ROLE OF TECHNOLOGICAL CAPABILITY ON FIRM PERFORMANCE AMONG PALM OIL MILLS IN MALAYSIA

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ABSTRACT

In spite of its strong economic performance since the 1970s, oil palm mills in Malaysia has faced low technological upgrading. Although the import of capital goods has acted as an effective channel for technology transfer (TT), the lack of strong firm-level in-house upgrading and the presence of barriers has affected mill efficiency levels. Hence, this thesis seeks to examine how firm-level technological capability development (TC) has impacted on firm performance. A quantitative research design using simple random sampling procedure was deployed to gather responses from 54 palm oil mills in Malaysia. The multiple regression analyses revealed that innovation strategy, TT, government support, and size of mills impacted on TC development very strongly, while organization learning, strategy alliance, and type of ownership were insignificant. In addition, innovation types and R&D capability show significant relationships with firm performance. Also, R&D capability and innovation performance influences significantly marketing performance. The findings also highlight the complexity and cost of new technologies as technological barriers. The lack of financial resources and technical skills have posed as organizational barriers to TC development. The lack of government policy as also affected the shift to greening environment practices and the adoption of advanced processing technologies. The results also show that top management support and increasing the size of mills positively raise the adoption of advanced processing technologies and firm performance. However, the findings indicate that all significant factors have been critical to non-adopters, whereas complexity, top management support, technical skill, and size of mills were the most critical factors for adopters. This thesis complements past works by showing evidence that TC development has a strong impact on firm performance in oil palm mills. Secondly, it complements the resource-based view

(RBV) and evolutionary theories that effective links between firm resources and capabilities are critical to drive firm performance. Policy-wise, firstly, the thesis makes the point that new technologies development and diffusion is important to quicken technological upgrading in palm oil mills. Secondly, it calls for governments to review their incentives and policies to improve TC development. Thirdly, there is a need for top management to support greening and new technology development strategies in the oil palm mills.

Keywords: technological capability, innovation, oil palm mills, firm performance, Malaysia

PERANAN KEUPAYAAN TEKNOLOGI DALAM PRESTASI FIRMA DI PENGILANG KELAPA SAWIT DI MALAYSIA

ABSTRAK

Meskipun prestasi ekonominya sungguh kuat sejak 1970an, pengilang kelapa sawit di Malaysia telah mengalami penambahbaikan teknologi yang rendah. Biarpun import barangan modal telah mendukung pemindahan teknologi (TT), kekurangan keupayaan untuk menambahbaik teknologi untuk menyokong pembangunan keupayaan teknologi (TC) diperingkat firma dan kewujudan rintangan telah menjejaskan prestasi kecekapan kilang. Memandangkan TC rendah, sangat penting untuk memahami apa yang menentukan pembangunan TC dan bagaimana ia mempengaruhi prestasi firma. Dengan itu, tesis ini cuba meninjau bagaimana keupayaan teknologi diperingkat firma telah mempengaruhi prestasi firma. Suatu rekabentuk kuantitatif dengan menggunakan kerangka persampelan rambang dipakai untuk mengumpul respon daripada 54 pengilang kelapa sawit di Malaysia. Analisis regressi menunjukkan bahawa strategi inovasi, TT, sokongan kerajaan, dan saiz pengilang membawa dampak kuat keatas pembangunan TC, sementara pembelajaran organisasi, persekutuan strategik, dan jenis hakmilik tidak signifikan. Tambahan pula, jenis inovasi dan keupayaan R&D menunjukkan hubungan signifikan dengan prestasi firma. Sementara itu, keupayaan R&D dan prestasi inovasi mempengaruhi secara signifikan prestasi pemasaran. Dapatan juga memperlihatkan complexity dan kos teknologi baru sebagai halangan teknologi. Kekurangan sumber kewangan dan kemahiran teknik bertindak sebagai rintangan organisasi pada pembangunan TC. Kekurangan dasar kerajaan juga telah mengugat peralihan kepada amalan hijau dan penggunaan teknologi pemprosesan maju. Dapatan juga menunjukkan bahawa sokongan pengurusan atasan dan perluasan saiz kilang meningkatkan penggunaan teknologi pemprosesan dan prestasi firma. Walau bagaimanapun, dapatan menunjukkan bahawa semua faktor penting sangat penting bagi orang yang tidak mengadopsi, sedangkan kerumitan, sokongan pengurusan atasan, kemahiran teknikal, dan ukuran kilang adalah faktor yang paling penting bagi orang yang mengadopsi. Tesis ini, pertamanya, melengkapkan dapatan lama dengan menunjukkan bahawa pembangunan TC memberi dampak kuat keatas firma pengilang kelapa sawit. Keduanya, ia mendukung pendekatan berasaskan sumber (RBV) dan evolusionari bahawa hubungan antara sumber dan keupayaan firma adalah penting untuk memandu prestasi firma. Berasaskan dasar, pertamanya, tesis ini menekankan bahawa pembangunan teknologi baru dan penyerapan adalah mustahak untuk mempercepatkan peralihan teknologi di pengilang kelapa sawit. Keduanya, ia menyarankan agar kerajaan mengkaji semula galakan dan dasar untuk menambahbaik pembangunan TC. Ketiganya, sokongan pengurusan atasan adalah penting untuk mendukung strategi penghijauan dan pembangunan teknologi baru dalam pengilang kelapa sawit.

Kata kunci: keupayaan teknologi, inovasi, pengilang kelapa sawit, prestasi firma, Malaysia

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LIST OF SYMBOLS AND ABBREVIATION

AR	Augmented Reality
B2B	Business to Business
BOD	Biological Oxygen Demand
CAS	Computerized Accounting System
CPO	Crude Palm Oil
CPKO	Crude Palm Kernel Oil
E-SCM	Electronic Supply Chain Management
DOI	Diffusion of Innovation
ETP	Economic Transformation Programme
EU	European Union
FDI	Foreign Direct Investment
FFB	Fresh Fruit Bunches
GDP	Gross Domestic Product
ICS	Inventory Control System
ICT	Information and Communication Technology
IMP2	Second Industrial Master Plan
IMP3	Third Industrial Master Plan
ISO	International Standards Organization
JIT	Just-In-Time
JV	Joint Ventures
ME	Machinery and Equipment
MPOB	Malaysian Palm Oil Board
NIEs	Newly Industrializing Economies
OER	Oil Extraction Rate
PCA	Principal Component Analysis
POMs	Palm Oil Mills
POME	Palm Oil Mill Effluent
PORLA	Palm Oil Registration and Licensing Authority
PT	Process Technology
RBV	Resource Based View
R&D	Research and Development
RD	Product Technological Capabilities
RSPO	Round Sustainable Palm Oil
SMEs	Small and Medium-sized Enterprises
SPC	Statistical Process Control
TAM	Technology Acceptance Model
TC	Technological Capability
TCI	Technology Capability Index
TOE	Technology–Organization–Environment
TPM	Total Preventive Maintenance
TQM	Total Quality Management
TTM	Technology Transfer Mode
VIF	Variance Inflated Factor

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CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter is dedicated to the introduction of this research. The first part provides the study's background, including background information regarding technological capability and innovation and the related areas such as developing countries. The next part is the problem statement that explains the problems that this study efforts to address. The research questions and objectives are presented in the following sections, followed by the significance of the study and the study's scope. The final part is the organization of the study that explains the next part of the research.

1.2 Background of the Study

Technology is well-known as one of the most valuable resources that provide sustainable competitive advantages (Caloghirou et al., 2004). Technical advancement has been identified as a key driver and an essential source of economic and social development (Schumpeter, 1934; Smith, 1937; Nelson, 1987). Also, technology has emerged as the core of competition in the global market. The diffusion, assimilation, and development of innovative technology specify the patterns of competition, growth, and trade considerably around the world (Lall, 1990). The capability of accessing new technology thus affects the ability of companies in emerging countries to build indigenous technological capabilities and compete in world markets (Lall, 1990). Therefore, Technological Capability (TC) has become the center of consideration among scholars, corporate managers, and government directors (Kim, 1997; Miyazaki, 1995; Lall, 1990).

Industrial development is known to acquire TCs and convert them into product and process innovations throughout continuous technological change (Kim & Nelson, 2000). The process of industrial development is the process of generating TCs. So, TC is extensively recognized as a strategic source of growth and wealth at the national and firm levels (Monopoloulos et al., 2009). The utilization of technology needs substantial attempts to learn the new technology and increase the capability for efficient industry development.

In this perspective, since the 1980s, TC has become the major attention of conceptualizing technology study (Rosenberg, 1982; Bell & Pavitt, 1993). It is a significant factor in increasing competitive situations, competitive advantages, and sustained developments (Ca, 1999). The firm-level TC has been regarded as an important strategic resource, enabling firms to attain a competitive advantage in their industry. Those firms with higher TC can secure more efficiency achievements by innovative process innovations and gain advanced differentiation by innovating products in the changing market environment (Tsai, 2004).

TC's development is vital for firms, particularly Small and Medium-sized Enterprises (SMEs), to overcome the rapidly changing and aggressively competitive worldwide markets. Conversely, only a few SMEs are well equipped to develop essential TCs in developing economies (Caniels & Romijn, 2003). Several studies (e.g., Kim, 1997; Rosenberg, 1976) focused on the development of TC in developing economies, but most of those studies emphasized the industry and country phenomena, where the firm-level case has not been considerably highlighted (Caniels & Romijn, 2003).

Even though the development of TC has been studied in a great deal of research (Lall, 1990, 1996, 2000; Kim, 1997; Nelson, 1996; Seibert, 1997), the contemporary understanding of TC development is still insufficient, as per the fast-changing nature of technology and globalizing cooperation. Therefore, it is essential to study the development of TCs in developing countries in a globally competitive environment.

Previous firm-level research has employed proper proxies of TCs to demonstrate the significance of TC on firm performance (e.g., Wignaraja, 2002; Rasiah, 2006, 2007; Figueiredo, 2002a, 2002b). Finally, the TC of the companies impacts the TC of countries. Hence, this study concentrates on the development of TCs at the firm level.

As an emerging Asian economy, Malaysia would be to move in the direction of a technology-driven and high-Tech production-based pattern of development and therefore repeat the experience of the Newly Industrializing Economies (NIEs) of Asia. Indeed, Malaysia has been classified in the cluster of countries that can generate advanced technologies on their own (Mani, 2000). Despite the 1997 Asian financial crisis, the predictions stay promising, although no country in the area was saved. Over the past two decades, the fast technological development of the NIEs has caught the concentration not only on developed economies but also developing economies (Hobday, 1995). Concurrently, Malaysia and the NIEs are located in the same region and predominantly have the same trade structures and economic regimes. Given that, Malaysia has a robust foundation to deliberate formulating its technological development strategy according to those in the NIEs with proper adaptations to meet the economy's uniqueness (Lai & Yap, 2004).

Since 1970, Malaysia has continued fast average growth that exceeds 6.4% per year. Over the past few years, its growth has moderated slightly against intense global headwinds; nevertheless, it has stayed robust. The economy is expected to maintain its upward trend, increasing by 4.3% – 4.8% in 2019. Fiscal and monetary policy should continue judicious to aid steady growth and keep the economy's resilience to shocks. Speeding up structural reforms to boost productivity and extensiveness would also enhance the sustainability of growth in the medium term to contribute to achieving Malaysia's goal to become a high-income country in 2020 (Figure 1.1).

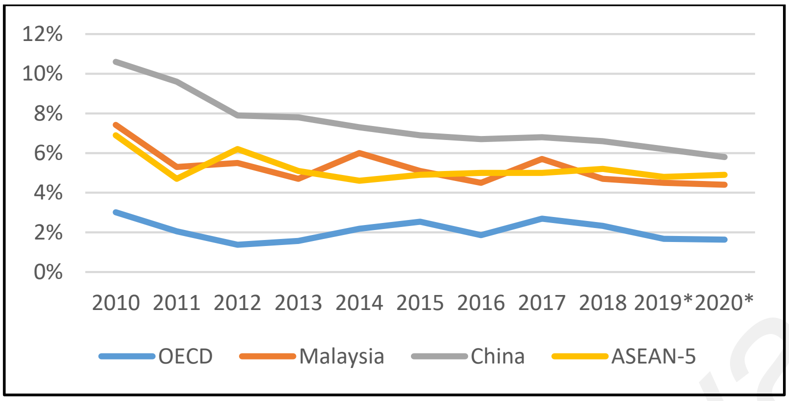

Figure 1.1: Real Gross Domestic Product (GDP) Growth
Source: OECD Economic Outlook database, national statistical offices.

During the first half of 2019, the services sector has been extended at 6.3%, benefiting robust domestic demand and accounted for 58% of GDP primarily supported by finance and insurance, information and communication, wholesale and retail trade, food & beverages, and accommodation subsectors. The manufacturing sector has been expanded by 4.2% and accounted for 22.2% of GDP primarily, mainly supported by domestic-oriented industries (Economic Outlook, 2020).

The agriculture sector has been grown considerably by 4.9%. It is anticipated to rise by 4.3% (7.3% of GDP) in December 2019. The sector's favorable performance is ascribed to the recovery of Crude Palm Oil (CPO) production and natural rubber, joined with other agriculture subsectors (Figure 1.2). In 2019, Oil palm subsectors as a significant contributor to the agriculture sector were anticipated to increase around 7.7%. Due to expansion in oil palm matured areas and favorable weather conditions, the subsector has performed better by increasing CPO production (Economic Outlook, 2020).

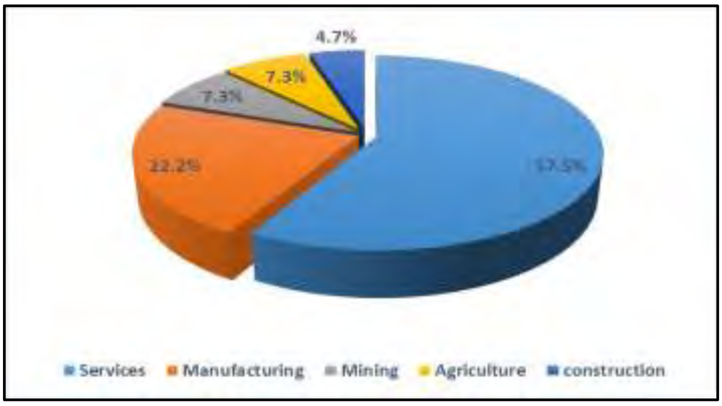

Figure 1.2: Share to GDP by Kind of Economic Activity

Source: Department of Statistics and Ministry of Finance, Malaysia.

However, Malaysia is still behind to catch-up to the higher level of technology as it is offered that the government should motivate upgrading in technological capacity by utilizing learning policies for greater spillovers among local firms (Rasiah et al., 2015a; Rasiah & Yap, 2019). Hence, the development of TC is a key factor that can help achieve Malaysia's target in 2020, especially in the palm oil milling industry.

1.3 The Significance of the Palm Oil Industry to the Malaysian Economy

Palm oil is one of the significant products of Malaysia. The palm oil industry acts as an economic backbone for the country. In the late nineteenth century, the oil palm was brought over from West Africa as a tropical crop. Until around the 1960s, the industry did not begin as a full profit-making industry. Since then, the industry has grown progressively because of a diversification policy planned to change the country from the production of then-dominant primary products such as rubber and tin. On average, both the planted area and yield increased at around 20% yearly through the 1960s and 1970s. From the 1960s until the 1980s, the industry grew 28 times over the 20 years in terms of absolute production volume. At the beginning of the 1980s, the growth speed slowed slightly, but output continued to expand around 10% yearly. From the 1990s, while encountered with limitations on cultivated land supply, the production speed rate remained about 5% yearly (Oikawa, 2016, p251).

The rapid expansion of the oil palm planted area has contributed to fresh fruit bunches (FFB) and CPO production growth. In 1960, Malaysia produced about 92,000 tonnes of CPO. However, after six years, with the considerable increase in Malaysia's CPO production, the country became the largest palm oil exporter in the world (Toh, 2017).

In parallel to cultivated lands, CPO production has progressed. Whereas it has increased by 7.5% annually, the cultivated lands have expanded by 5.7% since 1975 (Abdullah, 2014). CPO production amounted to 6.09 million tonnes in 1990 and increased from 10.84 million tonnes to 16.99 million tonnes one the period 2000-2010. Simultaneously, the planted area expanded from 3.38 to 4.85 million hectares (Figure 1.3).

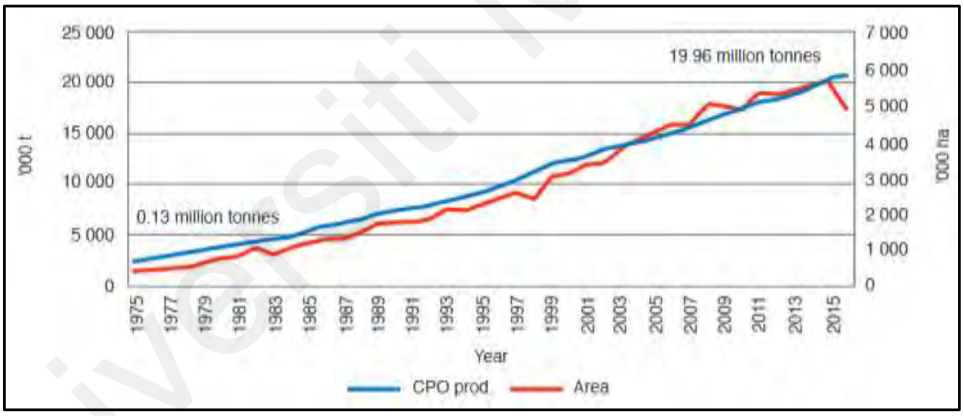

Figure 1.3: Malaysian oil palm planted area and crude palm oil (CPO) production (1975-2016)

Source: MPOB (2017a)

The planted area grew from 5.8 million hectares to 5.9 million hectares in 2017-2018. In contrast, CPO production declined 2% to 19.52 million tonnes in 2018 (19.92: 2017). Due to lower FFB yield, the decrease was down by 4.1% to 17.16 tonnes per hectare in 2018, while it reached 17.89 tonnes per hectare in the past year (Economic Outlook, 2020).

Palm oil stocks are a potent psychological factor to present the palm oil industry performance in Malaysia. Hence, to assess the palm oil market performance, the monthly closing stock is a significant criterion applied (Nordin et al., 2007). Since 1996, Malaysian palm oil stocks have indicated an upslope trend (Figure 1.4). The rise in total stocks is paralleled with total CPO production, which is the main contributor to Malaysia's total palm oil stocks (Abdullah, 2013).

From 1980 until 2016, the total palm oil stocks experienced a fluctuation from 0.35 million tonnes to 1.67 million tonnes. The highest level of the palm oil stocks was 2.63 million tonnes in 2012 and 2015, while the palm oil stocks at the lowest level ever verified since 1980 were at 0.19 million tonnes in 1983 (Figure 1.4). In December 2018, closing stocks were higher by 17.7% to 3.22 million tonnes vis-a-vis 2.73 million tonnes recorded in 2017 (Kushairi & Balu, 2019).

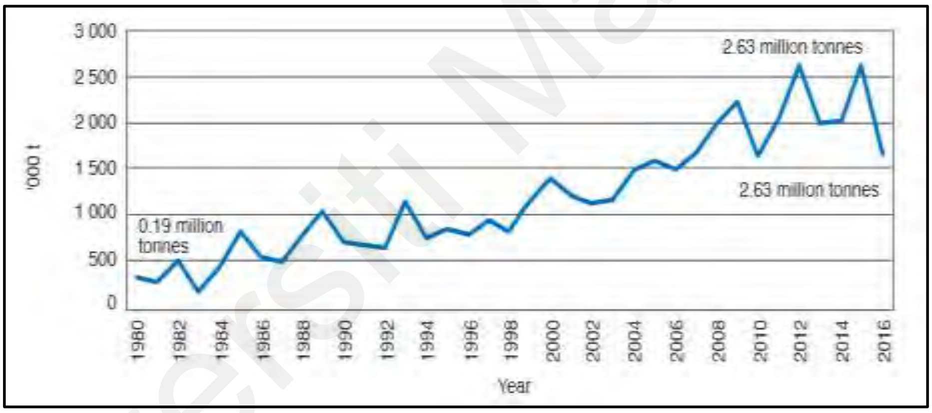

Figure 1.4: Malaysian palm oil stocks (1980-2016) (‘000 t).

Source: MPOB (2017a)

Malaysian palm oil exports had observed importantly increased, leaping from below 100,000 million tonnes to 16.05 million tonnes during the years of 1960-2016. In 1960, oil palm exports recorded 90,500 tonnes, in which CPO was its most important output in that period (Fold & Whitfield, 2012). With the founding of palm oil refining in 1975 (PORLA, 1999), the export volume of processed palm oil products surpassed that of CPO. It slowly formed a significant part of exports at the latter expense (Fold & Whitfield, 2012), from only 0.22 million tonnes rising to 2.07 million tonnes from 1975 till 1980, which has increased greater than ninefold.

In 2018, Malaysia continued as a significant player in the export market of oils and fats. Its oil palm exports of 18.08 million tonnes compared with 16.47 million tonnes recorded in 2017 (Figure 1.5). During the past decade, global consumption of oils and fats has significantly increased, recording an average annual growth of 6.4 million tonnes per year. Of this, 4.8 million tonnes of oil palm production were used mainly for food, and 1.6 million tonnes (around 15%) as biofuel (Mielke, 2017; Neslen, 2016; OECD/FAO, 2019). Malaysia currently represented 28% of worldwide palm oil production and 36.7% of world exports (Oil world, 2018). It is expected that the global consumption of oils and fats will be reached around 58 million tonnes in 2020 (Basiron & Weng, 2004). Domestic demand for palm oil aimed at food consumption, industrial non-edible, and biodiesel uses have been forecasted to rise by over 200% to 1.4 million tonnes in 2035, with exports to rise by over 25 million tonnes in 2035 (Gan & Li, 2014; Mielke, 2017).

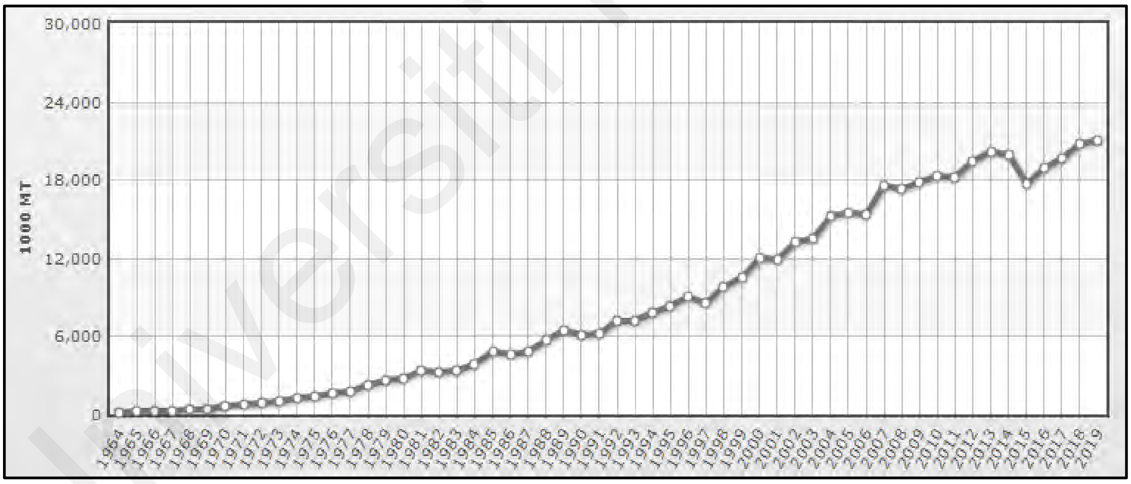

Figure.1.5: Palm oil production by years (1964-2019)
Source: United States Department of Agriculture (Index Mundi, 2019)

However, despite generating exports to over 200 countries worldwide, the industry is still reliant on limited chosen markets as main export destinations, such as China, the European Union (EU), India, Pakistan, Egypt, and Japan (Ming & Chandramohan, 2002). In 2016, other countries (such as China, India, Japan, the EU, and Pakistan) remained the primary Malaysia palm oil export market, except Egypt (Nambiappan et al., 2018).

