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# The Indispensable Role of Firms in Technological Innovation

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## Introduction

Malaysia has been on a quest to become an innovation-driven economy, at least since the late 1990s when government policies moved away from a reliance on primary commodities and manufacturing towards a more knowledge-based economy. The government has rightly viewed innovation as an important aspect of improving productivity and increasing the country's income. However, there can be a tendency to think that to achieve that goal, we should primarily focus on university-based research. In the following, I will argue that innovation for economic growth should primarily be local firm driven. However, this is not to say that the role of universities is not important for innovation. They play an important supporting role as discussed in the following, although the primary driver should be local firms. I conclude that innovation policy for economic growth should emphasise the development and retention of the technological capabilities of local firms.

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## Institutional Obstacles to University Research in Innovation

The primary challenge for university research in driving economically viable innovation lies in the starkly **different cognitive focuses of academic and industrial environments**[1]. While both aim for optimal outcomes, their definitions and priorities diverge significantly. Academic research emphasises addressing novel gaps or inventive steps, creating elegant solutions, and producing broadly applicable knowledge with the potential to catalyse advancements across various fields. Conversely, the industry values practicality, prioritising cost efficiency, system reliability, time to market, and the economic viability of inputs. Academics often pursue groundbreaking and intellectually stimulating work that fosters scholarly dialogue, while industry engineers concentrate on delivering dependable, market-ready solutions. These contrasting priorities result in fundamentally different mental frameworks and approaches to problem-solving in each context.

Furthermore, as far as the university faculty is only encouraged to conduct research in basic science, assuming that research findings to understand natural phenomena can immediately be processed to become technology, the result is unlikely to be so. Most of the time, innovative technologies are the product of the already established knowledge ingrained in engineers' minds rather than from entirely new scientific ideas[2]. When new scientific ideas are employed in technology, it is usually to address novel problems that existing technologies cannot resolve. This process often requires the intervention of the engineering sciences to bridge the gap, translating scientific findings into practical applications that engineers can use[3].

Secondly, **academic faculty might not be naturally interested to invest their time and effort to ensure that inventions provide economic returns**. This can be seen in the process of invention disclosure[4]. The academic career system provides no natural incentive for scientists to patent new research methods or instruments that have been created for internal use. As much as the scientist's career depends on reputation, their goal will be to solve problems through some kind of "do-it-yourself" practices. Profit objectives are, therefore, nonexistent at this stage, and dedicated regulatory structures such as technology audits would be required to avoid the danger of missed innovation opportunities because the scientist simply would not disclose them.

Thirdly, **university and industry view different economic logic with respect to relative importance of "appropriability" versus the benefits of full and costless knowledge appropriation**[5]. Private industry model of innovation seeks economic returns resulting from private goods and the ability to control exclusive use of the new knowledge. Uncompensated dissemination of proprietary technologies reduces innovators' profits from their investments. Within the academic research community, the reward system is based on the academic's rapid publication and dissemination in order to achieve prior claim as author, either for discovery or an invention. This means that in regards to ownership and control of technologies, academics

[1] Foray and Lissoni (2010)
[2] Dosi (2023); Arthur (2009)
[3] Foray and Lissoni (2010)
[4] Ibid.
[5] Foray and Lissoni (2010)

prefer the freedom to operate and publish rather than be curtailed by exclusive rights demanded by the private sector. There are benefits and drawbacks to both models. Making knowledge open access preferred by universities removes barriers to scientific research, encourages a larger base of researchers, and potentially accelerates scientific discovery. However, from the point of view of compensation for investors and employees, some exclusive rights are needed to appropriate economic returns from innovations and inventions.

The lack of commercial incentives university researchers face compared to what is offered in the industry often results in inventions or innovations that are not fully refined for commercial use[6]. Consequently, researchers typically need to collaborate with commercial partners to fine-tune and optimise these technologies before they are market ready. Furthermore, it is likely due to these institutional differences mentioned above that we find most inventions originate from firms rather than from universities[7].

## The Advantages of Firms to Provide Technological Learning

### Firms Provide Opportunities to Discover Bottlenecks and Structural Imbalances

The critical distinction between firms and universities lies in their differing opportunities for learning to improve products for commercial use. Compared to universities, firms are more intensively engaged in the production process. This direct engagement with the structural world of production exposes engineers and technicians to 'learning by doing', 'learning by using', and 'learning by exporting', allowing them to discover bottlenecks and structural imbalances in the interplay of inputs and processes[8]. Solving these challenges results in innovations that enhance products, systems, or production processes.

