervention in target industrial sectors, activities, and firms.

IV. REORIENTATION OF THAILAND'S NATIONAL R&D PROGRAMMES FOR CATCH-UP

A. Transition of Science Tehcnology and Innovation (STI) Governance in Thailand

National Science Tehcnology and Innovation (STI) reform has been on the agenda since the establishment of the General Prayut Chan-o-cha's government in 2014, whose goal was increased effectiveness of public-private linkages and partnerships. In 2015, the Ministry of Science and Technology was reclassified as an economic (rather than social) ministry, which allowed it to act and co-ordinate more closely with other economic ministries such as the Ministry of Finance, the Ministry of Commerce, and the Ministry of Agriculture and Co-operatives. Although this was not the first time the government had attempted to link STI policy to social and economic development, the government had adopted quite radical new measures (Stipcompass International Database on STI Policies, 2018).

The reform of the National Science Technology and Innovation Policy and Plan 2012-21 took account of the 20-Year National Strategy 2017-36; the 12th National Economic and Social Development Plan 2017-21; and the Thailand 4.0 initiative. It addressed 12 priority areas: food, agriculture and biotechnology, public medical technology, water management, energy, climate change, ageing society, digital government, high-value services, urbanisation and smart city, logistics and 21st-century Thai society.

Not only Research & Innovation became a key driver of the national STI strategy, but also the utilisation of Research and Innovation (R&I) results with significant impacts on national economy and societal development was highly emphasised. As a result, the government had put the utmost effort to reform the national research and innovation system which focused on resolving complicated operations regarding infrastructure, institution and system (Juntong, 2018).

Guideline for the reform in STI governance aimed to address the current problems of the system covering five main pillars: 1) the establishment of the National Research and Innovation Policy Council (NRIC) chaired by Prime Minister; 2) the formulation of policy and strategy on research and innovation; 3) the reform of budgeting system to be consistent with R&I policy and strategy; 4) the develop of human resources on research, science, technology and innovation both in terms of quantity and quality; and 5) the re-alignment of related agencies in research and innovation system as well as the improvement of relevant laws and regulations to promote the utilisation of R&I results. It is believed that the new Council helped unify and streamline science, technology and innovation (STI) policies across all ministries. However, the successful adoption and implementation of these reforms remained ambiguous, due to the highly volatile political landscape as well as the need for new capabilities in planning and implementation innovative STI policies.

B. Thailand's Research and Innovation (R&I) Funding Landscape

Before the STI reform, Thailand's national R&I financing scheme can be categorised into two groups: the public funding for academic research, and the public funding for private-public R&D cooperation (Degelsegger, Gruber, Remøe and Trienes, 2014).

It is worth noting that there was no direct public funding for private sector in Thailand, as Thailand does not favour the idea of giving public money directly to private firms. The prospect of losing public money, if grant projects were to fail, is not well accepted by government authorities, especially those in charge of the budget (Intarakumnerd, 2015). As a result, the government gave research grants mostly to public research institutes and universities. For activities extending thematically or resource-wise beyond the regular research tasks, researchers at the universities and the other public research organisations had to apply for funding from other major funding agencies such as the Thailand Research Fund (TRF), the National Research Council of Thailand. (NRCT), the National Science, Technology and Development Agency (NSTDA), the Agricultural

Research and Development Agency (ARDA) and the Health Systems Research Institute (HSRI), the Ministry of Health's funding agency. This in turn led to the fragmented and overlapping research and innovation programmes.

On the other hand, R&D funding schemes to to support the private sector in acquiring relevant knowledge from the public sector are rather limited in variety and size. The innovation financing schemes were provided only in the form of matching funds for consultancy service (iTAP) and government loan (Good Innovation, Zero Interest). The former scheme is Industrial Technology Assistance Programme (iTAP), started in 1992, where SMEs were provided with necessary technical and scientific expertise. NSTDA provided iTAP Fund up to 50 percent of project cost, but the financial support was for hiring Thai or foreign consultants (freelancers or university professors) to help solve SMEs' technological problems; the ceiling of financial support was very small, up to only THB 500,000. iTAP projects were usually very focused and lasted for around six months. More than 1,000 firms had received financial support from this program. Meanwhile, the National Innovation Agency (NIA) had been testing a programme similar to iTAP, offering innovation coupons. SMEs can apply for funding up to THB 400,000 for any prototyping R&D activities done jointly with university partners. The Federation of Thai Industries, the largest manufacturing association, was a partner in the scheme to help the NIA select the right projects. Unlike NSTDA's iTAP, the innovation coupon focused more on the application of existing knowledge that is new to certain regions in Thailand. Yet, the innovation coupon had been discontinued due to budget shifts.