As a natural crop, oil palm contributes significantly to feeding over three billion people in more than 200 countries. With limited arable lands, providing an additional two billion people will be no small task by 2050 (Nambiappan et al., 2018). Oil palm is an extremely effective source of vegetable oil compared with other oil-bearing crops. It needs only 0.26 hectares to produce 1 tonne of oil while soybean, sunflower, and rapeseed demand 2.2, 2.0, and 1.5 hectares, respectively (Wahid et al., 2011). In 2018, Malaysia produced 31% of the global palm oil output, whereas soybean oil output contributed 25% and rapeseed oil recorded 11.4% (Figure 1.6).

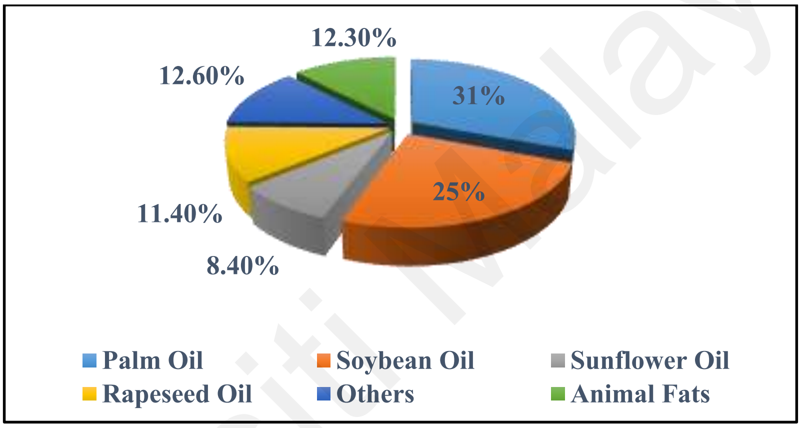

Figure.1.6: World Oils & Fats Production (2018)

Source: Oil world & MPOC estimates

As a prominent producer of palm oil through the Malaysian Palm Oil Board (MPOB), Malaysia has carried out extensive research and development on palm biodiesel using palm oil and its products since the 1980s. Research effort on this has been realized by commercializing MPOB-advanced palm biodiesel technology on regular and winter grade biodiesel in the country and abroad (Loh & Choo, 2013). The palm biodiesel plan was commissioned by collaborating with MPOB-Carotino in 2006, after that MPOB-Titian Asli and MPOB-Sime Darby in 2008. The palm biodiesel plant was commissioned by MPOB in South Korea in 2007 and in Thailand in 2008 (Nambiappan et al., 2018). The oil palm industry has strong potential for Malaysia to change from only oil producer to renewable energy producer (Loh & Choo, 2013). Palm oil is appeared as a highly sustainable biofuel feedstock compared to other first-generation biofuel feedstock such as soybean, corn, and rapeseed (Basiron & Foong-Kheong, 2013). The market risk of crude oil and CPO price fluctuations and trade obstacles poses serious challenges to biodiesel manufacturers (Loh & Choo, 2013).

Thus, the Malaysian palm oil industry's success has made it a major contributor to the country's Gross Domestic Product (GDP), currency incomes, and creating employment opportunities. Generally, the palm oil industry contributes 5% to 7% of Malaysia's GDP, averaging at RM 64.2 billion with export revenue in the past five years. In 2018, the Malaysian palm oil industry generated RM 65.1 billion from export income, equating to 6.1% of the country's GDP for the year (Nambiappan et al., 2018; MPOB, 2019). In this regard, the Malaysian palm oil milling sector significantly contributed to the revenue of the oil palm industry (Begum et al., 2019), with export revenue reaching RM38.03 billion in 2019 (MPOB, 2019).

In addition, the industry contributes considerably to Malaysia's economic development by providing many advantages consisting of employment generation and revenue, development of infrastructure and food expansion, and product supply for both consumers and producers in the world marketplaces. Over 500,000 people make a living by the industry that provides a large sum in revenues to Malaysia's economy (Palm oil today, 2014).

Although the palm oil industry is recognized as a backbone to Malaysia's economy and has a substantial contribution to the country's development, the industry is at a crossroads. As a responsible industry contributing to the national economy, it will stagnate unless it can attain more growth and stay competitive (Ming & Chandramohan, 2002).

In this regard, Tan Sri Datuk Dr. Yusof Basiron stated that to stay competitive, the Malaysian palm oil industry has to continue concentrating on product development, technology, and innovation to produce improved and high-quality products annually (Palm oil today, 2014).

"For the record, the industry has gone through the process of improving and re-engineering itself. We have developed a number of new ways of producing palm oil. Continued research and development (R & D) is always the best method to bring about a revolution in the industry. As such, the palm oil industry has recorded significant achievements thus far. We are now producing products of a wider variety and better quality for our customers."(Palm oil today, 2014).

Malaysia was successful at upgrading itself by moving from a traditional primary commodity producer to the world's major processed palm oil exporter (Gopal, 2001). To overcome the problems of upgrading the palm oil industry, the Malaysian government performed a vital role (Oikawa, 2016).

1.4 Problem Statement

The Malaysian palm oil milling industry is progressively developing despite the CPO and crude palm kernel oil (CPKO) price fluctuations (MPOB, 2019); nevertheless, the industry has faced several challenges during the last decade.

The national Oil Extraction Rate (OER) has not significantly increased during the past years. Before 2004, the national average of OER was less than 19%, and in 2004 the national OER managed to graze 20% to achieve 20.03% after ten years (Hassan et al., 2012). The OER rate continued to stagnate until it reached 20.62% in 2014. The national OER rate had a downward trend one the period 2014-2018 (Figure 1.7). The OER rate represented the fluctuating trend from 20.62% to 19.95% during this period. This rate is because of the low quality of FFB delivered to the mills and high oil loss resulting from some old Palm Oil Mills (POMs) inefficiency which they had not upgraded their machinery (Hassan et al., 2012). Furthermore, the increasing OER to 23% at POMs by 2020 is the goal of the fourth entry point project under palm oil national significant economic area (Hassan et al., 2012).

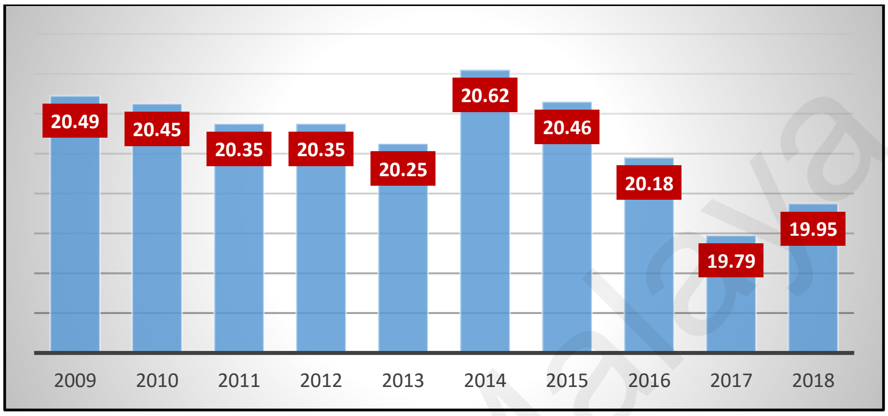

Figure 1.7: National average oil extraction rate (OER) 2009-2018 (%)
Source: MPOB (2018)

Inefficient POMs have caused relatively high oil losses to FFB, exceeding 1.8% during the CPO production process due to ineffective machinery in oil extraction, poor production control (Hassan et al., 2012), and the waste streams during processing (Nadzim et al., 2020). Moreover, oil losses and OER have a significant effect on the profitability of POMs. Thus, the considerable reduction of these two factors may adversely impact the financial strength of the mill (Simeh, 2002; Zulkefli et al., 2017; Nadzim et al., 2020).

Although the utilization of advanced milling technologies is widespread across the palm oil milling industry, several firms continue to reply on second and third-generation milling technologies. Hassan et al. (2012) provided evidence to show that only 58% of palm oil mills in Malaysia operated with moderate efficiency, and another 18% were efficient. Most critical equipment and machinery in POMs are first-generation process technologies designed in the 1950s and 1960s (Sivasothy et al., 2006). In contrast, many

POMs outsource maintenance for new-generation decanters and turbines (Baluch, Abdullah, & Mohtar, 2013).

Regarding environmental pollutions, Malaysia has been known as the country that generates a large quantity of palm oil mill effluent (POME) pollution (Kamarudin et al., 2015; Obibuzor et al., 2012). Evidence shows that More than 85% of POMs in Malaysia have applied ponding system in the treatment of POME (Chin et al., 1996; Ahmad et al., 2003; Rupani et al., 2010; Kamarudin et al., 2015), while the rest have been adopted the open digesting tank (Yacob et al., 2005). These systems are introduced as conventional POME treatment systems, which required a longer retention time and large treatment areas (Poh & Chong, 2009). The exiting effluent from the POMs is hazardous to the ecosystem because of its high-volume composition. The discharge can cause river and land pollution if it is left unprocessed (Aliyu, 2012). Due to this fact, the POME treatment is vital to prevent environmental pollution, and the palm oil milling industry faces the challenge of balancing environmental protection and sustainable development.

Therefore, developments in processing technologies in the Malaysian palm oil milling industry require to effectively address these problems to increase oil extraction, reduce oil losses, improve mill efficiency and productivity, decrease environmental pollution, and increase mills' competitive advantage.

It is clear from past studies that technological change will have to play a major role in the growth of the palm oil industry in Malaysia (see Tai-Yue & Shih-Chien, 2007). In the palm oil milling industry, technology is largely associated with the use of machinery and equipment for multi-purpose functions, problem-solving, and creating value (Jin, 2002; Karlsson et al., 2010; Mat and Razak, 2011). Although POMs need to develop TCs and increase the adoption of advanced milling technologies to raise efficiency and productivity, the remaining firms have yet to do so due to their challenges (Madaki & Seng, 2013a).

Many developing countries focus on developing their industry's TCs through the technology transfer process, including ASEAN countries (i.e., Glass & Saggi, 2002; Blalock & Gertler, 2008). Research on TC developments focused more on internal and external factors of TC development in different industries (e.g., Ofoka & Nwalieji, 2019; Akinwale et al., 2018; Sobanke et al., 2014). Although few studies have been embodied Technology Transfer Mode (TTM) between the technology donor and firms (see Madanmohan et al., 2004), studies on factors that influence TC development in POMs have largely been neglected.

Moreover, research on the link between TC and organization performance is required to understand better firms in emerging economies (Tsai, 2004; Camisón & Villar-López, 2012). Firm-level studies on TC development and firm performance have mainly embodied in R&D capability, including R&D investments (e.g., Hall, 1995; Kafouros et al., 2008), patents indicators (e.g., Griliches et al., 1988; Hall & Bagchi-Sen, 2002; Chen et al., 2009; Reichert & Zawislak, 2014), and/or various types of innovation capabilities (e.g., Rajapathirana & Hui, 2018; Gunday et al., 2011; Rosli & Sidek, 2014). Despite substantial research in each of these research areas, studies that examine the relationship between them and firm performance are rare (e.g., Rasiah et al., 2016; Ruffoni et al., 2018), particularly in POMs in Malaysia.

Existing accounts of explaining why so many POMs have not adopted advanced technologies have not gone beyond a lack of financial resources and awareness to address this problem (Pawanchik & Sulaiman, 2010). Therefore, investigating the critical factors that drove the adoption of advanced milling technologies and the barriers that have discouraged others will be important to address the problem.

While there are several studies that have addressed new technology adoption (e.g., Adaigho & Romanus, 2018; Nur et al., 2014; Ajayi & Solomon, 2010), few have focused on milling technologies. The few exceptions include Madaki & Seng (2013a) and Hassan et al. (2012). Moreover, the latter studies have not rigorously tested the variables believed to be the drivers of advanced milling technology adoption and their barriers.

Finally, companies currently compete in the environment with business and innovation globalization and the diffusion of new technologies (e. g. Gassmann & Von Zedtwitz, 1998, 1999). However, the research on TC development in such a business environment is inadequate. Thus, it is necessary to study the development of TCs in the Malaysian palm oil milling industry to contribute to the research on TCs. Consequently, this study strives to close this research gap.

1.5 Research Questions

Based on the above research gaps existing in TC development and the fast change of the business environment, it is necessary to explore the role of TC development in the palm oil milling industry.

To drive the study and to guide the exploration of the problem statement, three key research questions have been developed, as listed below.

What are the factors that significantly affect the TC development of palm oil mill firms in Malaysia?
What is the impact of TC development and innovations on the Malaysian palm oil mill firm’s performance?
What are the barriers faced by the Malaysian palm oil mill firms in the adoption of advanced technologies?

1.6 Research Objectives

The main objective of the current study focuses on TC development in Malaysian palm oil mill firms. This study investigates the factors influencing the development of TC, examining the relationship between TC development and innovation types on firm performance and identifying the barriers faced by mill firms to adopt advanced technologies. Thus, the following research objectives have been developed.

To investigate factors that significantly influence the TC development of oil palm mill firms in Malaysia.

To examine the impact of TC development and innovations on oil palm mill firms' performance in Malaysia.

To identify and overcome barriers for the adoption of advanced technologies in oil palm mill firms in Malaysia.

1.7 Significance of the Study

This study is considered significant in some areas. First, the research contribution lies in developing a conceptual framework for studying the TC development of mill firms in the Malaysian palm oil milling industry. The study provides insightful information and contributes to further knowledge in the TC development field. Since the resource-based theory suggests that differences in capabilities and competencies lead to variation in firm performance and competitiveness, the theory in business strategy stands to obtain through an empirical study that explains the role of TC development in improving the performance of a firm. For this reason, the research uses Resource-Based View (RBV) and Evolutionary theory to model the relationship between TC development, innovations, and firm performance.

Moreover, technology adoption by firms depends on the technology's characteristics and other factors related to inter-organizational and environmental features. It is for these reasons the study deploys the Technology–Organization–Environment (TOE) framework

(Tornatzky & Fleischer, 1990) and the Diffusion of Innovation (DOI) (Rogers, 2003) to investigate the adoption and non-adoption of advanced milling technologies by Malaysian POMs.

Secondly, the research provides offers on how the palm oil milling industry can develop a TC strategy by finding the factors involved in its successful development based on data attained from the managers of mill firms. Since past studies trying to relate internal factors (e.g., organizational training efforts) and external factors (e.g., government support) with TC development have not been conclusive, the research measures these relationships while providing for the role of TTM. Investigators in business strategies benefit from this comprehensive and cohesive analysis to explain the TC in determining the level of firm competitiveness.

Thirdly, the research provides offers on how mill firms can increase the adoption of advanced technology in the Malaysian palm oil milling industry. Also, it offers ways to overcome their barriers of advanced technology adoption to increase efficiency and sustainability, increase extraction rates, improve the quality and quantity of CPO & CPKO, and value addition in their POMs.

Finally, the findings of the study point at TC development in which mill CEOs and managers benefit by investing in R&D capability, innovations, and advanced milling technologies to support mill firm processes, consequently improving firm performance. Above all, the findings point at critical factors that stimulate the TC development and the adoption of advanced milling technologies among POMs that can assist planning by policymakers and mill managers.

Besides, the study provides recommendations that contribute to the proper and effective utilization of advanced milling technologies for the industry's future.

1.8 Scope of the Study

The study covered the development of TC by Malaysian oil palm mill firms to improved firm performance. Since the important role of manufacturing firms is highlighted in the literature as the main actors in accumulating TC (Bell & Pavitt, 1993; Wignaraja, 2002), the research is concentrated on the mill firms. This study also focused on TC development in the POMs because most mill firms in Malaysia fall into this category facing the cutting edge of technology. Furthermore, this study covered the relationship between TC development, innovations, and firm performance in Malaysian POMs. Moreover, the study identified critical factors that affect new technology adoption among mill firms in the Malaysian palm oil milling industry.

1.9 Organization of the Study

This research is organized into seven chapters. Chapter 1 presents the research background, problem statement, research questions, and research objectives for the study. The significance and scope of the study are also covered.

Chapter 2 covers the theoretical literature review on the critical relevant concepts and theories and an empirical review of the research objectives. The research hypothesizes of the study are presented in this chapter.

Chapter 3 presents the proposed research methodology, the research framework, sample techniques, the data collection approach, proper research instrument, pilot study, and validation of the research instrument. Lastly, the models and methods used in data analysis are described. Finally explains the methods used in data analysis of the study and how to deal with data concerns.

Chapter 4 focuses on reporting the findings of the first research objective and discusses the developed statistical model to investigate affecting factors of TC development in Malaysian POMs.

Chapter 5 concentrates on describing the results of the second research objective for the study and discusses the developed statistical model to examine the impact of TC development and innovation types on mill firm performance in the Malaysian palm oil milling industry.

Chapter 6 focuses on presenting the findings of the third research objective and discusses the developed statistical model to identify the barriers faced by mill firms for new technology adoption in the Malaysian palm oil milling industry.

Chapter 7 ends the thesis by discussing the contributions of this research to theory and practice. Besides, the chapter discusses the implications of the results to mill CEOs, managers, and policymakers. Lastly concludes with future research.

1.10 Chapter Summary

This chapter provides a background of the study along with the problem statement. The research questions and the research objectives for the study are specified. The significance and scope of the study are outlined, followed by an outline of the organization of the study.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter presents an extensive literature review relevant to the research. The discussion has been divided into six general sections: 1) theoretical backgrounds and justifications; 2) conceptualizations; 3) determinants of TC; 4) determinants of technology adoption; 5) TC, innovations, and firm performance; and 6) development of palm oil technologies. Lastly, the hypotheses are summarized.

2.2 Theoretical Backgrounds and Justifications

Several interacting theories of strategic business explain the influence of TC on promoting the competitive advantage of a firm through improving performance. The Resource-Based View (RBV) theory explains the distinctive combination of firm resources and capabilities that increase the firm's competitiveness and performance. Regarding technical changes, the Evolutionary theory explains competencies and complex interactions at the firm level. The technology adoption is defined by the Technology–Organization–Environment (TOE) framework and the Diffusion of Innovation (DOI) theory. Therefore, the theoretical contextual covers resource-based view, Evolutionary theory, DOI theory, and TOE framework. The justifications of using these theories also are included.

2.2.1 Resource-Based View (RBV) Theory

Initially, going back to Penrose's (1959) seminal studies on RBV, it has been mentioned to view the firms as a more comprehensive set of resources that can be managed, deployed, and reorganized, contributing to firm's distinctive values. Followed by Wernerfelt's (1984) study, he reviewed the RBV theory as to how a firm's competitive advantage will be realized through the organizational processes of tangible and intangible resources and capabilities. Later, Barney (1991) refined a more concise model to understand how sustainable competitive advantage can be recognized through resources based on two assumptions: the heterogeneity of resources and the degree of resource mobility. He also argued that firms that possessed the potential resources and capabilities that were rare, valuable, complicated to imitate, and complicated to replace would achieve competitive advantage and enjoy enhanced performance shortly.

First, valuable resources enable an organization to make a differentiated strategy; this helps the organization create value for its shareholders. Second, resources should be rare, assuring that a particular resource is challenging to be increased by other competitors. Third, resources should be inimitable. Without a doubt, resources need to be challenging to imitate, which helps firms to make strategies based on resources that are complicated to imitate. Competitors can repeat the firm's strategy based on the difficulty of imitable resources, but it is impossible to ultimately imitate and obtain the same advantage. Lastly, resources should not be replaceable; this means that the organization's resources cannot have comparable or the same resources in the market.

Barney et al. (2001) stated that the bundles of tangible and intangible assets of resources and capabilities would take into account the management skills of the firm, its organizational processes, and the information and know-how it controls. Amit and Schoemaker (1993) defined resources as the productive assets that the firm possesses, while capability is recognized as the ability by the productive activity of the firm to exploit these resources efficiently, produce products, or develop services in attaining business objectives. A resource is the tangible and intangible assets that can be valued and exchanged; in contrast, a capability is invisible tangible and intangible assets, which cannot be valued and switches hands only in its entire unit. Therefore, capabilities may be valuable due to their ability to increase the value of other resources (Makadok, 2001). Competitors will combine these diverse characteristics of resources in the firm to generate some specific capabilities that are difficult to imitate potentially (Amit & Schoemaker, 1993).

The fundamental argument of RBV points to the particular configuration of resources and capabilities that the firm owns (Sirmon et al., 2011; Gruber et al., 2010). Hence, the response to why firms within the same industry experience different performance levels and how firms achieve and sustain their competitive advantage are found by looking inside the firm.

According to Makhija (2003), the RBV better explains the firm's performance under rapidly changing environmental conditions. While Ketchen et al. (2007) assume that RBV is not tautological as the firm's resources and performance are indirectly related, realizing the potential value of the resources be subject to the firm’s strategies to utilize the resources. Rumelt (1991) found that the firm profit differentials within industries were more significant than the across industries. This result implied that specific differences of the firm should be contributed to these differences. RBV emphasizes the firm's internal resources and capabilities in assimilating them to obtain distinctive competencies and continued high-performance levels. The utilization of RBV to the firm-level innovative activity highlights the complementary role of innovation types and their collective impact on the organizational result. Therefore, firm performance is caused by the synergistic application of the firm’s internal resources, such as technological processes and organizational knowledge resources, resulting in the continuous adoption of different types of innovation (Walker, 2004; Pablo et al., 2007; MacDuffie, 1995). Due to the firm resources are heterogeneous, there is a potential that all resources are not of an equivalent significance or possess a characteristic to be the source of sustainable competitive advantage.

Moreover, Lawson and Samson (2001) mentioned the challenges in performing and realizing RBV, which might become the core reason for the firm's rigidity. The challenges include recognizing precious resources and capabilities, the difficulty in incorporating complementary resources and capabilities, and the confrontation of resource value fluctuation due to the changes over time. However, more or less, it is firmly suggested that it is simply easier to explain a firm's competitiveness by its complex resources as opposed to its products (Löfsten, 2016; Wernerfelt, 1984).

Hitt and Ireland (2000) stated that capabilities are mainly expanded through the transmission and interchange of knowledge and information among the firm's individuals, leading to cooperative learning in the organization (Prahalad & Hamel, 1990). In this regard, *"the ability to use knowledge to develop new products, services, and processes… is essential to the development of technological capabilities"*(Zahra et al., 2007, p.1070). Therefore, firms not only should have rare, valuable, inimitable, non-replacement resources and capabilities, they also need to be accompanied by the ability to configure and re-configure the resources to take advantage of their potential.

Although RBV theory shows differences in TC cause differences in the performance and competitiveness of a firm, empirical research was by no means conclusive. Also, future research has not recommended related concepts that could be embedded in modeling the connotation. Therefore the role of TC in improving firm performance is not understood clearly. Even though few studies investigate determinates of TC in different developing countries based on RBV theory (e.g., Sobanke et al., 2014; Akinwale et al., 2018; López-Salazar et al., 2014), it has not been employed in POMs in Malaysia. Thus, the perspective of the RBV theory was applied in this research to determine the internal variables of TC development in Malaysian POMs.