A crucial element of this learning process is the feedback mechanism inherent in the design and development cycle[9], particularly from the market, as commercial viability is a central goal. Firms are naturally equipped to conduct market research and establish routines to understand customer needs, often facilitated by dedicated marketing departments. This market-driven feedback ensures innovations are both practical and commercially viable, a dimension typically underemphasised in university-driven innovation efforts.

### Firms are Critical in Retaining Technological Capabilities

More fundamentally, productive organisations must first build and retain productive capabilities before they can innovate. Like opportunities for innovation, these capabilities are developed and sustained through active participation in production[10]. Productive knowledge often includes elements of tacit knowledge that cannot be fully codified or transmitted through text. For instance, skills like drawing designs or welding are learned through practice and experience, much like riding a bicycle. Similarly, organisational routines—such as knowing when and what

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[6] Kline and Rosenberg (2009)
[7] Kline and Rosenberg (2009); Dosi (2023)
[8] Andreoni (2014)
[9] Kline and Rosenberg (2009)
[10] Nelson and Winter (1985)

to do without explicit instructions—rely heavily on tacit knowledge gained through repeated application[11]. It is through the act of doing that these capabilities are developed, retained, and refined. Without such productive capabilities, innovation is impossible. The suite of skills and routines required to make innovations commercially viable resides primarily within firms. Unlike universities, firms focus on refining product designs to ensure market readiness, making them the primary agents of commercially driven innovation.

## Firms are Needed in Building the Background Knowledge for Innovation

In addition to identifying bottlenecks and structural imbalances, active participation in production provides the background experience necessary to resolve these challenges. This background experience is also a form of tacit knowledge essential to designers or engineers. It can be argued that innovation often begins with an unclear starting point but a reasonably clear goal that producers aim to achieve[12]. To problem-solve and meet this desired objective, engineers rely on their reservoir of practical, experience-based knowledge. Drawing on solutions to similar problems from the past, they extrapolate and adapt them to address current challenges. Innovation frequently involves recognising similarities within a shared technological tradition, as these traditions provide a framework for understanding and resolving technological problems[13].

The concept of technologies belonging to a tradition underpins W. Brian Arthur's[14] comparison of technology to languages, where distinct technological domains—such as electronics or genetic engineering—serve as unique linguistic systems. Each domain has its own "vocabulary" (available components) and "grammar" (rules for combining them), and practitioners develop varying levels of fluency. While not all combinations are effective or "fluent," innovation relies on familiarity with these components and their interrelationships. Engineering handbooks, such as the *Mechanism and Mechanical Devices Sourcebook*[15], demonstrate this reliance on existing knowledge, cataloging solutions to standard problems like "nineteen methods for coupling rotating shafts" and "fifteen different cam mechanisms."

Firms are instrumental in cultivating and retaining these skills within each technological tradition, as their active production processes provide the practice necessary for skill development. This environment enables engineers and designers to deepen their understanding of components, refine problem-solving methods, and innovate by combining technologies and techniques within a domain. Additionally, firms serve as the primary platform for skill demand and retention through practical application. Industry, as the ultimate driver of university education, often determines the relevance of courses or skills offered, framing them around the specific demands of firms.

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[11] Ibid.
[12] Nightingale (1998)
[13] Ibid.
[14] Arthur (2009)
[15] Sclater and Chironis (2001)

### Firms are Critical for Technological Fusion

Moreover, firms' roles as the main source of demand for skilled labour and retainers of technological capabilities mean they are vital in preserving the basic elements from which new technologies can emerge. New technological domains can result from the fusion of two or more existing technological clusters or domains that are complementary but dissimilar in capabilities[16]. For example, the field of mechatronics emerged from the fusion of electronics and mechanical engineering capabilities. In the fourth industrial revolution, we expect to see more complex combinations and interdependencies between traditionally separate and specialised fields of knowledge. The capital goods sector, for instance, will see various technologies merge with ICT to develop smart machine tools, smart vehicles, and smart power grids. Therefore, having firms with capabilities in the component technological domains is essential for innovating and developing future technologies. Lacking these foundational technological capabilities in local firms or allowing them to erode would distance Malaysian industry from being able to develop future technologies.