According to the recent reform, there was increasing pressure on public universities and research institutes to commercialise research results. Yet, Thailand's R&I funding landscape before the reform had shown that most of public funding for R&D were clustering around basic research and early prototype stage. From the R&D prototype stage onwards, there was no R&D grant available for mature research projects with higher probability of getting into the market at all.

V. THE SPEARHEAD R&D PROGRAMME FOR STRATEGIC STI DEVELOPMENT

The debate on Thai research policy had centred on the problem of thinly spread resources among several research organisations and overlapping work among numerous organisations, and resulted in ineffective and inefficient budget spending (Intarakumnerd and Wonglimpiyarat, 2012; Olsson and Meek, 2013; Lao, 2015). The lack of budget and limited commitment were important factors underlying the fragmented research landscape as well as the missing significant outcome and impact in Thailand. Nevertheless, the Thai government had recently introduced a mission-oriented approach for STI budget allocation in the Fiscal Year 2019. The budget for each mission was allocated on the basis of its objectives and expected results, and allotted to a lead agency, who must collaborate with other agencies to deliver the promised results. By aligning STI spending with four strategic priorities: Economic prosperity; Social and environment development; Knowledge pool; and Infrastructure, human resources and systemic structure, the new approach was expected to promote cost effectiveness and accountability of national R&D programmes.

A. Overview of the Spearhead Programme

The Spearhead Programme was set up as the novel financing schemes for large-scaled research and innovation projects that were capable of generating high levels of tangible value-added in key strategic sectors. In this regard, the initial strategic plans were determined in line with the 20-year National Research and Innovation Strategy (2017-2036). As a result, the National Science Technology and Innovation Policy Office had been made responsible for this financing schemes, turning it partly into a funding agency for a test run of this policy experiment.

The framework governing Spearhead R&D Programme was approved by the sub-committee on research and innovation budget system reform on 29 August 2017. This outlined the Spearhead Programmes' management structure and the division of responsibilities among management

bodies; the tender cycle and applications; the eligibility requirements of applicants; reporting and evaluation during the project implementation phase, as well as the conclusion procedures to undertake at the end of the project. Refering to the 20-year National Research and Innovation Strategy (2017-2036), the Spearhead Programme had targeted selective sectors, covering, 1) food, agriculture, biotech and medical technology, 2) digital and information economy, 3) logistics systems, 4) high-value added services, and 5) energy.

Under the Spearhead R&D Programme, the eligibility criteria explicitly demanded specific deliverables and commercial feasibility of R&D outputs, which can then be measured and evaluated. There are two crucial requirements that applicants must possess in order to apply to these Programmes. First, any applicants from the private sector must be Thai majority-owned companies. Second, a project must be a joint-collaboration between industry and university partners. A project must consist of at least one private party and one university/research organisation that is eligible to receive funding from the government. Regarding additional requirements, the private party shall provide additional funds of no less than 20% of the project value, and at least 10% of that value must be invested in cash. Certificates of origin of funds must also be submitted as part of the application materials.

B. Conceptual and Operational Design

In principle, the Spearhead R&D Programme was equipped with novel features that had never been introduced in Thailand before. There were four conceptual and operational features: first, the large-scaled and mission-oriented R&D Programme for strategic STI goals; second, the promotion of industry-university collaboration and the commercialisation of research outputs; third, the transformation of STI budgeting system towards block grant and multi-year budget allocation; and finally the proactive research management under mission-oriented approach.

The large-scaled and mission-oriented R&D programme for strategic STI goals

The Spearhead R&D Programme was a new kind of funding scheme created after the 2016 reform of the national STI funding system. Regarding the mission-oriented approach, the R&D programme targeted well-defined objectives in terms of technology, production, and product standards together with feasible and executable outcomes to be achieved in a period ranging from three to five years. Focused on large-scaled R&D, the value of the planned project at the *de jure* must be no less than 100 million Baht for the entire project, with the scope of the plan being between 1-3 years, which can be extended to 5 years if needed. The continuation of the projects will be monitored and evaluated on the yearly basis based on its real performance.