2.2.2 Evolutionary Theory

The evolutionary theory explains the TC at the micro-level of the firm. This evolutionary approach to technological changes takes into account TCs as the result of internal technological competencies and complicated collaborations among individuals, firms, and organizations within a specific socially and economically, and institutional environment (Iammarino et al., 2012). This theory defines TCs as knowledge and skills that a firm continuously obtains, adapts, develops, and creates a new technology to attain sustainable innovative capacity (Zahra & George, 2002; Lall, 1993; Cerulli, 2014). The theory also focuses on specific knowledge competencies of the firm as the main reason for its existence (Nelson & Winter, 1982; Penrose, 1959; Cyert & March, 1963). The key competencies that create competitive advantages include learning capacity in respect of learning by doing, by using, by searching, by interacting, and by monitoring as well as skills in the shapes of models, codes, and practices for decoding and integrating internal and external particular knowledge (Cerulli, 2014). The learnings and skills mentioned above are based on what Nelson and Winter (1982) called 'firm routines' are frequent efforts through which firms carry out their organizational activities.

Since the evolutionary theory has allocated an essential role to indigenous technological effort in mastering, adapting, improving, and diffusing new technologies within the economy (Lall, 1992), it is therefore considered suitable for the current study. Consequently, the study has applied the viewpoints of the theory to determine the external variables of the TC development and the TTM as external learning resources and innovations as a core value capability in enhancing the firm's performance. The following part is a review of several previous empirical studies on TC and its influencing factors:

The study of Panda and Ramanathan (1996), which assessed TC in the electricity sector in Thailand and France, found that both internal and external factors impact the TC of a firm. The internal factors found include technology availability, organization size, organization culture and structure, organization strategy, experience, and learning. In contrast, the external factors comprise the firm's size, financial and fiscal policies, inward/outward-looking trade regime, state of related and supporting industries, market conditions, and market rivalry.

Vinding (2006) also examined the factors contributing to the firm's absorptive capacity by including 1,544 firms from Denmark's service and manufacturing industry. The results revealed that the educated employees, use of human resource management practices, improvement of collaborations with the knowledge institutions and the related actors, the competitive pressure, and firm's affiliation to a subsidiary firm were all significant in developing the TC of the firms. Boujelben and Fedhila (2010) investigated influencing factors innovation development in manufacturing firms in Tunisian. Their results showed that in-house R&D activities and technological collaboration contracts significantly promote products and innovation processes.

Iammarino et al. (2009) studied the main determinants of advanced TCs of firms in the electronics industry in Mexico. Their results showed that the size of firms, human capital, exports, and utilization of external sources of technology were significant factors firm-level TCs. Furthermore, local staff's primary technology transfer method to developing capabilities was the knowledge attained by the local team through work for foreign enterprises. In addition, Iammarino et al. (2012) further examined the influencing factors of TCs and the innovative collaboration of firms in the UK regions. Their results revealed that the size and age of firms, affiliation to a group, the extent of internationalization of the markets served by the firm, human capital, and innovative cooperative agreement (with the suppliers, customers, and universities) showed all significant relationships with the UK firms' TCs.

Börjesson and Löfsten (2012) investigated capabilities critical to innovation performance among small high-tech firms. The education level of the employees, work experience, R&D efforts, and external networks were significant capability variables. Even though collaboration with universities negatively affected a patent, partnership with universities and operational planning and advice positively influenced innovation performance. In the study of Mauritius garment innovations, Wignaraja (2002) constructed a technology index and conducted an econometric analysis to examine factors influencing technological development and export performance. The findings showed that firm size, technical human resources, training expenditures, and external technical aid positively affect the technology index. This result confirms that investments in human capital and seeking information, both facilitated by firm size, enhance technological performance.

In the study of Urata and Kawai (2002) on the determinant of technological progress among SMEs in Japan, the technical assistance, in-house R&D with full-time researchers, collaborative R&D with universities and other research institutes, size of firms, materials and equipment suppliers, patents introduced, and subcontracting were all significant in increasing the firm's total factor productivity levels and growth.

Madanmohan et al. (2004) examined the influencing factors on the ability of manufacturing firms to cultivate TC through imported technology in Indian and Indonesia. The findings indicated that internal (the availability of technical human resources and R&D investment) and external (learning culture and government support) factors significantly contribute to the TC of the recipient firms. In addition, the transfer channels are significant contributors to the TC process.

In the Indian auto component industry study, Parhi (2005) showed that skilled and educated workforce, size of the firm, investment in R&D, the age of the firm, and external learning and cooperation were all significant facilitators for firms in developing absorptive capability.

Owolarafe and Arumughan (2007) conducted a study of TC under the Contract-Growers Scheme in India. The researchers evaluated the palm oil mill's performance in production efficiency, product quality, and technology acquisition. Their findings indicated that most technologies adopted come from locally sourced. Technologies imported and adopted were also maintained locally. Mills significantly enjoyed the high extraction efficiencies and the quality of CPO.

Hinkkanen et al. (2012) analyzed the level of cooperation for R&D in Russian firms. They found that firms use their R&D collaborations to a specific extent to obtain knowledge absorption, resulting in modify their capabilities and skills. Also, the ratio of R&D costs showed a significant relationship with the collaboration with external partners.

In the study of Nigerian metalworking firms, Sobanke et al. (2014) found that in-house training of technical staff, prior work experience of the entrepreneur, and networking with the industry connotation positively and significantly impact the accumulation of the TC at the firm level. A weak correlation between firms' collaboration and research institutes was also found. Also, firm-specific assets such as entrepreneurs' training and experience and in-house training were more significant for accumulating the firm's TC in developing countries.

López-Salazar et al. (2014) investigated the determinants of TCs of the agribusiness sector in Mexico, found that the firm's size, investment in R&D, cooperation with partners, social capital, and age of the firm are factors that influence the level of TC. From the survey conducted in the Nigerian cable and wire manufacturing sub-sector by

Egbetokun et al. (2012), the application of new technologies, firm-level leadership, and collaboration with suppliers and customers were significant factors in improving innovation capability.

Jegede et al. (2012) used descriptive statistics to examine the factors influencing TCs among the servicing firms in Nigeria's oil industry and found that qualifications and experience of the heads of technical departments and staff training were the significant factors that accounted for the firms' TC.

Hansen and Ockwell (2014) investigated the accumulation of TCs by the utilization of various learning mechanisms in the biomass power equipment industry in Malaysia. The results indicated that firms that enjoy planned learning and experiments from foreign technology partners generate a high level of development in their TCs. In the study of indigenous oil firms in Nigeria, Akinwale et al. (2018) examined the factors affecting technology and innovation capabilities. The results found that the in-house R&D and fund allocation for R&D were significantly contributed to the extent of the firm's R&D captured. The size of technical staff, staff qualification, and staff work experience substantially affect the firms' TCs. Training, acquisition of cutting-edge machinery, and age and size of the firm were also important in influencing the TC of the firms.

Ofoka and Nwalieji (2019) investigated the TCs of mill owners/operators in palm oil processing firms in Anambra State. The findings showed that most mill operators operated semi-automated oil mill systems, had no capability in equipment investment, had no investment capability in human resource development, acquired production, and linkage capabilities. Lack of human resources, market forces, insufficient revenue, lack of interactions, seasonal scarcity of fruits, and lack of funds for business expansion were the limitations to the TCs of the mill owners/operators. However, human resources, technical, personnel, and infrastructural factors influenced mill operators' TCs.

Despite the various studies on TC among the firms, it is clear that there is an absence of studies in POMs in the Malaysia mid-stream palm oil sector. Past studies emphasized the internal and external factors of the TC development while less concentrated on technology transfer channels between the technology donor and firms as technology recipients.

Along with the case of organizational learning, the development of TC is also focused on technology transferability. Therefore, the development of TC needs serving attempts aimed at assimilating, adapting, and modifying current technologies and/or developing new technologies. Thus, the study added the technology transfer mode factor between internal and external factors to investigate factors that significantly affect the TC development of POMs in Malaysia.

Moreover, R&D investments and/or patents have been deemed to be more prevalent as indicators of TC in assessing the link between TC and firm performance among almost all studies (e.g., Kafouros et al., 2008; Zhang et al., 2009; Chen et al., 2008). Given that empirical evidence has suggested the positive linkages between innovations and the performance of a firm (e.g., Gunday et al., 2011; Ul Hassan et al., 2013; Rajapathirana & Hui, 2018; YuSheng & Ibrahim, 2020), hence, it can be stated that TC and innovations beside each other can have a higher level impact on the firm performance.

Drawing upon a robust theoretical background, the correctness with firm-level resources and competencies relevance, satisfactory empirical evidence of other researchers, and the suitability for the factors examined for the development of TC and its impact on firm performance. The above theories would develop the conceptual framework for this research.

Hence, the conceptual framework developed for this study takes account of the organizational learnings, innovation strategy (use of technology), type of ownership, and size of the firm in the context of internal factors; and strategic alliances (collaboration with external networks) and government support in the external contexts; factor TTM; and innovations. Therefore, it can be stated that an effective combination of suitable determinating factors improves the strength of firm's TC, which in turn leads to enhanced performance, and in addition to TC, through innovations.

2.2.3 TOE Framework

The extant literature on technology adoption indicates that the socio-economic characteristics and the technology acceptance model (TAM) specifically target technology acceptance for understanding users' adoption, which often underpins studies on palm oil processing (e.g., Agwu, 2006; Ugwu, 2009; Ajayi & Solomon, 2010; Dennis & Romanus, 2018; Adaigho & Nwadiolu, 2018).[1] Thus, it can be stated that the firm-level research on the adoption of technology is inadequate (Kung et al., 2015), particularly in POMs in Malaysia.

Since the decision to adopt advanced technology is created as a strategic firm-level initiative, it is essential to utilize a firm-level theory to investigate critical factors of the new technology adoption by the firm. A combination of concepts from various theories provides an increased ability to understand better the latest technology adoption (Oliveira et al., 2014). Thus, the research is concentrated chiefly on the TOE framework and DOI theory.

TOE framework was developed by Tornatzky and Fleischer in 1990. The framework is classified into three characteristics in the organizational-level contexts that affect the adoption decision process of innovation, namely technological context, organizational

[1] Technological adoption requires learning and soft adaptation by human capital that uses it, including production reorganization. However, It does not require the development of profound physical adaptation of technologies, albeit the latter would surely enhance the technological capabilities of firms (Rasiah, 2018).

context, and environmental context (Figure 2.1). The definition of these three dimensions is as follows.

Technological context addresses the suitable technologies available inside the firms and the market pool.

Organizational context refers to the administrative aspects and resources, such as scope, size, hierarchy, and organizational structure.

External environment context refers to the administrative aspects and resources, such as scope, size, hierarchy, and organizational structure.

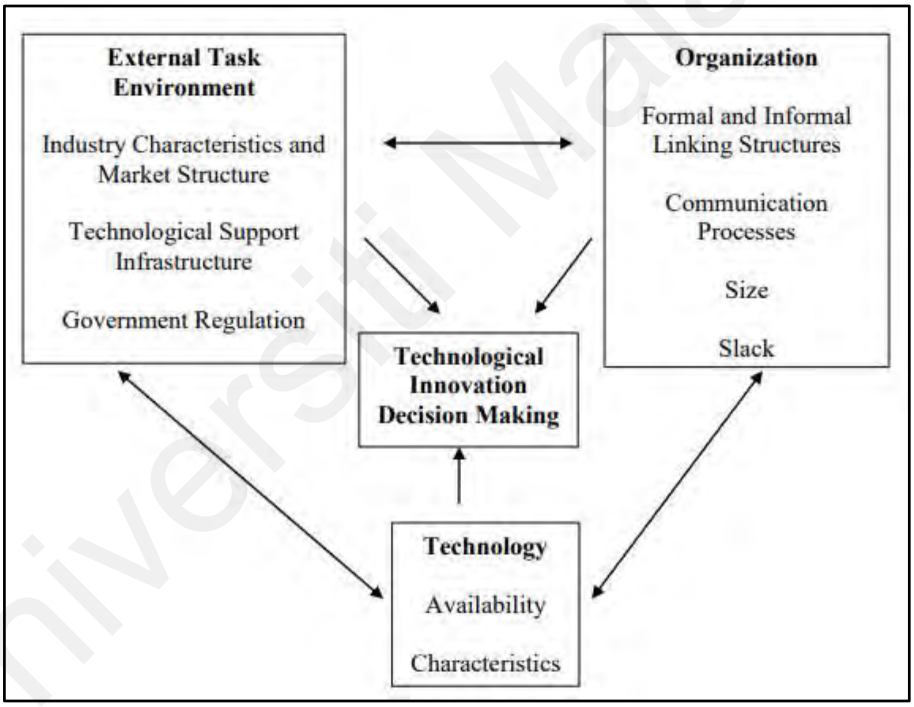

Figure 2.1: TOE framework

Source: Tornatzky and Fleischer, (1990, p.154)

The technological construct focuses on how technological characteristics can impact the adoption decision. These characteristics comprise the following factors: perceived benefits, perceived importance of compliance, perceived barriers, complexity, compatibility, trialability, perceived ease of use, and perceived risks (Oliveira et al., 2014).

The organizational context emphasizes the features and resources of the organization. The structure and processes of an organization indicate that it limits or simplifies the adoption and implementation of innovations (Chau & Tam, 1997). These characteristics cover the following factors: organization readiness, top management support, firm size, financial capacity, employee's knowledge, and employee's expert (Chiu, Chen, & Chen, 2017; Yoon & George, 2013; Low, Chen, & Wu, 2011a; Ramdani et al., 2009; Teo et al., 2006; Oliveira et al., 2014).

The environment context focuses on the features of the industry, practices, limitations, and opportunities, and authorized regulations that can affect the adoption decision (Zhai & Liu, 2013; Oliveira et al., 2014). These features comprise the following factors: competitive pressure, government support and policy, and vendor support (Ahmadi et al., 2015, 2017; Wan Ismail & Mokhtar, 2016; Low, Chen, & Wu, 2011a; Oliveira & Martins, 2010; Pan & Jang, 2008).

The researchers have applied the TOE framework for some of the reasons. First, the framework has inclusive applicability and can explain adoption in specified technological, industrial, and national contexts. Second, the framework perfectly deals with environmental factors. It implies that it can propose a clear explanation of innovation adoption. Third, it also confirms that the investigators look beyond the technological attributes and consequently enables research to evaluate both the intrinsic aspects of innovation and the organizational and environmental factors that affect its adoption (Oliveira & Martins, 2011).

In addition, the TOE framework has been applied in many technology adoption studies in different industries in developed and developing countries (e.g., Gangwar et al., 2015;

Maduku et al., 2016; Wang & Hwang, 2012; Wang et al., 2016; MacLennan & Van Belle, 2014; Zailani et al., 2019). Nonetheless, it has not been employed in POMs in Malaysia. Due to the focus on POM's adoption and based on the above reasons, the researcher applied the most commonly adapted TOE framework (Tornatzky & Fleischer, 1990) to investigate the critical adoption or non-adoption factors of advanced milling technologies by POMs in Malaysia. The following section reviews several studies that have employed the TOE model.

Zailani et al. (2019) investigated the obstacles to adopting biodiesel among transportation companies in Malaysia, found that lack of competitive pressure, lack of environmental–commercial benefits, and lack of government support were the obstacles to adopting biodiesel. The findings also showed that differentiation strategy moderated the effect of lack of competitive pressure, lack of government support, lack of environmental-commercial benefits, and lack of customer demand on the adoption of biodiesel.

Chandra and Kumar (2018) used the TOE framework to investigate the influencing factors of organizational adoption of Augmented Reality (AR) in e-commerce in Singapore, India, and the USA. The relative advantage, top management support, technology competence, technical competence, and consumer readiness were more significant influencing factors of the AR adoption intention.

Chiu, Chen, & Chen (2017) combined theories DOI with TOE to study critical factors of the adoption of broadband mobile application through evaluating technological (relative advantage, compatibility, trialability, observability, and complexity), organizational (management support, information intensity, absorptive capability, and employee's knowledge), and environmental (business partner, external support, competitive pressure, and government support) factors. Their findings indicated that all factors, except government support, complexity, and observability, were significant factors.

Ngah et al. (2017) identified the influencing factors to adopting Halal warehousing services in Malaysian Halal manufacturers. The results indicated that customer pressure, perceived benefits, cost, and organizational readiness influenced Halal warehousing services. Furthermore, organizational readiness, customer pressure, and perceived usefulness were the adoption drivers, but the factor cost acts as an obstacle.

Awa, Ukoha, and Emecheta (2016) studied the adoption of enterprise resource planning software in Nigerian SMEs. Their results indicated that technological factors have more influence than organizational and environmental factors in the SMEs' adoption of enterprise resource planning software.

Wan Ismail and Mokhtar (2016) investigated the critical factors in pre-and-post adoption of Computerized Accounting System (CAS) in Malaysian SMEs. They found that all factors under technological (relative advantage, complexity, and compatibility), organizational (organizational readiness, satisfaction with manual systems, and employees IT knowledge), environmental (vendor support, competition, and government influence), and Owner-Manager (knowledge, attitude towards IT, and commitment) aspects showed significant impacts on CAS.

In another study, Lin (2014) assessed the effect of top management support, perceived costs and benefits, firm size and absorptive capacity, competitive advantage, and trading partners on the adoption of Electronic Supply Chain Management (e-SCM) in large Taiwanese firms. The findings indicated that the organizational and environmental factors significantly impact the adoption of e-SCM.

Ramdani, Chevers, &Williams (2013) examined the TOE critical factors that drove enterprise applications adoption among SMEs. The findings revealed that all of the technological aspects (relative advantage, observability, compatibility, complexity, and trialability), organizational factors (organizational readiness, top management support, Information and Communications Technology (ICT) experience, and size), and environmental factors (competitive pressure, market scope, industry, and external ICT support) impact the decision to adopt enterprise applications, apart from ICT external support and experiences.

In the study of the IT innovation adoption process, Hameed et al. (2012) applied technological factors (relative advantage and cost), organizational factors (organization readiness, top management support, IT expertise, and organization size), and environmental factors (partners' readiness and competitive pressure). The results indicated that technological and environmental factors have a more substantial influence on the adoption of IT innovation than organizational factors.

Oliveira &Martins (2010) showed that the barriers of e-business technology, perceived benefits, competitive pressure, readiness, and trading partner cooperation were the critical factors of the e-Business adoption in the telecommunications and tourism industries in European countries. Teo et al. (2006) found that technological and organizational barriers are more important than environmental barriers to hinder Business to Business (B2B) e-commerce development. The lack of understanding of potential benefits, lack of top management support, and drawbacks relevant to B2B e-commerce were barriers that lead to rejecting the web-based B2B e-commerce applications.

The above literature shows that specified variables within the technological attributes and environmental and organizational factors differ from one study to another. However, such an approach of adapting and purifying theoretical frameworks to match particular research was considered suitable since "*innovation adoption decisions demanded, appropriates contexts and variables to be studied.*" (Chau & Tam, 1997, p. 3). Nonetheless, some previous studies used an integrated framework to explain better technology adoption (Alatawi et al., 2012). Thus, the researcher applied the TOE framework with DOI theory on new process technology, which comprises the mill's machinery, equipment, and processes used by Malaysian POMs.

From the literature mentioned above, this study absorbed organizational and environmental elements from TOE theory by Tornatzky and Fleischer (1990) to investigate the critical technological adoption factors of advanced milling technology. According to this approach, the organizational factors cover financial support and resources, top management support, managers' knowledge, technical skill resources, and size of the firm as well as the environmental factors cover the competitive pressure and government support.

2.2.4 Diffusion of Innovations Theory

In 1962, Everett M. Rogers developed the Diffusion of Innovations (DOI) theory, which is the most commonly adapted social science adoption theory in many subjects. Based on the DOI theory, the perceptions of the benefits and aspects of innovation by the adopters substantially affect their adoption decisions than the actual measures of these attributes (Rogers, 2003). In the beginning, DOI theory was referred to concerning innovation adoption at the individual level. Later, Rogers (2003) maintained that innovation features could also be used at the firm level. Thus, the DOI theory has been utilized in various firm-level studies (e.g., Thong, 1999; Premkumar & Roberts, 1999; Hussin & Noor, 2005; Ramdani & Kawalek, 2007; Ramdani et al., 2009).

Rogers (2003, p. 96) is justified the continual acceptance of innovation diffusion study by stating that:

"The diffusion model is a conceptual paradigm with relevance for many disciplines. The multidisciplinary nature of diffusion research cuts across various scientific fields; diffusion provides a common conceptual ground that bridges these divergent disciplines

and methodologies. There are few disciplinary limits on who studies innovation. Most social scientists are interested in social change; diffusion research offers a particularly useful means to gain such understanding because innovations are a type of communication message whose effects are relatively easy to isolate. Economists are centrally interested in growth in society. Students of the organization are concerned with processes of change within formal institutions and how an organizational structure is altered by the introduction of new technology. Social psychologists try to understand the sources and causes of human behavior change. Sociologists and anthropologists share an academic interest in social change but use different methodological tools. The diffusion of innovation is of note to each of the social sciences."

Several works of literature considered the idioms 'diffusion' and 'adoption' as synonymous. The definitions of these terms are given by Rogers (2003, p.5, 12) as follows:

"1. Diffusion is the process by which an innovation is communicated through various channels over time among the members of the social system.

2. Adoption is the decision to make full use of an innovation as the best course of action.

3. Innovation (technology) is an idea, practice, or object that is perceived as new by an individual or other unit of adoption."

Adopters' decision about technology is not an immediate action but a process that occurs over time, including a series of actions and decisions (Rogers, 2003). Hence, Rogers (2003, p. 169) proposed the five stages of innovation-decision processes as follows.

"Knowledge occurs when an individual (or other decision-making units) is exposed to an innovation (technology) and knows how it functions.

Persuasion occurs when an individual (or other decision-making units) forms a favorable or unfavorable attitude towards the technology.

The decision occurs when an individual (or other decision-making units) becomes engaged in activities, which concluded in the decision of implementing or rejecting the innovation.

Implementation occurs when an individual (or other decision-making units) moves an innovation into use.

Confirmation occurs when an individual (or other decision-making units) would like to seek re-enforcement for a technology decision already made, or reverse a previous decision to adopt or reject the technology."

The DOI theory postulates adoption as a function of innovation attributes that covers five technological characteristics (Rogers, 2003), which comprise relative advantage, compatibility, complexity, observability, and trialability that may raise or reduce technology adoption (Yunus, 2014). The definitions of these five innovation characteristics that introduced by Rogers (2003, p. 15, 16) are as follows:

"*Relative advantage is the degree to which an innovation is perceived as being better than its precursor.*

Compatibility is the degree to which an innovation is perceived as being consistent with the existing values, needs, and past experiences of potential adopters.

Complexity is the degree to which an innovation is perceived as difficult to understand and use.

Observability is the degree to which the results of an innovation are visible to others.

Trial-ability is the degree to which the technology may be experimented with before adoption."

The DOI theory is the most referred to in new technology adoption because of its advanced concept and several empirical findings. The following section is a review of some studies that have applied the DOI theory.

With the use of DOI theory, Yunus (2014) investigated the effect of compatibility, relative advantage, and trial-ability on consumer intentions and attitudes to use mobile banking in Indonesia. In the same way, Gerpott (2011) applied the DOI-TAM integrated model to study the acceptance of mobile Internet in mobile users in Germany. Both researchers realized that the diffusion characteristics of innovations strongly affect the intention of using them.