### Local Firms are Important for Capabilities Development

The arguments above on the advantage of firms in cultivating innovation for commercial use must consider that these firms are not hindered by prohibitive governance structures or other constraints. This is often not the case for subsidiaries of multinational corporations (MNCs), where activities are determined by the head office in an advanced country. MNCs typically cite insufficient institutional, infrastructure, and skilled labour resources as reasons for not conducting R&D in host countries with developing status, which might be true. However, even if these resources are adequate, there is no guarantee that foreign MNCs would conduct frontier-level R&D in the host country, as decisions are ultimately subject to some arbitrariness. Additionally, MNCs may have concerns about technological leakage, where developing countries' firms could use the technology to build competitive advancements. Therefore, in the context of developing countries, the preceding arguments reflect local technology-centric firms.

## The Importance of Universities for Firm-based Innovation

With all that being said about firms, universities still play a crucial role in the innovation process for commercial purposes. Firstly, they provide effective training for researchers and research managers, enhancing the effectiveness of corporate R&D programs[17]. Secondly, universities offer open access to new information on research methods and findings, greatly facilitating the ability of research-intensive enterprises to monitor advances that could transform technologies and markets[18]. Thirdly, certain disciplines, such as engineering, are vital in transferring knowledge from basic science research (which seeks to explain natural phenomena) to industry[19]. While the results of basic science research may be too abstract for direct industrial applications, engineering sciences support the gradual transformation of knowledge from ideas into

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[16] Andreoni, Chang, and Labrunie (2021)
[17] Foray and Lissoni (2010)
[18] Ibid.
[19] Ibid.

operational concepts. They adapt this knowledge from a highly abstract, codified form to one that is more applicable. Therefore, the issues highlighted previously regarding university research are expected to be less pronounced in engineering sciences compared to pure basic science research activities.

Since discoveries in basic science are not immediately applicable to technology development, it is more beneficial for universities in developing countries to prioritise applied sciences[20]. This focus aligns with their economic need to support industrial growth and close development gaps.

It should also be noted that different sectors of the economy have varying levels of reliance on research output from universities to drive innovation[21]. Other drivers of innovation may include the role of suppliers and the scale of a firm's production. The role of firms is evident in the supplier and production scale-driven innovation sector since suppliers and producers tend to be firms. However, the firms' role is also important in the innovation of science-driven industries not only because firms have the capabilities to make the innovation reach a commercially viable stage, but also because industrial needs and research can contribute to shaping the research agenda of universities[22], ensuring their research output is helpful for the industry.

## Conclusion

The critical role that firms play in the process of innovation, as well as their role in guiding industry-relevant university research, suggests that Malaysia's research policy for economic development should emphasise support for technological development by local firms. While Malaysia's current innovation policies, such as the Multimedia Super Corridor (MSC), R&D grants for firms, and technology parks, promote firm interaction, more is needed to encourage firms to conduct R&D. Data reveals that gross expenditure on R&D declined from RM13.9 billion in 2014 to RM13.5 billion in 2020[23] . As a percentage of GDP, this figure dropped from 1.26% to 0.95% over the same period. More importantly, the share of business enterprise R&D out of the gross expenditure decreased from 45.7% to 34.21%. Current R&D policies, mainly based on tax incentives, are insufficient. Firms must be encouraged to build technological capabilities before they can begin to conduct their own R&D. This requires incentives for technological learning and acquisition.

Furthermore, policies to preserve and support the advancement of local technology-based firms may lead to brighter prospects for the local industry to venture into future technologies, even if these firms are not yet economically competitive. As argued above, new technologies are likely to be created based on the principle of fusion, meaning the current stock of technological capabilities is essential for future innovation.

Over the past few years, the state has allowed local technological capabilities to be hollowed out by foreign acquisition. Firms such as Proton and Silverstone Tires have been acquired by MNCs and have subsequently not conducted R&D to the same level as before, or their capabilities have entirely disappeared due to plant closures, as in Silverstone's case. Even if the markets they

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[20] Lee (2019)
[21] Dosi (2023)
[22] Foray and Lissoni (2010)
[23] Malaysian Science and Technology Information Centre (n.d)

engaged in face technological obsolescence, the capabilities built within these firms might not be entirely obsolete. For example, as car manufacturers move towards electric-powered motors, the basic capabilities of building a vehicle's chassis, tuning its handling, and designing its aerodynamics remain valuable. Even if the country does not pursue developing a national EV vehicle, these capabilities can still be utilised to build public transport vehicles, military vehicles, or consult foreign manufacturers. Retaining these firms or creating new firms out of the existing capabilities not only creates opportunities for economic returns but also provides the high-skilled jobs that the country sorely needs to address its skill-based underemployment problem.

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