The promotion of industry-university research collaboration and the commercialisation of research outputs

The Spearhead Programme was intentionally designed to promote technology transfer and commercialisation of scientific results (e.g. new technologies, products, techniques, materials, etc.) previously achieved from other government funded R&D. Such design assumes that there were a good number of research outputs available and waiting in the research pipeline. With sufficient government investment, such research potentials can proceed to the later stages of innovation process. Thus, the Spearhead Programme is designed to overcome the valley of death and more appropriate for mature research projects with higher probability of getting to the market. According to the Technology Readiness Level (TRL), the entry point of eligible R&D project under the Spearhead Programme iwas at TRL 5, which means system or subsystem model or prototype validation in a relevant environment. With the industry-university collaboration, the presence of entrepreneurs willing to invest in actual manufacturing and distribution was required, as the project must generate fully practical and commercial-ready products at the end of the execution process.

The transformation of STI budgeting system towards block grant and multi-year budget allocation

It is well recognised that the Budget Bureau had an important role to play in policy making and policy implementation. The Budget Bureau is responsible for budget allocation, which in Thailand is traditionally negotiated annually. The need of multi-year budget allocation emerged from the fact that the usual practice of annual budget planning has adverse effects in the Thai innovation system. During the last 10 years, Thailand had seen around 10 different Ministers of Science and Technology. This sometimes resulted in R&D initiatives and programmes being discontinued due to not only limited public resources but also shifting priorities to be implemented under the initiatives of a newly appointed minister.

In addition, the block grant concept had been made to overcome the itemised budget and to provide greater flexibility and freedom in financial management for each research programme. The main problem was the process of budget management, which was too rigid and restrictive. For example, the universities had to carefully draft and estimate the budget by line-item. Remaining budget in one area cannot be used on other important items unless the Budget Bureau had approved. Therefore, the universities have the mentality to 'spend it all'. Otherwise, the remaining budget has to be given back to the Budget Bureau (Cresswell, 1999; Lao, 2015).

The proactive research and innovation management under mission-oriented approach

The government had long acknowledged that successful innovation needed more than R&D activities; it needed the support of a combination of several managerial and operational activities to ensure the determined results. As shown in Fig. 1, the Spearhead Programme had incorporated the new concept of administrative and management structure which had not been introduced in national R&D projects. At the *de facto* level, the Programme Chair and Outcome Delivery Unit (ODU) act as supervisors who facilitated and monitored the R&D operation. The Programme chair and Outcome Delivery Unit (ODU) played

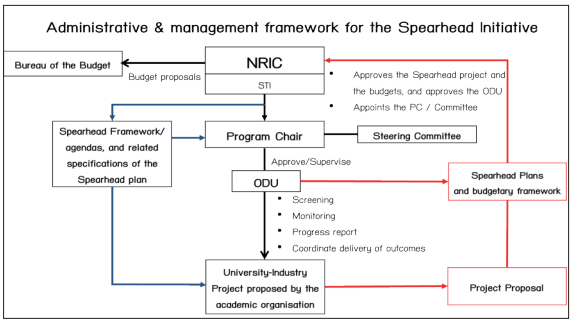

Figure 1. Administration and Management Framework of the Spearhead R&D Initiative

a vital role in offering necessary advice together with assessing research plans and progress.

VI. LIMITS AND CHALLENGES OF THAILAND'S NATIONAL R&D PROGRAMME: CONCEPT AND OPERATION

Considering the contextual constraints, the appropriateness of this novel funding scheme and its operational mechanism were analysed. Key findings from the interviews and focus groups showed that there are three inherent characteristics of the Spearhead R&D Programme that hamper the national effort to transform Thailand's R&I funding landscape: first, the lack of priorities and clarity for sectoral impact, second; the excessive complexity and detail of operation, and finally, the narrow focus on indigenous innovation with limited foreign partnership.

A. Priorities and Clarity for Sectoral Impact

Building a firms' technological and innovative capabilities takes a certain period of time and demands the explicit commitment in terms of the amount, duration, and continuity of government funding schemes. However, during the launch of this R&D programme in the first year (Fiscal Year 2019), it was found that the final budget allocation for the Science, Technology, Research and Innovation Integration Plan was much less than what was pre-agreed. Moreover, even though the priorities areas were announced based on the draft of 20-year National Research and innovation

Strategy (2017-2036), the agenda setting was still done based on bottom-up approach by gathering the idea and opinion from local researchers. As a result, the research agendas seemed to be inward looking rather than outward looking. Also, there was a problem arising from the emphasis on commercialisation based on the assumption that there are a good number of R&D results available and waiting in the research pipeline. The project selection then preferred those ready-to-commercialise research projects to other unclear projects that may have greater sectoral contribution and downstream industrial spillover. Thus, the awarded projects narrowly focused on accelerating available public funded technologies into commercialisation, rather than proactively using this funding scheme to target and catch up with technological advancement in other countries. In addition, to avoid being trapped in the declining industrialisation pathway, there was a need to balance the priorities between sustaining existing industries and creating new ones.