In another study, Archibald and Clark (2014) using five innovation characteristics from DOI theory to investigate the adoption of Twitter by nurses. Similarly, Gulati and Williams (2013) utilized the DOI theory to examine Facebook's adoption in the campaigns for the U.S. Congress. Both research findings showed that the awareness of the DOI attributes strongly affects the intention of utilizing the innovation. In the study in cloud computing adoption by SMEs, Alshamaila, Papagiannidis, and Li (2013) found that factors complexity, relative advantage, compatibility, and trial-ability significantly contribute to reducing uncertainties on adoption.

Although some of the reviewed studies above have applied complexity, observability, and trial-ability as an indicator to evaluate the adoption of technological innovations, most of the past studies showed that these attributes were less effective (Gerpott, 2011; Tweel, 2012; Yoon & George, 2013; Lee et al., 2011; Archibald & Clark, 2014; Wu, 2011; Yunus, 2014). Therefore, this study adopted two technological constructs from the DOI theory, which covered the specific aspects of advanced milling technology and added the factor cost of technology innovations (Tweel, 2012; Ngah et al., 2017; Yeh & Chen, 2018).

However, because of the TOE framework's limitations on providing specific characteristics of technological innovations in advanced milling technologies, this study absorbed elements of DOI theory by Rogers (2003) to investigate the critical technological adoption factors of advanced milling technology. The TOE-DOI integrated model explains better technology adoption (Awa et al., 2011; Ochola, 2015) and its competitive advantages (Mata et al., 1995; Ngongo et al., 2019), which provides a higher level of reliability and validity (Ramdani et al., 2009; Ngongo et al., 2019). Although this integrated framework has been deployed at the organizational level to investigate the adoption of new technologies, it has yet to be applied for studying the adoption of advanced milling technology by Malaysian POMs.

Hence, the conceptual framework developed for this study takes account of the compatibility, complexity, and cost in the technological construct; financial support and resources; top management support; managers' knowledge, technical skills, and size of the firm in the organizational construct; and environmental pressure and government support in the environment construct.

2.3 Conceptualization

In addition to the firm-level theories discussed in the earlier part, some strategic business concepts also affect the role of TC on the firm's performance. This part presents the empirical literature review covering the concepts of TC, innovations, technology adoption, and firm performance.

2.3.1 Technology Capability

TC has been studied since 1980 as based on the primary literature of model development on TC by Kim (1980). Initially, firms are technologically incapable and immature. They accumulate knowledge through the learning process over time, and, on these bases, they are able to carry out new activities and acquire new TCs progressively (Dutrénit, 2004). Technological development is gradual and may be identified stages of the accumulation of TCs. The building up of TC needs to be involved a long-term process rather than short-term planning (Husseini & O'Brien, 2004). Thus, it must acquire the result of the firm performance and obtain comparative advantages by taking every component's effort while simultaneously attempting to sustain commercial achievement in the local and global marketplace for a long time. From a long-term perspective, technological interactions between firms and their environments should be taken into consideration in manufacturing strategy development at both national and firm levels, where TCs of the firm help build technological attributes in internal and external contexts in an accumulating procedure (Husseini & O'Brien, 2004).

In addition, TC enables to renew by using the significant role of technological development and forecasting, including adopting, integrating, re-configuring the firm's skills and internal and external resources of the firm and functional competencies (Banerjee, 2012). The accumulation of such TCs involves developing extensive forms and skills of the knowledge essential to maximizing any technology investment effectiveness (Zhou & Wu, 2010).

According to industry reports, some innovations collectively point to some level of capabilities among SME enterprises in developing countries (Sobanke et al., 2014). At the firm level, TCs facilities innovation, which contributes to the growth of productivity (Sobanke et al., 2014; Ortega, 2010). Firms with superior TCs can be further innovative. Thus, they carry out at a high level by responding to the changing market circumstances and producing more significant differences of innovative products than their rivals, ensuring greater efficiency during the innovation processes and obtaining more revenues (Ortega, 2010; Shu & Ming, 2007). TCs can also improve the quality of a product and get higher quality processes to a firm that would cause increased customer satisfaction (Akroush, 2012).

The importance of TC has been well known in today's demanding and competitive business environments (Jin et al., 2004). Indeed, identifying the TC and its level is one of the fundamental activities to aiding firms in assessing the firm's strengths and weaknesses, planning for innovative technology strategies, and enhancing competitive advantages and firm performance (Son et al., 2018). Thus, the right kind of innovation and investments in new technologies and strategies would help firms improve their productivity and overall performance and growth (Beck et al., 2012; Stiglitz, 2010).

Generally, a firm can operate, maintain, adapt, and assimilate the transferred technology. Nevertheless, the question arises: To what extent can the firm's TC level generate a competitive environment that might compete better than competitors in the global competitiveness. Hence, the activities and strategies are the two key aspects of TC that need to be evaluated significantly (Bergek et al., 2008). The activities involve R&D concerning problem-solving and product launching, while the strategies will take into account the technology sourcing strategy. Recently, vast numbers of studies have been carried out on the TC area, highlighting the important role of TC in attaining competitive advantages and increasing the performance of organizations, industries, and even countries.

Previous studies on TC has been conducted in several sectors and industries, such as *manufacturing* (Hajihoseini, Akhavan, & Abbasi, 2009; Iammarino et al., 2009; Isobe, Makino, & Montgomery, 2008; Aamer, 2015; Rasiah, 2009; Nurazwa, 2016; Ahmad et al. 2019; Lin & Lai, 2020), *biotechnology* (Garcia-Muina & Navas-Lopez, 2007;

Haeussler et al., 2012; Renko, Carsrud, & Brännback, 2009), *automotive* (Khan & Haleem, 2008; Liu & Tylecote, 2009; Rasiah, 2009), *high technology* (Wang et al., 2006; Zhou & Wu, 2010; Zou et al., 2010), *services* (Abeysinghe & Paul, 2005; Ortega, 2010; Oyebisi, Olamade, & Agboola, 2004), and *construction* (Takim et al., 2008). Although most previous studies have covered the manufacturing sector against other sectors, few studies on the resources-based manufacturing, mainly the palm oil sector, are applied (e.g., Razali et al., 2013; Ofoka & Nwalieji, 2019). This review has brought the idea that TC studies are almost known to the industry heavily involved in the relevant processes to the use of machinery equipment. Therefore, TC is widely known as critically important for the manufacturing companies' competitive advantages and the resources-based manufacturing companies' competitive advantages that drive the performance of an organization (Ofoka & Nwalieji, 2019; Coombs & Bierly III, 2006). However, studies on the association between the TC and the performance of POMs in developing countries appear to be few, especially in Malaysia.

2.3.1.1 Definition of Technological Capability

In early studies, many researchers have defined the term TC in a broad area of knowledge. The role and explanation of TC differ from different perspectives of the studies, as presented in Table 2.1. Since TC exceeds the scope of science, engineering, and technology, it comprises both organizational learning and knowledge of behavioral models of staff, customers, and suppliers, which are evolutionary. This knowledge and capabilities derive from accumulative learning (by using and by doing), reiterative trial and error, and internal and external collaborations of a firm (Oyebisi et al., 2004).

To fully use the function of TC hence, one must recognize on which level the TC has been evaluated, whether it is at the highest national level or to the lowest level of machinery, factory, firm, industry, industrial clusters. Notably, previous studies have defined TC in a different way (Table 2.1). Although the definitions were revealed in wide-ranging studies based on specified objectives, the descriptions were not so many dissimilar from each other, as the majority of them operationalized TC as part of their technology and manufacturing. Consequently, this study is defined TC as the knowledge and skills needed for firms to select, install, operate, maintain, adapt, improve, and develop technologies.

Table 2.1: Technological Capability Definitions

Definitions	Source
The competency rate of companies in inventing new products about the age of the company.	(Kim, 1980)
The competency to implement every technicalities about the operation, upgrading and the updating the manufacturing facilities of the company.	(Lall, 1990)
The acquisition of sources required to create and administer the changes in the aspect of technical that have been built up and personified in expertise, education, experience and the system in the company.	(Bell & Pavitt, 1993)
The capability to choose applicable technologies to carry out the current task, the aptitude to take in, adjust and localize the technologies, and invent new technologies, procedures, and manufactured goods through innovations in the local scene.	(Wilson, 1995)
The capability to carry out any related organizational technological task or mass production action together with the capability to invent new items and processes and to efficiently running the facilities.	(Teece et al., 1997)
The capability to adjust or absorb and integrate foreign technology by utilizing productively the newly obtained added and diversified techniques.	(Aw & Batra, 1998)
The required expertise, know-how, and experience to ensure the company succeeds at various technological transformation stages.	(Costa & de Queiroz, 2002)
The expertise that a company acquires in developing and utilizing diversified technologies and schemes.	(Zahra & Nielsen, 2002)
The required elements to produce and to control the upgrading in processes and manufacturing company, merchandise, equipment, and engineering developments	(Figueiredo, 2002b)
The required expertise and know-how to enable a company to select, set up, run, sustain, acclimatize, upgrade, and building technologies.	(Madanmohan et al., 2004)
How a country meets its growth target by utilizing its capability to select, obtain, produce and accommodate technologies (International Labour Office, 1986).	(Oyebisi et al., 2004)

'Table 2.1, Continued'

Definitions	Source
The absorption and practice of the technological know-how that is gained from the R&D actions to the production	(Tsai, 2004)
The competency of a firm in generating output from input effectively as against its competitor.	(Coombs & Bierly III, 2006)
The organizational alignment between the tangible (machines, equipment, systems, and procedure) and intangible (skills, knowledge, and experience) that define to create firm competitive advantages through a capacity to effectively and efficiently leverage the technological sources	(Shamsuddin & Bititci, 2006)
The competency to build up and invent new products and processes and uniquely enhance knowledge of the actual situation theoretically and practically (know-how, methods, procedures, experience, and physical devices and equipment) can incorporate the knowledge in the planning and instructions of the targeted objectives.	(Wang et al., 2006)
The general capability in knowledge-intensive to activate various resources in scientific and technical to allow a firm to invent new products and/of the productive process by performing a competitive and value-wise strategy on certain occasions.	(Garcia-Muina & Navas-Lopez, 2007)
The possession of capability and knowledge to run, develop, and spread the available technological know-how.	(Sethi et al., 2007)
The essential elements that are required to produce and organize changes in technology.	(Figueiredo, 2008)
The expertise that promotes innovations for individuals, organizations and institutions that comes from similar location.	(Iammarino et al., 2009)
To utilize the technical expertise effectively to go further than just an effort to upgrade and create products but upgrade existing technological knowledge to face competitors.	(Jin & von Zedtwitz, 2008)
The skills of technical, managerial or organizational that firms need to utilize efficiently the hardware (equipment) and software (information) of technology, and to accomplish any process of technological change.	(Morrison, Pietrobelli, & Rabellotti, 2008)
The firm's current and potential ability to absorb and apply its firm-specific technology to solve technical problems and to enhance the technical functioning of its finished or developing products.	(Tsai, Chuang, & Chen, 2008)
A specific capability that cater a different level of discipline or function, which consist of acquiring, operating and shifting capability.	(Guifu & Hongjia, 2009)
An emphasis on production capacities and technology indicates technical experience, technological capabilities and equipment, and an efficient and effective manufacturing department.	(Ortega, 2010)

'Table 2.1, Continued'

Definitions	Source
The required skills and proficiency in the specified field to introduce and administer the technological transformations that meet the organization's aspirations and investments increase production and move towards innovation.	(Voudouris et al., 2012)
The technical, managerial, or organizational skills firms need to efficiently utilize the hardware, i.e., equipment and software, i.e., information of technology, and to accomplish any technological change process consisting of a three-stage model of acquisition, assimilation, and development technology.	(Wu, Yu, & Wu, 2012b)
The soft (comprises the skills, knowledge and experience), hard (machines, equipment, systems, procedure), and also the organizational alignment that define a firm's ability to effectively and efficiently leverage its technological resources to create competitive advantage.	(Shamsuddin et al., 2012)
The firm's ability to develop and use substantial technological resources which concerns new product development, manufacturing processes, technology development, and forecasting technological change in the industry.	(Su et al., 2013)
The organizational skills and abilities that enable firms to employ various technologies to develop new products and services are critical for firms to create differentiation advantage and achieve superior performance.	(Ju, Zhou, Gao, & Lu, 2013)
The firm's ability to exploit the best knowledge to produce and present its offers in product technology, process technology, and technology management.	(Rahmani & Keshavarz, 2015)
The ability to acquire important technologies, identify new technology opportunities and respond to technology changes while mastering state-of-the-art technologies.	(Tzokas et al., 2015)
The firm's ability to developing and employing advanced diagnostic and treatment technology.	Zang & Li (2017)

Source: Author's collecting from several literature reviews.

2.3.1.2 Technological Capability Assessment Model

In TC assessment models, Lall (1992) proposed the most extensive explanatory framework on the investment, production, and linkages types on the basic, intermediate, and advanced levels of TCs. Bell and Pavitt (1993) indicated the combination of factors leading to TCs comprises organizational structures, experience, knowledge, and skills. Followed by Kim (1999) identified that investment, production, and innovation are crucial. Under the following model, TC could be categorized into investment, production, and linkages, with three levels: basic, intermediate, and advanced. Table 2.2 briefly presents details of each TC level according to the studies of Lall (1992) and Bell and Pavitt (1995).

Table 2.2: Technological Capability Matrix

		Technological Capability Development Level		
		Basic (Simple)	**Intermediate (Adaptive)**	**Advance (Innovative)**
Investment	**Pre Investment**	Pre-feasibility, Feasibility study, Selecting site, Scheduling of investment	Search and evaluation for technology sources, Bargaining and negotiation of terms and contract	Scheduling investment in research and design, Developing of new production systems
	Project Execution	Construction of the plant, Standard procurement, Ancillary services, Hiring labour	Equipment acquirement, Engineering detail, Recruitment and training of skilled personal	Fundamental process designs, Equipment supply and design
Production	**Process Engineering**	Commissioning, debugging, and balancing quality control and maintenance	Equipment stretching processes, improvement and adaptation, New technology licensing	In-house process innovation, Well researched process innovation in organization
	Product Engineering	Product design integration, minor market needs adaptations, Improvement of product quality	Incremental new product design, improvement of product quality, unique product technology licensing	Internal product innovation and associated research and design
Linkage	**Industrial Engineering**	Scheduling workflow, Inventory control, Copying of new types of plant and machinery	Incrementally innovative engineering and monitoring, Improvement of coordination	Research and design for new specifications, plants, and machinery
	Linkages within Economy	Local acquirement of goods and services, exchange of information with suppliers	Technology transfer of local supplies, synchronized design, Raising of efficiency and quality of local sourcing	Turnkey capability, Cooperative research and design, Licensing of own technology to others

Source: Adopted (Lall, 1992; and Bell & Pavitt 1995)

The substantial dissimilarities among these three levels result from the type of technologies, skills, and knowledge required in understanding and using for adaptive and innovating technology (Bell & Pavitt, 1993). The basic level is experienced-based and straightforward, the intermediate level is adaptive and duplicative, nonetheless is research-based, and the advanced level is innovative and risky but also research-based. After that, Lall's classifications were refined to absorb the industrial specification of technology by Figueiredo (2002a), Ariffin, and Figueiredo (2004).

Past researchers have studied various types of TCs, for instance; *acquisition capability* (Kim, 1980; Panda & Ramanathan, 1996; Takim et al., 2008; Wu, Yu, & Wu, 2012b), investment capability (Wu, Gu, & Zhang, 2008), *production or process capability* (Costa & de Queiroz, 2002; Gammeltoft, 2004; Wu, Gu, & Zhang, 2008), *process and product-centered capability* (Iammarino et al., 2009; Figueiredo, 2008; Rasiah, 2009), *learning capability* (Kumar et al., 1999; Costa & de Queiroz, 2002), *product and process change capability* (Gammeltoft, 2004), innovation capability (Wu, Gu, & Zhang, 2008; Takim et al., 2008), *networking capability* (Park et al., 2008; Wu, Gu, & Zhang, 2008), *human resource capability* (Abeysinghe & Paul, 2005; Park et al., 2008; Rasiah, 2009), and *R&D capability* (Rasiah, 2009).

Given that organizations are disinclined to divulge detailed functioning reports, executives are less reluctant to share impartial functioning information (Ward & Duray, 2000; Boyer et al., 1997), mainly information on TC investment functions. Therefore it can be said that access to the investment capability of the firms to be more challenging to collect data in the case of POMs in Malaysia. In addition to that, the technology and innovation capabilities have mainly been emphasized in the palm processing industries (see Ilori, Lawal, & Simeon-Oke, 2017).

Hence, this study evaluated TC based on a typology of product and process capabilities, which are in sync with Lall's (1992) concept of capabilities. To measure the product and process TCs, the study employed product technological capabilities (RD) in terms of R&D expenditure and R&D personnel, whereas applied the proxies of inventory control systems (ICS), age of machinery and equipment (ME), and process technology restructuring expenses in total sales (RE) for the process technology (PT) utilized in firms. The variables are calculated as:

$$RD = \frac{1}{2} [RDexp, RDper] \quad \& \quad PT = 1/3 [ICS, ME, RE]$$

TCs imply having improved knowledge and skills to utilize technology more efficiently, but it means integrating changes systematically, for which the evaluation of TCs should contain technology acquisition.

2.3.2 Innovation

The importance of innovation in developing a firm's competitive edge is well known among management and innovation scholars (Martín-de Castro et al., 2011; Mendoza-Silva, 2020). Innovation is recognized as one of the most important competitive weapons and a firm's core value capability (Porter, 1990). Increased global competition has led firms to build or sustain a competitive advantage by engaging in innovation. To be successful and obtain stability in performance, firms should seek new opportunities and be highly innovative (Tajeddini et al., 2006).

Innovation is also considered a key driver for firms' long-term success in highly competitive markets (Darroch & McNaugton, 2002; Baker & Sinkula, 2002). Firms with the capacity to innovate can rapidly and effectively reply to market challenges than non-innovative firms (Miles et al., 1978; Brown & Eisenhard, 1995; Faiña Medín et al., 2016). The right kind of innovation and investments in new technologies and strategies would help firms improve their productivity, performance, and growth (Stiglitz, 2010; Beck et al., 2012).

Innovation literature claims that innovation is a significant driver for firms' success and survival (Damanpour, 1996; Cho & Pucik, 2005; Jiménez-Jiménez & Sanz-Valle, 2011; Abbing, 2010) and sustainable competitive advantage (Mumford & Licuanan, 2004; Johannessen, 2008; Standing & Kiniti, 2011; Bartel & Garud, 2009). Schumpeter (1934) has defined innovation as a driving force for growth, which proposed five innovation indicators in his definition: new industrial process, new products or qualitative improvements in existing products, new market openings, new sources of supply, and new industrial organizations forms. Damanpour and Gopalakrishnan (2001, p 47) proposed the definition of innovation as "*the acceptance of any idea or conduct related to a product, service, system, device, policy or program that is new to the adopting organization.*" In a similar vein, Nohria and Gulati (1996, p. 1251) defined innovation as "*the inclusion of any policy, program, structure, process, market or product that a manager perceives to be true.*"

Amabile et al. (1996) defined innovation as the successful implementation of innovative ideas within an organization. In other words, as stated by Camisón-Zornoza et al. (2004), the core of innovation is the latest phenomenon that consequently enhances organizational performance. Şimşit et al. (2014) defined innovation as a continuous process for developing productive resources, which are then employed to manufacture existing products with superior quality at a lower cost. In the same vein, Ilori et al. (2017) defined innovation as implementing new knowledge into processes, products, and services. The authors' categorized innovation based on technological development, marketing activities, and organizational characteristics.

Given that not all the innovative activities relevant to performance are similar, therefore, in this study, the OECD Oslo Manual (2005) has been considered the primary reference source to describe, identify, and classify innovations at the firm level. OECD Oslo Manual (2005) is introduced four varied types of innovation as product, process, organization, and marketing innovations. Product and process innovations are intimately allied to the concept of technological developments. Product innovation introduces a good/service that is new or significantly improved on the subject of its characteristics or intended uses, including significant improvements in technical specifications, components, and materials, incorporated software, accessibility, or other functional aspects (OECD, 2005). Product innovation is a complicated process directed by technological developments, changing customer needs, shortening product life cycles, and increasing global competition. It is mainly seen as a vital factor of competitiveness, placed in the organizational structure, processes, products, operations, and services within a firm (Gunday et al., 2011). This type of innovation is vital as significant growth instruments' strategies are required to enter new markets, increase the existing market share, and provide the company with a competitive edge. Firms introduce new products or modify existing products according to their needs (Adner & Levinthal, 2001).

Process innovation implements a new or significantly improved production or delivery method, including significant changes in techniques, equipment and/or software. Process innovations can decrease production or delivery unit costs, increase quality, or produce or deliver new or significantly improved products (OECD, 2005). Firms bring process innovation to make innovative products, and modifications are also brought in their processes to produce new products (Adner & Levinthal, 2001). Process innovation can impact the firm's efficiency, productivity, and growth (Nguyen & Nguyen,2012; Ul Hassan et al., 2013). Therefore, bringing automation in production methods can increase the organizations' productivity and efficiency (Ettlie & Reza, 1992).

Marketing innovation introduces new marketing methods involving significant product design changes, product placement, and product promotion or pricing (OECD, 2005). The main target of marketing innovations is to address customers' needs better, enter new markets, or place the new firm's product to increase its sales. Marketing innovation is associated with pricing strategies, credit facilities to customers, product package design properties, and promotion activities (Ilori et al., 2017; Kotler, 1991). Lastly, organizational innovation is implementing a new organizational method in the firm's business practice, workplace organizations, or external relations (OECD, 2005). Organizational innovation can improve firm performance by reducing administrative and transaction costs. The activities oriented toward organizational change can be consequently linked to corporate innovation (Tether & Tajar, 2008). Thus organizational innovations are strongly connected with all the administrative efforts, including renewing the organizational systems, procedures, routines to encourage team cohesiveness, coordination, collaboration, information sharing practice, and knowledge sharing and learning (Van der Aa & Elfring, 2002).

Since the focus of this study to examine the relationship between TC, innovations, and firm performance, this classification provides a base to direct the research in achieving this objective.

2.3.3 Technology Adoption

Technology adoption refers to the stage at which technology is chosen for use by an individual or an organization, whereas technology diffusion refers to how technology diffuses into general use and application (Carr, 1999; Rogers, 2003). The adoption models examine the decisions of an individual in respect to accept or reject a specific technology. In contrast, diffusion models explain the stage in which a group accepts or rejects a particular technology (Straub, 2009). Thus, both adoption and diffusion terms are substantial, as adoption will generally result in diffusion.

Initially, contributions of this subject were ascribed to the sociological and researchers who noted an analogy between the adoption process of epidemic and social. From a sociological perspective, Rogers (2003) investigated the diffusion problem most strongly and established the innovation-decision process model.

Diffusion of new technology is also defined as an evolutionary process of replacing low technology with newer ones for solving the same problems of attaining similar goals. Organizations will be lagged behind in adopting new technology if they do not change themselves to accept and adopt advanced technologies (Davidoff & Kleiner, 1991).

Understanding technology diffusion contributes to improving the knowledge of technology adoption and the technology decision. Rogers's (2003, p 5) definition of diffusion is *"a process by which an innovation is communicated through certain channels over time among the members of a social system, based on some decision and action as to whether to incorporate the new idea or not."* Another definition of diffusion in the management of technology conducted by Narayanan (2001, p 97), defined diffusion as "*the process by which an innovation is propagated through certain channels over time along with the units of systems.*"

Diffusion scholars are mainly involved in discovering how innovations spread among the individuals of a social organization, why several innovations are spread over faster than others carry out, and what attributes of innovations leading simplify or hinder their adoption (Damanpour, 1988). Since diffusion research concentrates on innovation, the practical concern is increasing and diffusing innovations to elevate faster acceptance Kimberly & Evanisko, 1981). Adoption has also been deemed under the diffusion process and a scale of its success (Albors et al., 2006).

Unlike a typical assessment of technology adoption, this study focuses the review specifically on the critical factors of the adoption of advanced milling technology as this is a very processed-based industry that is quite different from other industries. The purpose is to obtain a focused review from the perspective of evolutionary theory, which stipulates that they are conditioned by the type of industry, timing, and location (Nelson, 2008).

2.4 Determinants of Technology Capability

In the context of the TC determinants, there are varied viewpoints about which factor is more significant. Nevertheless, the elements are mostly similar. Hence, the conceptual framework developed for this study takes account of the internal factors (organizational learning, innovation strategy, size of the firm, and type of ownership), external factors (strategy alliance and government support), and factor TTM.

It is essential to investigate the critical factors mentioned to determine a milling firm's ability to develop TC, particularly through TTMs. The support of these factors under each group as well as factor TTM for the development of TC by POMs is discussed below.

2.4.1 Internal Factors

2.4.1.1 Organizational Learning

The importance of the development of TC and human resources in enabling firms to survive in the current competitive environment has been emphasized by Dufficy(2001). Accumulating TCs as a learning process needs absorptive capacity, which absorbs present knowledge, assimilates it, and generates new knowledge in developing countries (Jin & Von Zedtwitz, 2008; Kim, 1997). This process emphasizes the significance of learning as an imperative for innovativeness (Jerez-Gómez et al., 2005; Alegre & Chiva, 2008). Organizational skilled and qualified human personnel are essential for developing and utilizing technology within firms (Munyua, 2010), especially in firms with a low level of TC. The appropriate abilities and skills brought into the organization by employees and managers through their past formal education and training create the firm capability base (Sobanke et al., 2014).

Organizational learning treats learning as a continuous process of development which is fundamental to business success (Armstrong & Baron, 1998). It aims to bring about a systematic learning environment in a firm where knowledge is captured and transferred to benefit an organization, its investors, and its staff, its customers. Organizations successful in establishing such an environment seem to be better at developing innovation, learning from their experiences, problem-solving, and transferring new creativities and innovations to their organizations. Organization learning studies have been followed from three perspectives: learning by changes, learning as an information-oriented process, and learning by doing. The organization learning by changes involves changes in an organization either in knowledge or in achievement. Organization learning as an information-oriented process refers to the process of knowledge or message acquisition, distribution, clarification, accommodation, and utilization. Organization learning by-doing refers to the learning, which is embedded in cultural norms, work experiences, and shared practices.

Hence, organizational learning is recognized as the capability of a firm to create, accumulate, transfer knowledge, and improve its behavior (Hall, 1995). In the technology management context, internal and external organizational learning processes are differentiated (Kessler et al., 2000). The internal learning process starts with individuals generating and using technology, while the external learning process starts with the recognition of knowledge generated externally to the organization (Simon, 1991). Both learning processes are well-known to affect accumulating TC significantly in any organization.

Learning mechanisms enable firms to enhance the endowments of their TC. These mechanisms comprise in-house training programs, learning-by-doing, robust networking with research and financial institutes, universities, governments, industry, suppliers, customers, regional or foreign experts, and strong relationships among various firm units (Biggs et al., 1988). Past studies in different industries observed that technical human resources, external learning, in-house training of technical staff, and learning from imported technology partners play a significant role in improving the firm's ability to accumulate TC (Madanmohan et al., 2004; Wignaraja, 2002; Egbetokun et al., 2010; Börjesson & Löfsten, 2012; Sobanke et al., 2014; López-Salazar et al., 2014; Hansen & Ockwell, 2014; Toyama et al., 2014; Akinwale et al., 2018; Ofoka & Nwalieji, 2019).

Firm learning processes conducted internally, such as participation in organized research in new investment projects, can increase by "*learning-by-changing*" by altering machinery, mainly if created immediately on the accumulated experience obtained in diverse projects. In such new investment projects, attaining the maximum effective learning results can be possible if the learning process is actively approached by expert efforts to project and manage how knowledge will be achieved and joined into the organization (Kim, 1997). Moreover, formal in-house training programs in different types, both on-the-job training and course-based for staff, managers, and supervisors, could make available "*learning by training*" potentials for workforces (Jonker et al., 2006). Externally mediated learning through several different ways contribute to attaining knowledge from firms' outside sources and internalized it into the organization (Bell & Figueiredo, 2012).

Therefore, to learn and manage technologies, firms need to acquire, create, merge, and use knowledge (Hitt et al., 2000), which can be done through continuous training of the firm's employees on the crucial knowledge and skills required in the industry (Freel, 2003). Hence, the ability of a firm to absorb the knowledge and develop innovation capability depends on the training level of its employees in using new technology. (Vinding, 2006; Walsworth & Verma, 2007; Adeyeye et al., 2013).

In this study, the firm's learning mechanisms in POMs focus on learning as an experience-oriented process and learning involving changes (learning by training), based on the difficulty of technology transfer in preparation for the technology transfer project. Therefore, POMs that effort to accumulate TCs and develop efficiency their own approaches can drive organizational learning.

In addition to organizational learning mechanisms, innovation strategies contribute to technology efforts. Innovation strategy specifies to what extent and how a firm utilizes innovation to perform its business strategy and develop its productivity (Gilbert, 1994; Wei &Wang, 2011). The innovation strategy acts as an innovative guide for firms to choose goals, procedures, and modes to fully use and develop the firm's creative capacity (Lendel & Varmus, 2011).

2.4.1.2 Innovation Strategy

An innovation strategy leads to decisions on how resources meet a firm's aims for innovation, delivering value, and making a competitive advantage through helping the firms to determine collectively which type of innovation closely fits their objectives (Lendel &Varmus, 2012; Dodgson et al., 2008). Moreover, innovation strategies could result in new technologies, products, or processes planned to reduce the costs of the ecological consequence of company activities and promote productivity in using resources (Mariadoss et al., 2011). Among categorized innovation strategies by Venkatraman (1989), proactive approach pursues new opportunities created by the changes and enhancements in the environment, generating new opportunities, and developing innovations through using these opportunities (Droge et al., 2008).

However, implementing an innovation strategy requires not only changes in the current business model of an organization but also changes in products, processes, services, and production processes (Lindgren, 2012). An innovation strategy directs firms to promote internal business processes, learning, and growth productivity (Karabulut, 2015). Regardless of whether innovation strategies are complex and straightforward innovation strategies, an organization carries out the final target at higher productivity and quality, better performances, and lower production costs while improving or maintaining the market share (Gunday et al., 2011; Hervas-Oliver et al., 2014).

Advanced milling technologies embrace a diverse range of process technologies known as the second and third generation of palm oil process technologies and aimed at increasing productivity by improving product recovery. In palm oil sectors, wide-ranging R&D activities in the industry with significant improvements developed and introduced innovative technologies to the plantation industry and predominantly the palm oil milling industry (Hashim et al., 2012). Hence this study considers the ability of mill firms to modify their products and processes through the technological changes introduced to successfully implement a proactive stance on the minor improvement of OER, reduction of oil losses, and environmental issues.

2.4.1.3 Firm Size

Firm size is a significant factor in stimulating TC development at the firm level (Iammarino et al., 2012; Parhi, 2005; López-Salazar et al., 2014). Schumpeter (1961) stated that innovative activity had a positive association with the size of the firm because of the existence and fixed-cost nature of R&D sectors. Similarly, Katrak (1991) emphasized the importance of the firms' size on the level of their technological activities.

Desai (1980) revealed that large firms have a higher research intensity, are aimed at great innovative efforts, and look further ahead than small firms.

Typically the financial reach of large firms has offered them the capacity to invest in risky and uncertain R&D activities (Schumpeter, 1934; David, 1975; Davies, 1979; Nelson & Winter, 1982; Dewar & Dutton, 1986; Alpar & Reeves, 1990; Lall, 1999; Geroski, 2000; Hall & Khan, 2003). First, given that the high risks and fixed-cost nature included in the R&D sectors, large firms are better endowed than small firms to allocate capital for innovation activities. Second, in markets distorted by information asymmetries, large firms also have easier access to financial resources required for investment in R&D activities. Third, large firms typically have the human capital and requisite skills and other resources to develop TC and succeed in innovative activities. Lastly, large firms enjoy economies of scale to quickly amortize the investment in R&D activities and human capital training costs. Meanwhile, Iammarino et al. (2012) argued larger firms do have not only more financial resources for R&D investments but also have a strong collaboration with non-local competitors more than smaller firms.

Over the past decades, the Schumpeterian hypothesis has been supported by diverse empirical evidence (e.g., Cohen & Levinthal, 1989; Kleinknecht & Reijnen, 1991; Audretsch, 1995; Breschi et al., 2000). Previous studies revealed the linkage between the firm's size and TC in various industries. Some of them found that the size of the firm positively influences TC, yet a few studies reported a negative relationship between them (Panda & Ramanathan, 1996; Wignaraja, 2002; Parhi, 2005; Wu, 2006; Punnose, 2008; Iammarino et al., 2009; Iammarino et al., 2012; Chandran, & Rasiah, 2013; López-Salazar et al., 2014; Akinwale et al., 2018). Firm size is frequently determined by the number of employees (e.g., Teo & Pian, 2003, 2004). As a result, in this study, firm size is measured by the number of employees to determine that to what extent large, medium, and small firms can contribute to developing their TCs.

2.4.1.4 Type of Ownership

The extant literature on TC development indicates that corporate ownership plays a significant role in explaining innovative activities within the firm (e.g., Gu & Lundvall, 2006; Choi, Park, & Hong, 2012). Some studies indicated the influence of types of ownership on the external control (Hill & Snell, 1988), R&D strategy (Baysinger, Kosnik, & Turk, 1991), organizational innovation (Balkin, Markman, & Gomez-Mejia, 2000), and CEO compensation (Tosi &Gomez-Mejia, 1989).

Francis and Smith (1995) examined the association between corporate ownership structure and innovation. They found that focused ownership and stockholder monitoring effectively alleviate the high agency and costs of contracting related to innovation. Gedajlovic et al. (2012) indicated that shareholdings by senior executives stimulate the exploratory and exploitative innovations in high-tech SMEs in China. Nevertheless, the government shared ownership showed an orientation focusing on none of them.

Wu, Lin, and Chen (2007) addressed that a firm's internal governance, via a competent board and managers' incentives with a clear picture of differentiation in high-tech industries, contributes to innovation performance in Taiwanese firms. Boubakri and Cosset (1998) examined the change in financial and operating performance in full or partial privatization firms in 21 developing countries. The findings showed that firms that experienced privatization bear more significant benefits in capital investment spending, profitability, operating efficiency, dividends, and total employment.

Furthermore, through industrialization and economic transition in developing countries, state-owned or controlled firms enjoy significant advantages in increasing their technological innovation performance by laying down state owners' legality and policy support. In this way, firms benefit from accessing financial resources for internal R&D activities and foreign owners' innovative technology and know-how (Gu & Lundvall

(2006). In the same vein, the ownership transference from the government to privately-owned resulted in a significant decrease in resources allocated to R&D activities, particularly in developing markets (Munari et al., 2002).

The importance of certain ownership types has been emphasized by Choi, Park, & Hong (2012) and Talaja (2013) who found that institutional and foreign-owned companies perform better in developing new products and processes methods and increased market share, which, in turn, lead to technological innovation performance.

In Malaysian POMs, the lowest-cost producers belong to partnerships and private limited firms. The source of the difference in cost in different types of mill ownership is the higher cost of maintenance and repairs (Noor et al., 2004). Also, privately owned plantation firms are more cost-effectively managed than partial privatization among palm oil plantations in Malaysia (Ramasamy et al., 2005).

Therefore, the ownership structure stimulates firms to undertake high-risk, high-return projects, including R&D activities. Thus, this study examines whether the type of ownership in the shape of private ownership or partial privatization is accountable for the development of TC in Malaysian POMs. Consequently, this study hypothesizes that:

H1a: Organizational learning mechanism has a significant influence on the development of TC.

H1b: Innovation strategy has a significant influence on the development of TC.

H1c: Firm size has a significant influence on the development of TC.

H1d: Type of ownership has a significant influence on the development of TC.

2.4.2 External Factors

2.4.2.1 Strategic Alliance

The strategic alliance is defined as a concept to describe various cooperative collaborations and JVs among firms in developed and developing countries (Mockler, 2001; Lynch, 1989). These alliances are contracts between firms (or partners) to attain purposes of shared interest partnership-based between these firms (Pellicelli, 2003). Strategic alliances have been considered inter-firm partnerships that include utilizing resources and the organizational structure of self-determining companies to reach a particular organization-related goal or an aim targeted by both companies (Parkhe, 1993). Such strategic alliances help distribute knowledge and adoption of TC that could be responsible for a firm's competitive advantage (Lee, 2007; Mowery & Rosenberg, 1989).

Regardless of size, some organizations have promoted by acquiring technologies via technological strategy alliances. These external technologies empower companies to be apprised of less time, cost, and complexity of internal technology development (Vanhaverbeke et al., 2002). The large number of alliances formed across countries shows organizations' remarkable attempts to improve their TCs (Norman, 2004; Hagedoorn & Sedaitis, 1998). Nevertheless, some studies have highlighted that less developed countries mainly faced a shortage of R&D resources and capabilities with developing their technologies (Ju et al., 2005; Lee & Tan, 2006; Tsai & Wang, 2008; Chen & Wang, 2009). Assessing the knowledge of external technological via R&D alliances enables companies with several various advantages such as accessing additional resources to improved new or developed products or processes, distinguish new markets, decrease risks and costs of R&D as well as produce economies from synergies of partners (Gerybadze & Reger, 1999; Sakakibara, 2002; Narula, 2001; Hagedoorn et al., 2000).

R&D alliances are based on innovation linkages shaped through two or more partners who combine their resources and harmonize their activities to achieve a shared objective. R&D activities form the main part of the collaborative endeavor of these linkages, which demonstrates a specific sub-group of cooperative contracts (Hagedoorn, 2002; Oxley, 1997) and joint R&D, technological alliances, strategic technology collaborating, or technological collaborative agreements (Narula & Martinez-Noya, 2015).

Typically, the level of technology substructure addresses R&D institutes, universities and research centers and training facilities for science and technology, research laboratories, technical training programs, the availability of skilled human resources, researchers and engineers, and R&D expenditure within the imports of the economy. The lack of these facilities forces companies to obtain and adopt external technologies through strategic technological alliances (Abdul Wahab et al., 2009), especially local firms in developing countries reliant on external sources (Lee, Bae, & Choi, 1988). Further research also indicates that when both upstream and downstream R&D cooperation is strong, process innovation is high (Un & Kazuhiro, 2015) and that external R&D collaborations with universities and suppliers are the most helpful. Such capabilities in the palm oil milling industry, if they become large and extensive, tend to exploit technological improvements at the firm level. In the same vein, Rasiah & Shahrin (2006) emphasized the importance of more severe collaboration between MPOB and private R&D agencies in the industry.

R&D collaboration between public and private research centers, universities (local, aboard), institutes, and government agencies, create a systematic harmonization between the government, and links of planters, processors, and manufacturers have offered a smooth development and information stream of the palm oil industry (Sime Darby, 2009). In addition, Monash University has announced the Monash-Industry Palm Oil education and research programme for university-industry-government collaboration to develop the competitiveness and sustainability of the industry in Malaysia and beyond (Chin, 2019).

Ilori, Lawal, & Simeon-Oke (2017) highlighted the importance of R&D collaborations among Nigerian palm kernel processing firms and found weak cooperation between the palm kernel processing industry and academic institutions resulting in firms experienced less innovation capability. Nevertheless, the technological and R&D collaboration between the firms and various actors (such as competitors, suppliers, and customers as well as research institutes and universities and partners) show empirical support for these cooperations (Urata & Kawai 2002; Amara et al., 2008; Massa & Testa 2008; Kaminski et al., 2008; Boujelben & Fedhila, 2010; Iammarino et al., 2012; Börjesson & Löfsten 2012; Hinkkanen et al., 2012; Sobanke et al., 2014; López-Salazar et al., 2014; Hansen & Ockwell 2014: Egbetokun et al., 2012; Akinwale et al., 2018).

2.4.2.2 Government Support

Since external sources contribute to building operational capability, hence government could stimulate the local firms to cultivate TCs through numerous policy implementations and programs (Madu, 1989; Santikarn, 1981). Malaysian government implemented various incentives for encouraging POMs to upgrade their technologies, including installing third-generation advanced milling technologies. The Malaysian government made significant forays into such support when it launched the Second Industrial Master Plan in 1996 and the Third Industrial Master Plan in 2006 (Rasiah & Shahrin, 2006). It also launched the Economic Transformation Programme (ETP) as an economic guideline targeted to promote upstream efficiency and raise downstream growth while concentrating on industry sustainability (Nambiappan et al., 2018; May, 2012). Moreover, to produce POME that conforms to the regulatory discharge limits, more efforts are being promoted by the government to develop additional treatment methods (Taha & Ibrahim, 2014).

To developing and upgrading the palm oil industry, the Malaysian government established diverse organizations and institutions such as the Palm Oil Research Institute of Malaysia to boost the development of relevant markets in 1979. Furthermore, it merged Palm Oil Research Institute of Malaysia, Palm Oil Licensing, and Registration Authority to establish MPOB in 2000 (Rasiah & Shahrin, 2006). MPOB performed continuous attempts on R&D to discover the further potential of the new outcomes such as biodiesel. Also, to develop specific technologies of common interest upon mutually agreed terms and conditions, MPOB cooperates with external parties (MPOB, 2019).

By providing and promoting strong scientific and technological support, MPOB commercializes its research findings and transfers knowledge and innovation through its commitment to R&D (Suzi, 2011). It has continued to provide leadership and has developed robust research expertise in different areas, introducing more than 340 technologies, including new products and services. MPOB has also been involved in speeding up the industry's development and providing investment opportunities in oil palm-relevant business (Suzi, 2011).

However, the firm-level evidence emphasized extensively the importance of government policies and incentives to accumulating TC, agricultural mechanization, and industry 4.0 technologies in different industries, especially the palm oil milling industry in Malaysia (Wei, 1995; Teitel, 1984; Lin & Ho, 2010; Veugelers 2012; Lee et al., 2014: Ismail et al., 2003; Madaki & Seng, 2013b; Abdullah et al., 2015; Egwu, 2015; Onwude et al., 2016; Adaigho & Nwadiolu, 2018). Consequently, Abas et al. (2011) argue that the government should develop a comprehensive and transparent policy to support the biomass sector, including providing a subsidy to oil palm biomass projects among POMs in Malaysia. The government support seems to stimulate the development of TC in POMs in Malaysia. Therefore, the study hypothesises that:

H1e: Strategic alliances have a significant influence on the development of TC.

H1f: Supportive government policy has a significant influence on the development of TC.

2.4.3 Technology Transfer Mode

The extant literature on TC in developing countries indicates that technology transfer is a critical technique for companies to adopt new technology to generate indigenous TC (e.g., Kim, 1997, 1999; Lall, 1993, 2001; Wei, 1995; Series, 2001; Iammarino et al., 2009; Urata & Kawai, 2002; Madanmohan et al., 2004; Akinwale et al., 2018). Technology Transfer Mode (TTM) is an institutional arrangement or a business channel through which the technology transfer from the supplier to the recipient occurs (Al-Obaidi, 1993).

Various modes of technology transfer exist based on the nature of technology and the relations between technology suppliers and technology recipients (Lall, 1993). Traditionally, foreign direct investment (FDI) has captured the main form of technology transfer. Some joint ventures (JV), licensing, merger and acquisition, capital goods imports, subcontracting, and technology cooperation in a project and collaborative R&D project have developed in importance (Khalil, 2000; Series, 2001; Lall, 1993; Dunning, 1981; Al-Obaidi, 1993).

The amount of TC transferred through some channels and formal and informal organizational ways depends on the specific method selected (Kumar et al., 2002; Contractor, 1984). For instance, more are transferred through FDI or JV agreements than under technical contracts. However, the transfer method could depend on the complexity of the technology (Mansfield & Romeo, 1980; Contractor, 1984; Contractor & Sagafi-Nejad, 1981). For example, technical contracts might be further suitable for embodied knowledge such as equipment and machinery, pattern, and design than for complex technologies.

Nature of technology, current TCs of technology receiver, strategies of technology suppliers, and the government policies of the host country are key driver factors in selecting TTMs. (Series, 2001; Lall, 1993). To the extent that the nature of technology is related, TTM choice is identified by technology's changing speed, the complexity of technology, novelty, technology's diffusion speed, standardized level of technology, R&D concentration level, and whether the technology is product or process-based (Lall, 1993).

POMs include process technologies that are simpler to absorb than manufacturing technologies in the palm oil milling industry. Those process technologies can be embodied into capital goods, intermediate inputs such as knowledge required to control production processes. Since most advanced milling technologies carry multiple functions (such as anaerobic digester tanks with the mechanical-assisted aerobic process) and aimed at increase productivity by improving product recovery, higher quality products, and value-added (Chandra & Kolavalli, 2006; Hashim et al., 2012), hence contribute to quick technology transfer that leads to the development of TCs in Malaysian POMs. For that reason, POMs applied such Methods of technology transfer to guide their imported technology transfers. Therefore, this study hypothesis that:

H1g: Technology transfer mode has a significant influence on the development of TC.

2.5 Determinants of New Technology Adoption

The conceptual framework developed for this study takes account of the technological constructs (compatibility, complexity, and cost), organizational constructs (financial support and resources; top management support; managers' knowledge, technical skills, and size of the firm), and environmental pressure and government support in the environment constructs.

It is essential to investigate the critical factors mentioned to determine a milling firm's ability to adopt innovative technology, especially advanced milling technologies. The support of these critical factors under each construct for advanced milling technology adoption by POMs is discussed below.

2.5.1 Technology Constructs

Among other reasons, palm oil production costs are high owing to the high cost of third-generation technologies, which is predominantly in installation and maintenance. While third-generation efficient milling technologies have already entered the market, there is limited evidence of how they will affect overall production costs. Technology adoption is strongly shaped by perceived compatibility, that is, the degree to which an innovation is perceived to be consistent with current values, past experiences, and needs of adopters, as well as complexity, which is perceived as the degree of difficulty associated with understanding and using an innovation (Rogers, 2003, p15). Consequently, several studies indicate that perceived compatibility (Ramdani et al., 2013; Awa et al., 2016; Chiu, Chen, & Chen, 2017), perceived complexity (Risselada et al., 2014; Gangwar et al., 2015; Ngongo et al., 2019), and costs (Thomas, 2016; Ngah et al., 2017; Yeh & Chen, 2018) are critical predictors of adoption.

For the effective adoption of new technology, the firm should consider the technologies in the market and in-house technologies in use. From the adopters' viewpoint, compatible technologies would save money, time and meet government regulations, and consequently would require making justifiable changes and modifications to existing processes, instead of deconstructing and substituting them with incompatible technologies (Yoon & George, 2013). Parthasarathy et al. (2016) found that the adopted aerobic pond system for POME treatment by Malaysian POMs was aligned with discharge regulations.

Similarly, milling firms that adopted multiple screw presses for oil extraction using new technology have experienced challenges to control the rate of water extra accurately to the press liquor to improve the separation of oil/sludge through clarification (Sivasothy et al., 2006; Wahid & Simeh, 2009). Indeed, if POMs recognize that the efficient adoption of advanced milling technologies offers more compatibility and less complexity, they would more likely invest in these technologies.