B. Complexity and Detail of Operation

According to the interviews with key funding agencies, it is found that the launch of new R&D programme seemed very rushed. As the application deadline was set to be aligned with the national budgeting calendar, the application deadline was only one month after the final tender guidelines had been announced. It is worth noting that the ability to do the long-term planning and securing the future funding had never been built in Thailand's R&D system before. At such a short application period, the timeframe was considered to be incredible for any inexperienced universities and businesses to prepare any good collaborative proposals.

Furthermore, the requirement for TRL 5 is also elusive and needs sufficient knowledge and effort to verify. Comparing TRL across disciplines may prove almost impossible. This makes the process of assigning TRL to a given project not easy. Bear in mind also that in Thailand the pool of qualified scientists/engineers is small, experts in a particular area are not easily found and, as a result, it was nearly impossible to do proper peer review and project evaluation in this first test run.

In addition, the screening was done by an independent expert group invited by the National Science Technology and Innovation Policy Office. Meanwhile, the Programme Chair and ODUs, who are substantially accountable for the project monitoring and project outcomes, had not been involved in application screening and project selection. To increase effectiveness and efficiency of the research activities, the synergy between programme chair, ODU and research team should be established as early as possible. It is suggested that programme chairs and ODUs should be given more active roles in sharpening the proposal from the preliminary evaluation till the final round.

C. Focus on Indigenous Innovation with Limited Foreign Partnership

The eligibility criteria of applicants towards Thai majority-owned firms reflected a preference for 'indigenous innovation' as opposed to international cooperation and open innovation. Considering that Thailand desired to be a manufacturing hub in the global value chain, the government needed to understand the role of multinational corporations (MNCs) and their global R&D networks strategies (Intarakumnerd, 2015; Wong, 2001). If sustaining the existing industrial competitiveness in food, electronics and automotive sectors was our key concern, the Spearhead R&D programme should not narrowly focus on innovation led by Thai majority-owned firms. Rather, it should explicitly encourage international cooperation between local Thai firms and Thai-based MNCs as well as the involvement of downstream supply chains. The utilisation of research outputs required broader activities outside R&D activities, such as business models and marketing. The inclusion of foreigner partners will attract local firms in the supply chain to participate in the Spearhead Programme and offer greater possibilities that R&D results will be adopted in the sectors.

There is room for the Sprearhead Programme to take part in attracting foreign's R&D activities to invest in Thailand. The Spearhead Programme can be used to actively invite MNCs to engage in Thailand's capability upgrading and level up the country's position in the global value chain.

The continued exclusion of foreign partners from the funding scheme was perceived as an obstacle for catch-up.

VII. CONCLUSION

The experiences of Japan and South Korea offer some references on the importance of aligning the concept and operation design in large-scaled mission-oriented R&D programmes. Meanwhile, our study highlighted that there is a misalignment between concept and operational design of the Spearhead R&D Programme in Thailand. However, a matter of trial and error was part of the policy learning process. The ability to initiate and implement new policy instruments to fit the changing needs of firms at different capability levels was critical. Developing countries need to conduct policy experiments to design their appropriate STI policies (Lundvall, Joseph and Chaminade, et al, 2009; Niosi, 2010; Marcelle, 2017). Only through the engagement in experimenting with new policy instruments, new groups of actors and new capabilities for planning and implementation STI policies can be trained and accumulated over time.

To avoid policy lock-in of the current industrialisation pathway, it is suggested that the Spearhead Programmes be more ambitious and purposefully benchmarked with international competitiveness. Then, such R&D programmes will require larger research teams or consortiums for implementation. To attract diverse sizes of firms (i.e. small-and-medium enterprises, large firms or multinational corporations) to participate in the national R&D programme, such programmes should be able to address diverse problems of various firm sizes and offer flexibility to tailor to their real needs. Going hand in hand with firms' capability upgrading, the strategic mission-oriented funding programme can be used to strengthen the capabilities of public research institutes, universities and funding agencies.

Lastly, to overcome the bottom-up approach and limited sectoral impact, the operation of Spearhead R&D Programme can be done by assigning consortium leaders. With the top-down management structure, the consortium leaders who have proper expertise in industries or technologies will take full responsibilities in specifying the tender guidelines as well as recruiting consortium members. This type of administration and management framework will help strengthen top-down strategic focus and unified coordination within sectors. This approach will give consortium leaders authority to steer the whole programme toward promised outcomes and also greater flexibility in policy learning.

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