There is also evidence that the cost and maintenance of new technologies have discouraged the adoption of advanced technologies in most parts of Asia and Africa (Clarke & Bishop, 2002). Also, Madaki and Seng (2013a) argue that several POMs in Malaysia have been reluctant to adopt advanced POME treatment technology due to the high initial investment cost. Many simply believe that reaching a final effluent discharge of Biological Oxygen Demand (BOD) of less than 20 PPM by adopting Waterwaste treatment technology is too costly (Nordin et al., 2019).

In addition, Baluch, Abdullah, & Mohtar (2013) note that most POMs outsource maintenance for new-generation decanters and turbines. Barrantes (2001) argued that the adoption of technology that separates kernels from shells depends on the availability of the right technology, costs, and maintenance of equipment, and availability of machinery and materials (see also Ravi Menon, 2017). The following three critical hypotheses are proposed:

H1: Compatibility is a critical influence on milling firms adopting advanced milling technology.

H2: Complexity is a critical influence on milling firms adopting advanced milling technology.

H3: Cost is a critical influence on milling firms adopting advanced milling technology.

2.5.2 Organizational Constructs

The organizational construct addresses the readiness for the utilization of internal resources (Wymer and Regan, 2005). Past work recognizes that organizational structure plays an important role in innovation (e.g., Burns & Stalker 1961; Daft & Becker 1978). Yet, for a variety of reasons, adopt of critical technology by firms can be low (Ukobitz, 2020).[2] For effective adoption of new technologies, a decentralized and well-coordinated organizational structure with employees' responsibilities and creative communication is clearly defined, and centralized, coordinated decision-making for implementing new technologies is vital (Baker, 2012; Zaltman et al., 1973). Firms' owners and top managers as decision-makers of technology adoption should be knowledgeable enough to understand their firm, innovative technologies, and customer needs (Brynjolfsson & Hitt 1996).

Organizational resources and skilled and qualified human personnel are essential for developing and utilizing technology within firms (Munyua, 2010), especially in firms that have adopted a complex technology. The lack of appropriate abilities and skills that can limit workers' productivity would, in turn, restrict the use of a given technology and could result in organizations facing challenges in applying new technologies (Cetindamar, Phaal & Probert, 2009).

Although innovation technologies are important to increase efficiency in organizations, their use is often faced by employees' resistance, mainly due to lack of communication about the strategic advantages of new technologies by the top managers (Knight, 2015). Therefore, the role of top management support is fundamental to promote advanced

[2] Ukobitz (2020) discussed the state in 3 dimensional printing.

technologies by introducing them within the firm's overall strategy and supporting innovations that run into the firm's main goal (Tushman & Nadler, 1986; Baker, 2012).

In addition to organizational resources regarding individuals, other features, such as information, equipment, and technology, financial support and resources are critical factors in stimulating innovation, adopting, and applying new processes and products in organizations. Because the implementation of innovative technologies needs capital investments, financial resources are vital for obtaining and supporting individuals to implement new technology and related infrastructure for supporting innovation (Griliches, 1990; Herold et al., 2006).

Lastly, firm size is a significant factor in stimulating the adoption of technological innovations (Hameed et al., 2012; Hutchinson et al., 2015). Large firms have been the first innovation adopters to achieve more economic value and competitive advantage (Markus & Loebbecke, 2013; Alali & Yeh, 2012). Hence, the critical factors identified for assessing the adoption of advanced milling technologies include financial support and resources, top management support, managers' knowledge, technical skills, and firm size under the rubric of organizational dimension.

Financial support and resources are essential to support the adoption of several environmental practices for the successful adoption of technology-based plans (Govindan et al., 2014; Chandra & Kumar, 2018; Wongsim, 2013). Firms' capacity to bearing installation costs significantly influences adoption decisions (Kuan & Chau, 2001; Ghobakhloo et al., 2011b; Thong & Yap, 1995; Pan & Jang, 2008). Hence, only firms with access to enough finance would be more able to adopt advanced technologies (Ghobakhloo et al., 2011b). In palm oil milling technologies, firms have to bear lumpy investments to install third-generation process technologies targeted at raising efficiency and productivity and reduce environmental pollution.

Management support has been recognized as a significant facilitator for firms in adopting technology (Kim et al., 2011; Qureshi et al., 2019). Senior managers could positively affect the adoption of new technology by clarifying a vision and reinforcing the values of their organizations (Ramdani et al., 2009). In general, passionate and innovative top managers welcome innovative technologies and are often ready to take risks. Top management plays an essential role in gaining resources and in implementing plans (Grover, 1999). In a firm where senior managers have a positive attitude to change, an organizational environment supportive of innovation is created. Thus, senior managers must provide their highest level of support and commitment to effect change (Hutchinson et al., 2015; Lee et al., 2016), especially in the implementation stage, including incoordination and dispute resolutions (Sila, 2013).

Given that advanced milling technologies are incredibly diverse compared to conventional technologies in terms of innovation intensity and complexity, as well as their effective utilization, POMs need to support sustained efforts in technical skills and training to ensure that the adopted technologies meet their expected operational needs. Such efforts need enormous support from top management.

Furthermore, the knowledge and experience of individuals are an important determining factor for the choice of the channel (Kim et al., 2011). Managers' knowledge and creativity play an important role in the adoption of technology; the higher these qualities are, the more likely a firm will adopt new technology (Wüstenhagen et al., 2007; Lin & Lee, 2005; Thong, 1999). Madaki & Seng's (2013b) study showed that the majority of POM operators (86%) claimed to know the new POME treatment technologies, while 2% were involved in the R&D of new technology in collaboration with research institutes and universities in and outside Malaysia. Meanwhile, Nordin et al. (2019) found that a few POMs have adopted patented zero-waste technology offered by MPOB due to the lack of knowledge of the economic benefits of this technology.

Although advanced milling technologies have the potential to raise strongly milling efficiency, these technologies come with unique challenges, which include adaptation to meet local conditions. Hence, mill managers should be aware of these problems to undertake the changes required. For instance, although membrane filtration technology is a third-generation oil recovery technology, it still needs further development to perfect materials use and cleaning techniques to overcome fouling problems (Hashim et al., 2012).

Technological changes call for more skills and competencies for firms to compete. However, past works show that the lack of technical skills is a significant factor that has delayed the adoption of new technologies by POM firms (Abdullah et al., 2015). Baluch, Abdullah, & Mohtar (2013) and Baluch (2012) went further to argue that the lack of in-house expert employees is one of the barriers that has restricted technological upgrading. Consequently, organizations must invest in cutting-edge technologies to compete effectively, which will invariably require the acquisition of new technical skills (Bennett & Pokingtorne, 1998).

Typically the financial reach of large firms have offered them the capacity to invest in risky and uncertain innovation activities (Schumpeter, 1934; David, 1975; Davies, 1979; Nelson & Winter, 1982; Lall, 1999; Geroski, 2000; Hall & Khan, 2003). First, considering the high risks and costs included in the early adoption of new technology, large firms are better endowed than small firms to allocate capital for the adoption of new technologies. Second, in markets distorted by information asymmetries, large firms also have easier access to financial resources required for buying and installing new technology. Third, large firms typically have the human capital and requisite skills, and other resources to introduce and implement new technology. Finally, large firms enjoy economies of scale to easily amortize the investment in new technologies.

Meanwhile, Zhu and Kraemer (2005) argued larger firms do not only have more financial resources for adopting innovations but also have the capacity to make adoption decisions more quickly than smaller firms. Such an argument has been contested, though, by those who find specialization on the basis of economies of the scope allows small lean firms to be more flexible to adopt new technologies (Piore & Sabel, 1984). Nevertheless, the scale-based nature of milling firms shows empirical support for scale (see Ahmad et al., 2020; Ngongo et al., 2019; Awa et al., 2016; Gallego et al., 2013, 2015; Ramdani et al., 2009; Jeyaraj et al., 2006). Consequently, the study hypotheses that:

H10a: Financial support and resources have a significant influence on the adoption of advanced milling technology.

H10b: Top management support has a significant influence on the adoption of advanced milling technology.

H10c: Managers' knowledge of new technologies has a significant influence on the adoption of advanced milling technology.

H10d: Human capital endowed with technical skills has a significant influence on the adoption of advanced milling technology.

H10e: Firm size has a significant influence on the adoption of advanced milling technology.

2.5.3 Environmental Constructs

The environment has increasingly become a critical variable in the conduct and performance of firms (Maqueira-Marín et al., 2017).[3] Hence, firms consider a

[3] Maqueira-Marín et al. (2017) discuss environmental determinants of firms' adoption of cloud computing.

comprehensive management framework that embraces consumers, competitors, government regulations/supports, and technology vendors when making decisions on technology choice and adoption. In the context of advanced milling technology, hence, pressures arising from environmental stakeholders and related government support have become important determinants of the choice of technology in firms. The structure of the industry and the number of POMs using advanced milling technologies can affect adoption by other firms as these firms may not wish to fall behind in the competition ladder (Oh et al., 2009). Therefore, environmental pressure is one of the influences firms take into account when adopting advanced technologies (Zhu et al., 2003), though a negative relationship between environmental pressure and new technology adoption was found by others (e.g., Zailani et al., 2019; Awa et al., 2016; Rodríguez-Ardura & Meseguer-Artola, 2010; Bayo-Moriones & Lera-Lopez, 2007). Such a finding could be a consequence of the difficulty POMs face trying to keep CPO production costs low as they often face considerable market uncertainty and volatile prices and competition from substitutes, such as soyabean oil. Hambali (2015) found such an experience in Turkey. Hence, although advanced milling technology raises CPO production yields, the lumpy investments required to install them may discourage new buyers.

As a means to underwrite uncertainties and risks, the Malaysian government implemented various incentives for encouraging POMs to upgrade their technologies, including installing third-generation advanced milling technologies. The Malaysian government made significant forays into such support when it launched the Second Industrial Master Plan (IMP2) in 1996 and the Third Industrial Master Plan (IMP3) in 2006 (Rasiah & Shahrin, 2006). Besides, to produce POME that conforms to the regulatory discharge limits, more efforts are being promoted by the government to develop additional treatment methods (Taha & Ibrahim, 2014).

However, several Malaysian POMs consider that existing policies and incentives on biomass and biogas are not sufficiently incisive to convince them to pursue advanced POME treatment technology projects (Madaki & Seng, 2013b). Consequently, Abas et al. (2011) argue that the government should develop a comprehensive and transparent policy to support the biomass sector, which includes providing a subsidy to oil palm biomass projects among POMs in Malaysia. The extant literature on this issue revealed a lack of adequate government policies and incentives to support agricultural mechanization and industry 4.0 technologies (e.g., Abdullah et al., 2015; Egwu, 2015; Onwude et al., 2016; Adaigho & Nwadiolu, 2018; Rasiah, 2018). The lack of government support seems to hamper the adoption of advanced milling technology in POMs in Malaysia. Therefore, the study hypotheses that:

H11a: Environmental pressure has a significant influence on the adoption of advanced milling technology.

H11b: Supportive government policy has a significant influence on the adoption of advanced milling.

2.6 Technology Capability, Innovations, and Firm Performance

It is clear from past studies that technological change will have to play a major role in the growth of the palm oil industry in Malaysia (see Tai-Yue & Shih-Chien, 2007). In the palm oil milling industry, technology is largely associated with the use of machinery and equipment for multi-purpose functions, problem-solving, and creating value (Jin, 2002; Karlsson et al., 2010; Mat & Razak, 2011).

Awareness of the importance of innovation in the palm oil mill sector for its economic growth is the latest phenomenon. Conventionally, the CPO extraction process in POMs involves several processes, including sterilization, thresher, oil extraction, oil recovery, kernel recovery, boiler operation, and water waste treatment that typically operate with low process losses and simple operating maintenance. Since these processes' technologies still appear to be staying stagnant, they need far-reaching changes tailored to the present technological innovations that are taking place in the industry. Besides, it is required that the industry goes beyond the current products into expanding the range of CPO products and palm kernels to embrace the innovative added value in using by-products to enjoy the unique needs such as biomass and bio-energies (Hashim et al., 2012). This new value added can only be obtained through innovation practices.

Additionally, innovation in palm oil processing is crucial to improving quality and increasing the quantity of CPO and CPKO, leading to increased productivity in POMs. Understanding the innovation competence for the developing firm-level competitiveness becomes more challenging for firms in developing countries to define the competitive landscape, especially those who compete in highly competitive markets. Hence, such firms need to manage their competence and identify their innovation capabilities to remain competitive in the global rivalry (Srivastava et al., 2017).

Traditionally, firm-level innovation studies have mainly followed two perspectives: R&D capability and various types of innovation capabilities. From the standpoint of R&D capability, R&D investment intensities are the most commonly used indicators of innovation. The provided evidence by researchers (e.g., Hall, 1995; Wakelin, 2001; Gonzalez & Gascon, 2004; Kafouros et al., 2008; Hashi & Stojčić, 2013; De Fuentes et al., 2015) pointed at the positive impact of R&D investments on the enhanced productivity and innovation performance. Although the R&D indicators would be a well-represented firm’s innovativeness (Romijn & Albaladejo, 2002), they only present an overview of the innovation input, not about the particular innovation of a firm. Therefore, R&D is an indirect measurement of innovation. However, research on the relationship between the R&D capability, process technology, and performance of firms, which considers their components are very seldom (e.g., Chandran & Rasiah, 2013).

From the innovation capabilities perspective, a firm's capability represents its accumulation of knowledge, skills, and experience, which would lead to achieving the firm's competitive advantages (Richardson, 1972). To figure out how product and process innovation create, Lall (1992) and Bell and Pavitt (1993) proposed models for the firm's technological capabilities. The concept of innovation capabilities has recently expanded as it exceeds technological aspects and deliberates organizational abilities as essential resources to developing capabilities (Dosi et al., 2000; Teece et al., 1997; Rasiah, 2004). Recent innovation capabilities models (e.g., Guan & Ma, 2003; Yam et al., 2011; Zawislak et al., 2012; Rajapathirana & Hui, 2018) seek to explain how different types of capabilities can be arranged to generate innovation.

Despite the development models of innovation and the presence of substantial research in any of these viewpoints, studies that examine the relationship between them and firm performance are rare (e.g., Reichert et al., 2016; Rasiah et al., 2016; Ruffoni et al., 2018). Besides, the empirical research considered a few dimensions of innovation types and/or a single aspect of firm performance. A few studies have intimately examined the link between types of innovation and firm performance (e.g., Ul Hassan et al.,2013; Gunday et al., 2011; Jin et al., 2004).

Therefore, this study empirically examines for the first time the effects of TC and innovation types (product, process, organizational, and marketing) on different aspects of firm performance, namely innovation performance, production performance, and market performance in POM firms in Malaysia to reveal the positive impacts among these factors. The use of Malaysian POM firms as a case is significant because past studies predominantly focused on the manufacturing sector (e.g., Kalay & Gary, 2015; Rosli & Sidek, 2013; Huhtala et al., 2014; Karabulut, 2015; Zhang & Hartley, 2018). In contrast, single research concentrated mainly on a specific industry or type of firm, including palm oil mills (e.g., Ilori, Lawal, & Simeon-Oke, 2017).

2.6.1 Technological Capability and Firm Performance

Research on TC at the firm level has been extensively the focus of attention since 1990 from the theoretical and empirical viewpoints (Miyazaki, 1995; Kim, 1997, 1999; Lall, 1992, 2000; Panda & Ramanathan, 1996). Past empirical studies have attempted to address the association between TC and firm's success (García-Muiña & Navas-López, 2007; Hall & Bagchi-Sen, 2002); to carry out sector studies (Jin & Von Zedtwitz, 2008; Archibugi & Pianta, 1996); and to seek to recognize how firms have different performances in the market place (Figueiredo, 2009).

The extant literature on the linkage between TC and firm performance indicates that technological development with a particular capability of R&D-related resources targets to create performance and increase competitive advantages for firms, which often underpins TC studies on developing countries (Panda & Ramanathan, 1996; Prasnikar et al., 2008; Tsai, 2004; Schoenecker & Swanson, 2002; Lee et al., 2001; Coombs & Bierly III, 2006; Wang, Zhang, & Xue, 2006; Isobe, Makino, & Montgomery, 2008; Ortega, 2010; Kylaheiko et al., 2011).

Most of the firm-level studies have been recognized the potential of TC as a competitive tool that competes in terms of incomes earned and achieves a high level of operational performance. Typically, the performance of firms is measured based on the financial accounting-based (e. g. Lee et al., 2001; Schoenecker & Swanson, 2002; Sher & Yang, 2005; Coombs & Bierly III, 2006; Wang, Zhang, & Xue, 2006; García-Muiña & Navas-López, 2007; Ortega, 2010; Zou et al., 2010; Kylaheiko et al., 2011; Gunday et al., 2011) and non-financial, including *economic performance* (Rasiah & Malakolunthu, 2009;

Reichert & Zawislak, 2014), *export performance* (Flor & Oltra, 2005; Chantanaphant et al., 2013; Wignaraja, 2008; Chandran & Rasiah, 2013), *innovation performance* (Renko et al., 2009; Guifu & Hongjia, 2009; Shan & Jolly, 2010; Yam et al., 2011; Zhou & Wu, 2010; Haeussler et al., 2012; Kalay & Gary, 2015; Rajapathirana & Hui, 2018), *new product development performance* (Wang et al., 2006; Yu et al., 2014; Tzokas et al., 2015), *launch strategy's success* (Hsieh & Tsai, 2007), value creation (García-Muiña & Navas-López, 2007), *system efficiency* (Oyebisi et al., 2004), *strategic orientation and strategy growth* (Zou et al., 2010), and *technology development process* (Hajihoseini et al., 2009). Nevertheless, only some studies included the operational measures of performance, for instance, strategic performance and efficiency (Isobe et al., 2008), cost and quality (Khan & Haleem, 2008), and productivity (Tasi, 2004).

Renko et al. (2009) suggested that the number of patents and share of R&D expenses considerably correlated to product innovativeness in high-tech firms. Similarly, Tsai (2004) indicated that TC plays an essential factor in productivity growth in Taiwan's high-tech firms. Shamsuddin et al. (2012) illustrated the causal associations between a firm's performance and its TC. It causes the TC developments and technological determination on the processes and underlines the financial and customer viewpoints in making investment decisions to improve its TC and firm performance.

Yam et al. (2004) showed the technological innovation capability has a minor influence on performance among Chinese firms. Wang (2007, p. 356) identified that "*new knowledge and new technology generated from R&D activities increase productivity, not only at the firm level but also at the industry and national levels*."

Rasiah and Malakolunthu (2009) found that TC expresses technological intensities; process technology, human resource, and research and development possess a negative association on export intensity, indicating that electronics manufacturers in Malaysia are dedicated to inward-oriented production. It showed that technological intensifying by way of growth in skills and R&D staff would notably increase labor productivity in the industry (Rasiah, 2010).

Ehie & Olibe (2010) highlighted that successful R&D investments lead to innovative products and services, which, in turn, enhance firms' intangible assets and performance in manufacturing and service industries. Sobanke et al. (2014) emphasized that TC facilitates innovation, leading to productivity growth. However, the number of patents and the amount of R&D spending could provide a misleading perception of the organization's performance measures (Coombs & Bierly III, 2006).

Khan and Haleem (2008) indicated that technology absorption capability influence manufacturing quality and cost of the final product, and TC is a key factor for the technology absorption process among Indian automobile component manufacturing. Also, technological and individuals capabilities affected organizational performances indirectly. Wang et al. (2006) confirmed the direct influence of TC on new product development and overall organization performance.

Su et al. (2013) revealed that technological turbulence boosted the performance impact of TC, but the market turbulence hampers the impact. The economic conditions of an emerging economy are mainly founded on low and medium-low technology industries; therefore, it is impossible to confirm that there is a positive relationship between firm performance and TC (Reichert & Zawislak, 2014). Other features enable firms to attain such success; for example, they are in more stable industries concentrated on operational efficiency, producing exceptional quality products, and operating at the lowest cost conceivable.

Tzokas et al. (2015) found that firm TC measured by the acquisition of essential technologies, identifying new technology opportunities, responding to technology changes, and mastering advanced technologies improved the firm's overall performance.

Siwadi & Pelser (2015) revealed that five apparent technological elements (patent registration, ISO certification, information technology, transfer of technology, and human resource development) positively impact the firm performance of return on assets in the Zimbabwean manufacturing sector.

Chepkemboi Limo (2016) stated that TC assessed in technology acquiring capability, technology operating capability, and technology upgrading capability have a considerable impact on the performance of SMEs by measuring customer satisfaction, profit growth, sales growth, return on investment, and market share. The findings indicated that technology upgrading capability grants the SMEs to further enhanced their products and processes to counterbalance the varying demands in the market. The study also showed definitive proof that technological operating capability has positive impacts on firm performance.

Peng et al. (2008) studied the correlation between two TC categories, innovation capability and improvement capability, and their effect on the operational performance of manufacturers in Germany, Korea, Finland, Sweden, the USA, and Japan. The findings showed that innovation capability significantly related to volume flexibility, unit manufacturing cost, product mix flexibility, speed of new product introduction, and slightly correlated to delivery performance. However, innovation capability has no direct correlation to conformance quality. Instead, improvement capability is significantly related to conformance quality, unit manufacturing cost, and on-time delivery. The findings showed that both capabilities are considerably correlated to operational performance, and the impact of their performance varies according to the operational performance concerned.

Shan and Jolly (2010) showed the implementation of TC has a significant influence on its competitive performances. Nevertheless, it varies with various performance indicators.

Mostly, it found that investment in in-house R&D delivers a positive correlation towards innovation, product, and sales performances.

Trott (2011) investigated hi-tech companies' R&D processes and determined that when R&D and technology management ability and performance are substantial new product development increases. Ren, Chandrasekar, and Li (2012) argued that R&D investments increased firm performance. Thus, productivity improvements were mainly derived from R&D activities (Sun & Anwar, 2015).

However, the above literature proves the critical role of TC on various dimensions of the organization's performance, even though the findings are mixed. Therefore, the following hypotheses are proposed:

H2a: TC has a positive effect on innovation performance.

H2b: TC has a positive effect on marketing performance.

2.6.2 Linkage among Innovation Types

Indubitably, firms possess various levels of innovative capabilities; nevertheless, innovative activities must be concentrated on several facets at the same time, for instance, new process technologies, new products, new marketing, and organizational practices or administrative mechanisms (Azadegan & Wagner, 2011; Drejer, 2002; Lin & Chen, 2007; Johannessen, Olsen, & Lumpkin, 2001; Garcia & Calantone, 2002). Furthermore, Damanpour and Evan (1984) stated that a balanced adoption rate of organizational and technological innovations helps firms sustain and increase their performance level than only implementing them. Walker (2004) decided that innovations impact each other and should be implemented jointly. Staropoli (1998) highlighted that technical innovation could be improved through cooperative organizational rearrangements and coordination mechanisms. In the same way, Germain (1996) realized the organizational restructuring in predicting process innovation, which indicates the link between organizational innovation and process innovation. Walker (2008) explicitly mentioned that organizational, product, and marketing innovations are interrelated, and additional research is needed to clarify the findings further. However, there is limited empirical literature regarding the linkage among innovation types (Ul Hassan et al., 2013; Gunday et al., 2011).

Given the literature mentioned above, this study argues that organizational innovations as structural developments resulting in the development of intra-organizational coordination and cooperation mechanisms would establish a proper internal environment for the other innovations (product, process, and marketing) to develop. Therefore, the following hypotheses are proposed:

H3a: Organization innovation has a positive effect on product innovation.

H3b: Organization innovation has a positive effect on process innovation.

H3c: Organization innovation has a positive effect on marketing innovation.

The study conducted by Li et al. (2007) on Chinese firms showed that process and product innovations were significantly correlated. Oke (2007) revealed that pursuing incremental product or service innovations is needed development of formal implementation processes, implying that the improvement of processes is an agent of output's success (product or service) innovations. Tan et al. (2017) and Kasmin et al. (2016) have examined the effect of microwave pretreatment on the yield and quality of CPO produced through solvent extraction systems. Both researchers found that this innovation process improves the yield and quality of the obtained CPO. Therefore innovative approaches providing the steps in the production processes with newly improved advantages (value, quality, speed, and cost-effectiveness) can increase the opportunity for the product's new elements, ingredients, specifications, etc., to respond to the needs of customers more than ever.

Gunday et al. (2011) conducted a study on Turkish manufacturing firms and found that higher marketing innovation leads to increased product innovation. Similarly, Ul Hassan et al.'s study (2013) on Pakestanian manufacturing firms identified that marketing innovation significantly impacts product innovation. Thus, product innovations are commonly formed via market developments and new customer needs. The customer's needs are encountered through marketing innovations, which make opportunities for added product innovations. Hence, the study hypotheses that:

H4: Process innovation has a positive effect on product innovation.

H5: Marketing innovation has a positive effect on product innovation.

2.6.3 Innovation Types and Firm Performance

Innovations can enhance the performance of firms in financial and/or non-financial aspects, including financial performance, product performance, innovative performance, and market performance. As Walker (2004) stated, innovation has a significant effect on firm performance by creating an improved market position that carries a competitive advantage and better performance. Several studies concentrating on the innovation-performance association have provided a positive evaluation of higher innovation leading to improved firm performance (e.g., Damanpour et al.,1989; Gunday et al., 2011; Wu, Mahajan, & Balasujbramanian, 2003; Yıldız et al., 2014; Rajapathirana & Hui, 2018; YuSheng, & Ibrahim, 2020). The innovation process could be seen as a significant driver for improving firm's innovation and business performance (Lendel & Varmus, 2014).

In a production activity, process innovation can be considered as advanced or improved technologies, instruments, machinery, and knowledge in making a product (Wan, Ong, & Lee, 2005; Gopalakrishnan & Damanpour, 1997; Langley, Pals, & Ort, 2005; Azadegan, Napshin, & Oke, 2013). Given that, POM products deal with different processes that result in producing CPO and CPKO. Intrinsically, any advanced milling process that seeks to improve CPO quality would enhance the POM performance. Oyebanji et al. (2012) examined the performance evaluation of two different palm kernel nut-crackers designed and found that the vertical centrifugal palm kernel cracker is more efficient than the centrifugal impact approach. Cheng et al. (2011) found that the CPO quality of the crude palm oil produced by microwave pretreatment followed with solvent extraction was superior compared to that produced by using conventional.

Wang and Hsu (2014) revealed that innovation has a fully mediating influence on the innovation performance of high-tech firms. They also suggested that technology-based product quality facilitates firms to generate superior innovation performance. Pett and Wolff (2009) and Walker (2004) conducted comparative research for the effects of product and process innovations on firm performance. Both researchers emphasized that product improvements are positively associated with firms' growth.

On the contrary, several studies have identified that organizational innovation has a positive effect on innovation performance (e.g., Chiang & Hung, 2010; Reed et al., 2012) and helps firms in understanding the types of capabilities needed to obtain a competitive advantage (Camisón & Villar-López, 2012). The study conducted by Yavarzadeh et al. (2015) on association innovation organization and firm performance in Iran's tax affairs organizations indicates that innovation types affect organizational performance relating to the internal process, financial, growth, and customer.

Altuough most studies considered some dimensions of innovation types (e.g., (Damanpour & Evan 1984; Johne & Davies, 2000; Çakar & Ertürk, 2010; Hervas-Oliver, Boronat-Moll, & Sempere-Ripoll, 2016; Mejía Vallejo & Arias-Pérez, 2017), few studies covered all innovation types together (e.g., Bruhn et al., 2016; De Martino & Magnotti, 2018; Ilori et al., 2017; Kafetzopoulos & Psomas, 2015; Maldonado-Guzmán et al., 2018). Among innovation types, product and process innovations were the most commonly researched (e.g., Hervas-Oliver et al., 2016; Han et al., 1998; Romijn & Albaladejo, 2002; Li & Atuagene-Gima, 2001; Whittington et al. 1999, Olson & Schwab, 2000; Knott, 2001; Baer & Frese, 2003; Yang, 2010; Mejía Vallejo & Arias-Pérez, 2017). Even though most of these studies embrace more or less a positive relationship between innovations and firm performance, several studies indicated a negative association or no association at all (see Capon et al., 1990; Chandler & Hanks, 1994; Subramanian & Nilakanta, 1996).

Innovative performance is the combination of overall organizational achievements resulting from renewal and improvement efforts completed considering various aspects of firm innovativeness, specifically products, processes, organizational structure, etc. (Gunday et al., 2011). As a result, innovative performance is a combined construct (Hagedoorn & Cloodt, 2003) relying on different performance indicators that affect, for instance, new organizational arrangements, new processes, and new product introduces.

Based on mentioned points, this study proposed that four types of innovations positively affect firm's innovative performance. Subsequently, the indirect impacts of these innovation types can be anticipated to enhance production and market performance via innovation performance mediation. From this point of view, innovative performance serves as an efficient pole that transfers the positive impacts of innovations on the different aspects of firm's performance. Thus, the study hypotheses that:

H6a: product innovation positively impacts innovative performance.

H6b: Product innovation positively impacts innovative performance.

H6c: Organizational innovation positively impacts innovative performance.

H6d: Marketing innovation positively impacts innovative performance.

Market performance can be derived as the extent to which firms profit market-related results than their competitors in terms of new customer acquisition, customer satisfaction, loyalty, and so on (Oh et al., 2015). Marketing concepts implied that better Judgmental performance, including customer satisfaction, quality is the prerequisite for better market and financial performances of the firm. Agrawal et al. (2003) suggest that market and financial performances can only be realized with superior judgmental/innovation performance. Innovation performance can enable firms to create market performance in various ways through aiding to identify technological capability with improving product and service quality, and superior value products to the customer can help gain new customers. Thus, innovation performance as new product success is associated with increased turnovers and market shares through customer satisfaction and recent customer acquisition (Wang & Wei, 2005).

Initially, innovation performance is associated with the non-financial aspects of firm performance, such as customer aspects, satisfaction, and subsequently enhanced financial performance (Gunday et al., 2011). Although innovation in a short period might cause possible loss (Visnjic et al., 2016), it might positively affect the market, production, and financial performance during the long term (Damanpour & Evan, 1984).

Han et al. (1998) stated that the link between innovation and market and financial performances is indirectly mediated through innovation performance. Wei and Morgan (2004) found that innovation performance can lead to a sustainable competitive edge by making greater value to customers vastly, leading to higher market performance and profitability. However, a few scholars identified the association between the innovation-market performance positively (Cheng & Krumweide, 2010; Gunday et al., 2011; Stock & Reiferscheid, 2014; Gök & Peker, 2017; Rajapathirana & Hui, 2018).

Also, production performance aspects (speed, quality, flexibility, and cost-efficiency) seem to be linked to the firms' performance in the product, process, and organization following previous literature (see Quadros et al., 2001). As Koufteros and Marcoulides (2006) stated, continued efforts and higher performance in innovations cultivate organizational learning and enhance the operations' speed and quality. Thus, technological developments can be assimilated quickly and succeed in dealing with any design or quality deficiencies faster than rivals.

Furthermore, Lo´pez-Mielgo et al. (2009) indicated that process innovations positively influence the organizations' Total Quality Management (TQM) efforts. In the same vein, Sadikoglu and Zehir (2010) also reported that innovation performance and operative performance moderately mediate the association between TQM practices and firm performance and suggested that firms requisite to improve innovativeness to become competitive in the face of rapid marketplace changes.

In the flexibility and cost-efficiency aspects of product performance, successful renewal efforts, particularly in new products, production processes, and managerial mechanisms, can contribute significantly to disseminating knowledge and coordination efficiency within the organization. Such efforts are required to operational flexibility and reduced costs related (Koufteros & Marcoulides, 2006). In the same way, Liu, Li, & Wei (2009) confirmed that operational flexibility positively affects new product success. As for the effects of production cost reduction, Peters (2008) claimed that only some process innovations could reduce costs and permit the organization to market products at competitive prices. Gunday et al. (2011) indicated that innovative performance improvement in manufacturing firms leads to higher production performance improvement. Consequently, Previous researchers confirmed that organizational, marketing, and product performance significantly and directly affect innovation performance through innovation capability (Langerak et al., 2004; Wei & Morgan, 2004). Hence, the study hypotheses that:

H7a: Innovation performance positively impacts marketing performance.

H7b: Innovation performance is positively related to production performance.

Production performance is the organizational success regarding improving quality, cost reduction, production flexibility, and speed to market, which leads the organization logically to the improvement of market position and cost-effectiveness (Günday et al., 2011). Past researchers confirmed that the incentive behind the development and implementation of such operations aims as including increasing speed for dependability, quality for customer satisfaction, flexibility for external adaptation, and cost reduction for profitability is to attempt to enhance overall firm performance ultimately (Ul Hassan et al., 2013; Gunday et al., 2011; Alpkan, Ceylan, & Aytekin, 2002, 2003). Therefore, the study hypothesis that:

H8: production performance positively impacts market performance.

2.7 Developments in Palm Oil Processing Technologies

Developing palm oil processing technologies requires effectively addressing the main challenges that create difficulties for mill firms, which include minor improvement to oil extraction rate (OER) and checking the sharply increasing production costs. The spiraling cost of machinery and its maintenance, stagnant productivity, and ecological problems that attract bad publicity have combined to affect prices and demand. The solution would require the installation of environment-friendly, less labour-intensive, and more creative production organizations that use advanced milling technologies.

Advanced milling technologies embrace a diverse range of process technologies that have been known as the second and third generation of palm oil process technologies. Since most advanced milling technologies carry multiple functions and are aimed at increasing productivity by improving product recovery, they support quick decision-making. A number of these technologies have been developed and introduced in palm oil milling, such as in the sterilization process. For example, continuous sterilization with inclined and spherical sterilizers (Lim, 2007), tilting sterilizers, and vertical sterilizers (Loh, 2009), as well as the modification of steam distributors and sterilization cages have raised sterilization efficiency in milling firms. In addition, new oil extraction machinery in the shape of a double screw press has expanded the screw pressing capacity, thereby increasing milling firms' oil extraction rate. The entry of more efficient third-generation technology in the oil extraction process has enabled oil recovery by utilizing solvent extraction in milling firms.

The introduction of a two-phase decanter to remove the dilution of the hot water needed for clarification has considerably lowered the quantity of POME produced (Schuchardt et al., 2008; Wong & Sivasothy, 2007). The POME output fell by around 50% compared to conventional oil recovery utilizing vertical clarifiers (Hashim et al., 2012). To achieve this, the bigger firms have replaced biological treatment using water waste treatments with rapid anaerobic digester tanks that also produces biogas. The automatically assisted aerobic processes with the support of tertiary treatment plants have also helped meet the legal discharge restrictions (Hashim et al., 2012).

Although there has been a surge in advanced milling technologies across the palm oil industry, the adoption rate has been low. Madaki and Seng (2013a) found that several milling firms are still not using advanced POME treatment technology to meet the zero discharge limits imposed by the Malaysia Department of Environment. This gap calls for understanding as to why advanced milling technology remains little used in POM firms in Malaysia.

2.8 Summery of the Research Hypotheses

Derived from the existing literature, the proposed relationships among variables are discussed; and hypotheses are developed to answer the research questions, which will be tested in chapters 4, 5, and 6.

H1a: Organizational learning mechanism has a significant influence on the development of TC.

H1b: Innovation strategy has a significant influence on the development of TC.

H1c: Firm size has a significant influence on the development of TC.

H1d: Type of ownership has a significant influence on the development of TC.

H1e: Strategic alliances have a significant influence on the development of TC.

H1f: Supportive government policy has a significant influence on the development of TC.

H1g: Technology transfer mode has a significant influence on the development of TC.

H2a: TC has a positive effect on innovation performance.

H2b: TC has a positive effect on marketing performance.

H3a: Organization innovation has a positive effect on product innovation.

H3b: Organization innovation has a positive effect on process innovation.

H3c: Organization innovation has a positive effect on marketing innovation.

H4: Process innovation has a positive effect on product innovation.

H5: Marketing innovation has a positive effect on product innovation.

H6a: Product innovation positively impacts innovative performance.

H6b: Process innovation positively impacts innovative performance.

H6c: Organizational innovation positively impacts innovative performance.

H6d: Marketing innovation positively impacts innovative performance.

H7a: Innovation performance positively impacts marketing performance.

H7b: Innovation performance positively impacts production performance.

H8: Production performance positively impacts market performance.

H9a: Compatibility is a critical influence on milling firms adopting advanced milling technology.

H9b: Complexity is a critical influence on milling firms adopting advanced milling technology.

H9c: Cost is a critical influence on milling firms adopting advanced milling technology.

H10a: Financial support and resources have a significant influence on the adoption of advanced milling technology.

H10b: Top management support has a significant influence on the adoption of advanced milling technology.

H10c: Managers' knowledge of new technologies has a significant influence on the adoption of advanced milling technology.

H10d: Human capital endowed with technical skills has a significant influence on the adoption of advanced milling technology.

H10e: Firm size has a significant influence on the adoption of advanced milling technology.

H11a: Environmental pressure has a significant influence on the adoption of advanced milling technology.

H11b: Supportive government policy has a significant influence on the adoption of advanced milling.

2.9 Chapter Summary

The second chapter mainly discusses the extensive literature reviews of the study. First, the chapter discussed the theoretical backgrounds and justifications related to TC and technological adoption. The concepts of TC, innovation and technological adoption are explained. Also, the chapter provides a background of the TC models and discusses its determinants, including internal and external factors and factor TTM. The following examines the determinants of technology adoption by providing critical factors of advanced milling technology adoption classified in technological attributes, organizational and environmental factors as are essential to making decisions about advanced technology adoption among firms. Since the improvement of the firm performance accrues not only by developing TCs but also by innovation types with various interactions, it discussed the relationships among TC, innovation types, and firm performance from three aspects. Therefore, TCs and product, process, marketing, and organization innovation can become crucial to increase innovation, marketing, and production performance. Lastly, the chapter highlighted and explained the development of palm oil technologies for the study. The following hypotheses are summarized in the end. The chapter attempted to provide transparent insight into the role of TC on firm performance by identifying dependent and independent variables from the relevant sections, which lead to the development of the conceptual frameworks that will be discussed in the next chapter.

CHAPTER 3

METHODOLOGY

3.1 Introduction

Following the previous chapter, this study formulated three research questions. These research questions will be investigated using a quantitative research method described in this chapter. This chapter possesses five significant sections. The first section describes the research design philosophy and discusses the quantitative research method. The frameworks of the study are presented in the next section. The third section discusses sampling and data collection for the research. The fourth section provides survey instruments and measurements, including questionnaire development, measures, and reliability and validity of variables. Follow by, the models and techniques of data analysis for the quantitative approach are presented, and lastly, it is explained how to deal with data concerns.

3.2 Research Design Philosophy

Philosophical perspectives indicate assured norms regarding the nature of the world and how the researcher comes to know about it. This viewpoint presents specific sets of rules and commitments. In addition, research philosophy believes in the technique of how data for a phenomenon should be collected, analyzed, and practiced (Kleinberg-Levin, 1988). Each philosophical viewpoint possesses its own ontological and epistemological assertions. The perspective suggested a particular method or set of techniques for a social inquiry. Thus, a primary overview of the critical philosophical viewpoints is significant for understanding the researcher's hypotheses and describing the strategy adopted.

The philosophical viewpoints are defined as a basis with three aspects and simplified them by describing the ontology, epistemology, and axiology of the philosophical standpoints (Saunders et al., 2009). Each aspect indicates the difference between the philosophical viewpoints. The definition of each element is presented in Table 3.1.

Table 3.1: Characteristics for Differentiation among Philosophical Perspectives

Factors	**Definition**
Ontology	Ontology is concerned with the nature of reality. It raises questions of the assumptions researchers have about how the world operates, and the committee held to particular views. "*What assumptions do we make about the way in which the world works*?"
Epistemology	Epistemology concerns about what constitutes adequate knowledge in a field of study. "*What is acceptable knowledge in a particular field of study*?"
Axiology	Axiology is a branch of philosophy that studies judgments about value. "*What roles do our values play in our research choices*?"

Source: Saunders, Lewis, and Thornhill, (2009, p.107)

Philosophical perspectives are categorized into four main views: positivism, realism, interpretivism, and pragmatism (Saunders et al., 2009). Table 3.2 presents the comparison of four research philosophies differentiated regarding ontology, epistemology, and axiology elements. Furthermore, the data collection methods applied for the philosophical perspective are showed. The researchers have to know the philosophical commitments through selections of research strategy, which affect understanding the research offered (Johnson & Clark, 2006).

Table 3.2: Comparison of Four Research Philosophies

	Positivism	Realism	Interpretivism	Pragmatism
Ontology: The researcher's view of the nature of reality or being	External, objective and independent of social actors	Is objective. Exists independently of human thoughts and beliefs or knowledge of their existence(realist), but is interpreted through social conditioning (critical realist)	Socially constructed, subjective, may change, multiple	External, multiple, view chosen to enable answering of research question best
Epistemology: The researcher's view regarding what constitutes acceptable knowledge	Only observable phenomena can provide credible data, facts. Focus on causality and law like generalizations, reducing phenomena to simplest elements	Observable phenomena provide credible data, facts. Insufficient data means inaccuracies in sensations (direct realism). Alternatively, phenomena create sensations which are open to misinterpretation(Critical realism).Focus on explaining within a context or contexts	Subjective meanings and social phenomena. Focus upon the details of situation, a reality behind these details, subjective meanings motivating actions.	Either or both observable phenomena and subjective meanings can provide adequate knowledge dependent upon the research question. Focus on practical applied research, integrating different perspectives to help interpret the data
Axiology: The researcher's view of the role of values in research	Research is undertaken in a value-free way, the researcher is independent of the data and maintains an objective stance	Research is value laden; the researcher is biased by worldviews, cultural experiences and upbringing. These will impact on the research	Research is value bound, the researcher is part of what is being researched, cannot be separated and so will be subjective	Values play a large role in interpreting results, the researcher adopting both objective and subjective points of view
Data collection techniques most often used	Highly structured, large samples, measurement, quantitative, but can use qualitative	Methods chosen must fit the subject matter, quantitative or qualitative	Small samples, in-depth investigations, qualitative	Mixed or multiple method designs, quantitative and qualitative

Source: Saunders, Lewis, and Thornhill, (2009, p. 108)

Among four research philosophies, positivism has targeted TC, innovation studies for understanding users' adoption and development of TC, which often underpins studies in developing countries (e.g., Madanmohan et al., 2004; Sobanke et al., 2014; Ul Hassan et al., 2013; Rajapathirana, & Hui, 2018). Positivism is a scientific paradigm employed in the natural sciences with scholars and experts to explore a specific phenomenon (Oates, 2006). A fundamental positivism principle is that scholars can consider a scientific perception when investigative social behavior with observation, survey procedures, and experimental analysis to create the results and test hypotheses practically (Travers, 2001;

Schiffman & Kanuk, 2009). As stated by Moore (2010, p. 123-124), "*Positivism assumes that scientific knowledge is the highest form of knowledge and that scientific knowledge comes from studying directly observable and measurable events. According to positivism, then, the world consists of laws and principles that are discovered through direct observation. If we do not know enough about some aspect of nature, we must study, measure, and otherwise directly observe our subject matter more closely. Indeed, if we cannot do so, we must assume that the purported subject matter does not even exist. Moreover, scientific knowledge has the degree of certainty necessary to be regarded as foundational, for example, as a basis for structuring society and thereby improving it."*

This procedure is carried out with quantitative methods as it involves the numbers to produce facts, including data collection and creating them into measurable variables. In behavioral science, this method perceives that individual behaviors can be described and anticipated with regard to cause-effect linkages (Myers, 1997).

A research strategy should be chosen on the basis of the purpose of the study, research objectives, and the philosophical perspective of the researcher. As stated by Hamilton and Ives (1992: p.143), "*the key to good research, though, is not just in choosing the right research strategy, but in asking the right questions and picking the most powerful method(s) for answering the questions given the objectives, research setting, and other salient factors.*"

The nature of the research questions determines the design, which is the comprehensive design plan in order to answer the research questions. Based on the purpose of the study and to what extent research currently exists on the topic, research designs are selected, which include descriptive, exploratory, or explanatory (Saunders et al., 2012).

This study aims to identify and investigate TC development and technological adoption determinants and examine the relationship between TC development, innovations, and firm performance in POMs in Malaysia. Therefore, the research questions by carrying out a literature review regarding TC development, innovation adoption, and firm performance are addressed. According to the presented literature, the research framework was developed to investigate critical factors TC development and TOE factors that affect the firm adoption of advanced milling technology and found the linkages of TC development and innovations with firm performance. Several hypotheses are then derived and will be tested by collecting and analyzing data. Research findings in line with the assumptions serve to endorse the proposed associations, whereas inconsistent findings result in rejection. Therefore, this sequential research method is in sync with deductive reasoning (Aaker et al., 2001; Blaikie, 2010).

Since TC development, innovations, and technology adoption are extensively covered by the present study, the research, generally, is based on existing literature and predefined concepts. Therefore, the thesis is mainly of a descriptive and definitive nature because it targets to describe and explain linkages between variables on the basis of theoretically underpins expectations regarding how and why the variables must be allied.

However, the review of TC development, innovations, and adoption literature also recognized considerable research gaps. Notably, limited researches have explored the development of TC, innovations, and adoption from a palm oil mill sector of analysis, a lot less in the context of advanced milling technology. Also, this study, for the first time, examined the relationship between TC, innovation types, and firm performance yet to be explored in empirical research on advanced milling technologies. For the above reasons, this study is also considered exploratory, as it pursues to endorse existing theory in a new context.

Moreover, this thesis is quantitative by nature since the data collection generated numeric information, which was accordingly subjected to the model and techniques of analysis statistically. As hypothesis testing in the social sciences calls for statistical analysis, a quantitative method is considered the most suitable. Typically, a quantitative inquiry is in sync with the deductive procedure used in this research (Saunders et al., 2012). On the contrary, a qualitative approach could have been employed to provide more detail and deeper insight into the development of TC and the technological adoption of advanced milling technology by POMs in Malaysia. However, for the particular purpose of testing developed hypotheses about a large number of theoretical factors, the highly detailed and controlled procedures associated with quantitative inquiry were preferred. Hence, the research design includes all the steps to achieve its objectives, as presented in Figure 3.1.

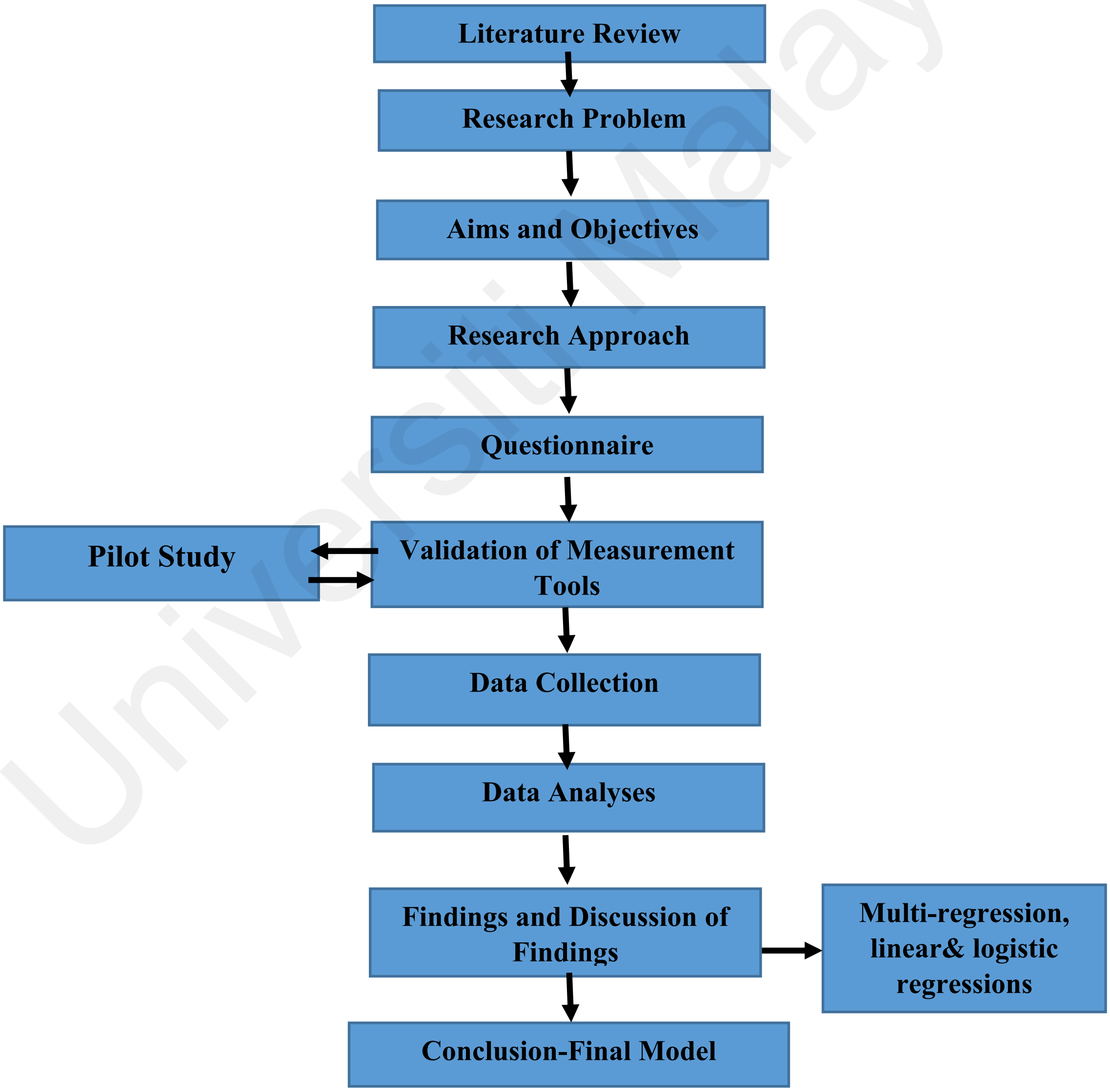

Figure 3.1: Research Design

3.3 Research Framework

A conceptual framework is defined as a structure that the researcher relies on to describe the phenomenon's objective evaluation to be studied (Camp, 2001). It is associated with the concepts, experiential study, and primary theories applied in improving and systemizing the knowledge supported by the researcher (Peshkin, 1993) to explaining how the research questions will be investigated. The conceptual framework provides an integrated approach to viewing a problem under study (Liehr & Smith, 1999). The conceptual model statistically explains the correlation between the principal factors of research. It is organized in a reasonable structure to help give a picture or obvious demonstration of how concepts in a study linkage to one another (Grant & Osanloo, 2014). Therefore, from the literature, the conceptual framework developed for this study considered the internal factors (organizational learning, innovation strategy, size of the firm, and type of ownership), external factors (strategy alliance and government support), and factor TTM. From the technological adoption perspective, it also considered the developed model of the technological constructs (compatibility, complexity, and cost), organizational constructs (financial support and resources; top management support; managers' knowledge, technical skills, and size of the firm), and environmental pressure and government support in the environment constructs. Moreover, this study empirically examines the effects of TC and innovation types (product, process, organizational, and marketing) on different aspects of firm performance, namely innovation performance, production performance, and market performance in POM firms in Malaysia, to reveal the positive impacts among these factors.

All of the key concepts are essential in constructing the conceptual framework in Figures 3.2 and 3.3. However, the hypotheses of these frameworks are summarized in chapter two, Section 2.8. The proposed hypotheses show the relationships between all the variables that this study intended to find out.

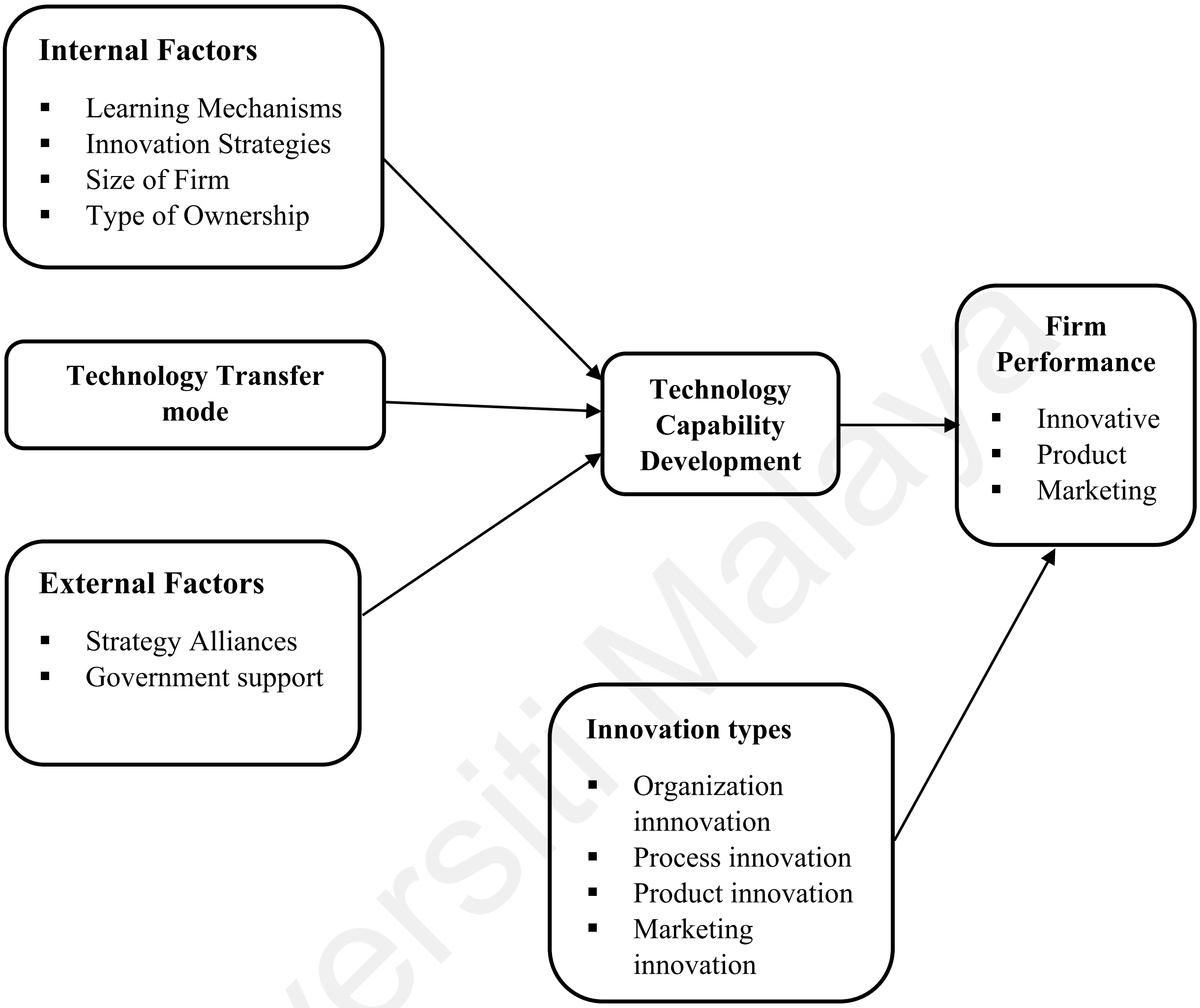

Figure 3.2: Conceptual Framework TC Development and Firm Performance

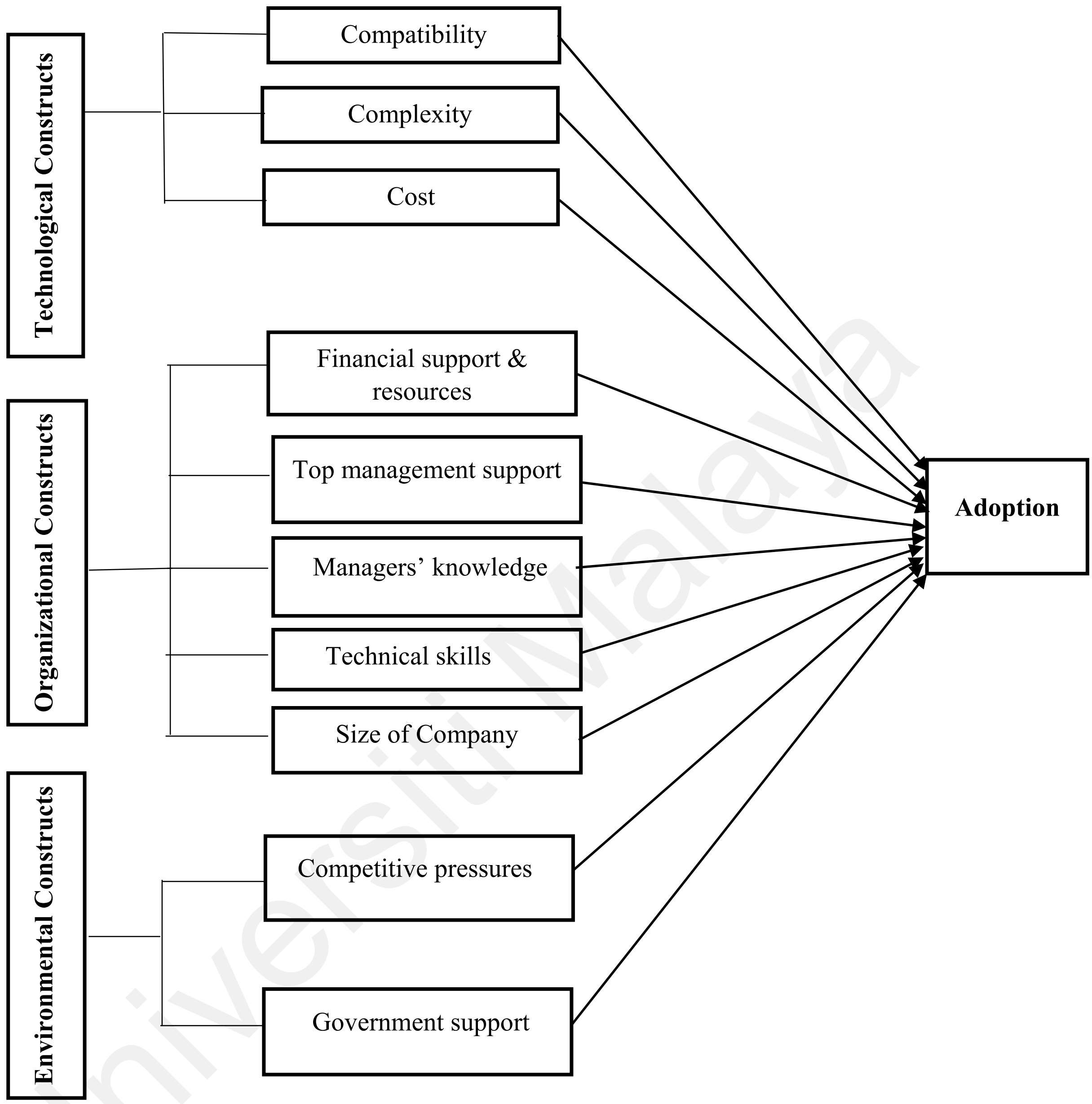

Figure 3.3: Conceptual Framework Adoption

3.4 Sampling and Data Collection

The purpose of quantitative research is to establish definite 'truth' about the social world to make generalizations. Thus, quantitative approaches to sampling need to ensure that the results represent the overall population under study (Hesse-Biber, 2010). Quantitative sampling designs rely on ‘laws of probability,’ where the sign is that all members of a given population have an equal and known probability of being selected in a sample to permit the use of statistical testing. It is also needed to ascertain whether the research findings are ‘true’ to the overall target population. Hence, the sampling design will entail the targeted population, the preferred sample size, and the sampling technique.

3.4.1 Sampling

A population signifies the whole group of people, events, or things of concern in which the researcher desired to examine (Sekaran & Bougie, 2009). The population of this study includes all POMs operating in Malaysia. Based on the Malaysian Oil Palm Statistics (2016) collected by the MPOB, the number of operating mills was 450 in 2017. From 450 mills, 243 (54.7%) mills were located in Peninsular Malaysia, 129 (29.0%) mills in Sabah, and the rest of 73 (16.4%) in Sarawak (see Figure, 3.4). In addition, Pahang (71 mills) and Johor (61 mills) embraced most of the POMs in peninsular Malaysia.

Over the past few decades, calls for further empirical studies in operational management have resulted in a sharp rise in the adoption of questionnaire-based survey methods (Malhotra & Grover, 1998: Scudder & Hill, 1998; Filippini, 1997). Since TC and advanced milling technology adoption are the concern of this study, the target respondents should possess the decision-making power to adopt new technologies and have sufficient knowledge about critical factors of new technology adoption that their mills face for adopting them. In addition, the targeted respondents should possess sufficient and massive knowledge of mill practices, level of firm’s TC, and vastly familiar with their mill firm performance. Thus, the targeted respondents were drawn from among the top management, including senior managers, general managers, managers or individuals in charge of the R & D department, operational managers, and assistant mill managers; the unit of analysis was one manager per mill.

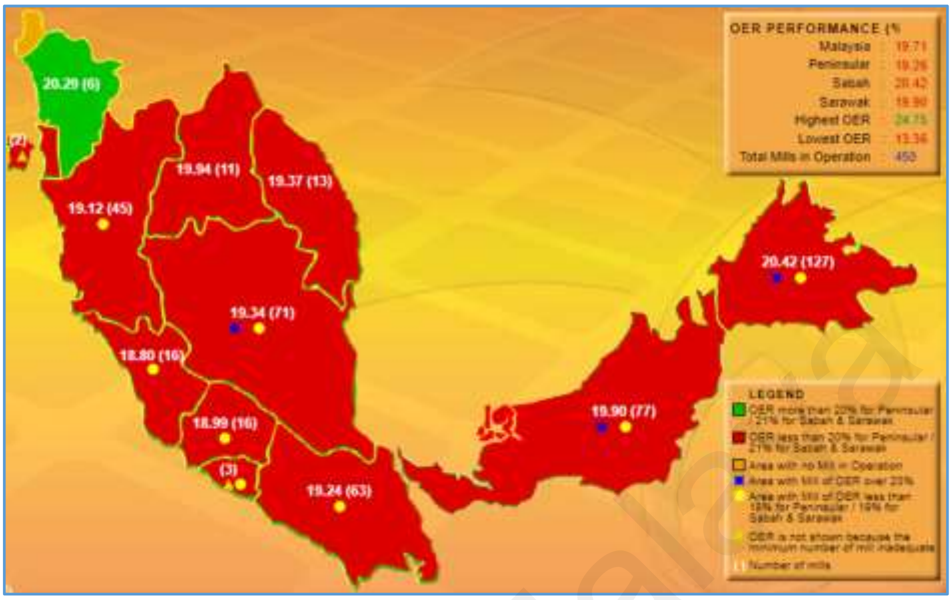

Figure 3.4: Palm Oil Mills in Operation and OER Performance

Source: MPOB (2017a)

The sample size is a selection of subgroups from the targeted population in which the results from the studied sample can be generalized for the population of interest (Sekaran & Bougie, 2013). The study used the standard sample size determination formula for a finite population (Keller, 2008; Berenson et al., 2014), as shown below, from a simple random sampling method, which yielded 95 from a population of 450 palm oil mills. Most statisticians concur that the minimum sample size should be 100 to gain any significant outcome. Since the study yielded 95 sample sizes from a population of 450 palm oil mills, almost close to the minimum sample size required, this study distributed the survey to all of them.

$$n = \frac{n_0 N}{n_0 + (N-1)} \; ; \; n_0 = \left(\frac{Z_{\alpha/2}}{ME}\right)^2 p(1-p)$$

Where:

n = required sample size;

n_0 = sample size for infinite population;

N = population size;

$Z_{\alpha/2}$ = Z critical value at chosen confidence level at 95% (1.96);

P = proportion of population (0.5); and

ME = margin of error.

Most of the selected mill firms possess at least one of the ISO 9000, 9001, 14000 and/or Roundtable on Sustainable Palm Oil (RSPO) certifications. These firms were considered the least and most suitable selection as respondents because they implemented various developed practices and represent efficiency improvements of performance in the firm (Anuar & Yusuff, 2011; Sohail & Hoong, 2003).

Furthermore, this research employed a simple random sampling method to ensure that the sample extracted represents the population. This sampling method is the most simple and most accurate probability sampling strategy and also the most common approach for selecting a sample amongst the population for a vast range of objectives. The probability of selected each member of the population is the same for members as part of the sample. The rationale behind why some researchers adapted the simple random sampling method is that it eliminates bias from the choosing method and should lead to representative samples (Gravetter & Forzano, 2011). For the above reasons, a simple random sampling method is a suitable sampling technique for the study.

3.4.2 Data Collection Procedures

Academics can select many research strategies, such as case studies, grounded theory, ethnography, archival research, survey, and experiments (Saunders et al., 2012). The extant literature on TC and technology adoption indicates that survey strategy has been the dominant strategy at the firm level (e.g., Madanmohan et al., 2004; Gunday et al., 2011; Sobanke et al., 2014; Ul Hassan et al., 2013; Rajapathirana, & Hui, 2018).

Data collection techniques are an essential part of the research design. To collect data and explain statistical findings, typically, the researcher applies a survey questionnaire. The numbers and statistics forms are output data of this method, which help decrease the time and struggle of researchers in explaining their outcome (Eyisi, 2016). Besides, the advantage of the questionnaire embraces the potential time, cost savings, and the elimination of interview bias (Ponto, 2015; Eyisi, 2016).

The data collection method of this research is solely using; survey questionnaires. In this study, the researcher prefers to use self-evaluation questionnaires to gather primary data. The model for the data collection has been designed by separating the questionnaire into segments that may extend the interest and concentrate among respondents. Even though the idea of the primary data is to gather opinions, the format adopted is highly structured where the respondent needs to circle or highlight the most relevant answer. The questionnaires will be short, simple sentences and facilitate the respondents. There was an argument that the self-evaluation approach tends to be biased (Rose, Kumar, & Ibrahim, 2008). However, subjective perceptual measures are considered reliable since any objective measures are absent (Youndt et al., 1996).

The researcher originates the primary data for a specific purpose when addressing issues that occur. It implies that when adopting the preliminary data as a data collection method, the researcher will gather information by creating primary data forms. In this research, the results come from the respondent who answered the questionnaires are, therefore, known as the researcher's leading data, which is to be processed further for research analysis. Moreover, the primary data collected shows the originality of this research.

The questionnaire was structured as closed-ended questions, and data collection was completed self-administered by the researcher. Before the self-administration of data collection, each respondent was contacted by e-mail, face-to-face, or phone to inform him or her about the questionnaires, confirm their address, and identify the key personnel responsible for the subject research area. Finally, a structured mail questionnaire was formulated to collect data from the sampled mills. During validation of the list of POMs, it was discovered that only 15% of the total POMs owned a valid e-mail address. Hence, the study conducted a face-to-face interview with some respondents who agreed to participate but reported not receiving the mail questionnaire. This method was applied as it is faster to administer and convenient for the respondents to complete the survey (Bryman, 2008).

A cover letter was enclosed together that mainly explained the purpose of the questionnaire to motivate and encourage respondents to participate (Appendix A). The researcher had also highlighted the confidentiality of every response as this is the main obstacle to gain the respondents' trust in getting their perception about the company's current situation. An approval letter for data collection (Appendix C) from the University of Malaya was enclosed to strengthen the respondents' trust in the survey.

3.5 Survey Instrument and Measurements

To assess the research model and hypotheses, this research designed a survey questionnaire and shaped the measurement instruments into four parts to collecting data from the respondents, which are as follows:

The introduction part that supports the information of the study comprised the UM logo, title of the study, the purpose of the questionnaire, research objective and importance, contact detail, and time to complete (Appendix A).

Part A: This part covers the respondents' information and the company, which were the position, the level of education, and working experiences of the respondents; Also, the company's ownership structure, the company's number of employees, years of operation were inquiries.

Part B: The first part of the instrument consists of 27 items classified on internal factors (organizational learning mechanisms and innovation strategy), external factors (strategy alliances and government support), and TTM. In addition, the TC development instrument consists of 14 items divided on R&D investment, R&D personal, and process capabilities.

Part C: This part contains 35 items that are allocated into seven main factors. These seven factors are organization innovation, product innovation, process innovation, marketing innovation, innovation performance, product performance, and marketing performance.

Part D: This part comprises 37 items that are divided into three key factors. These three factors were organizational, technological, and external environmental constructs (Appendix B).

The questionnaire was provided in English and was performed from 5 May 2017 to the end of November 2017. The research was able to use only 54 responses with a response rate of 56.8% (54/95). The extant literature on survey research response rate indicates that the average response rate was 57% across studies (Roth & BeVier, 1998), which closely supports the response rate of 56.8% in this study.

From the total 63 fulfilled questionnaires, 9 questionnaires were omitted due to incomplete respondent data. Consequently, the non-respondent rate was 43.15% (41/95). Moreover, the pilot study is not added.

3.5.1 Instrumentation and Measurement Development

The questionnaire instrument was formed and modified from existing instruments that were about (a) Product technological capabilities (RD) and Product technology capability (PT); Resource-Based View (RBV); Diffusion of Innovation (DOI); and Technological-Organizational-Environmental framework (TOE).

In the survey type of research, the questionnaire is deemed one of the most suitable data collection instruments (Asika, 1991). This method is also more applicable to obtaining information on quantitatively primary data (Malhotra, 2006). Generally, the statement used in a questionnaire must be effortlessly understood by the respondents (Oppenheim, 1992), and the statement in the survey instrument must not be leading the respondents (Parten, 1950). As suggested by Goldberg and Velicer (2006), using multi-step scales (i.e., Likert rating scale) giving plentiful benefits over other item formats (i.e., dichotomous choices or checklists) from the psychometric point of view where it produces better factor loadings than the other two formats. Even though the questionnaire's design consists of a series of formats, it is, however, depending on the researcher’s purpose of the study to measure, thus suggesting why scholars believe the format had better be ordinary and universal.

The majority of the measurement scale used in this study is an itemized rating scale as it is one of the scales of interval measurement. Likert scale is a psychometric type of scale used in instruments that can tap respondents’ degree of agreement or disagreement with a given item statement. Therefore, this study used a Likert scale type of questionnaire, where, according to Cavana et al. (2001), the rating scale permits researchers to practice the range of four, five, six, seven, nine, ten, and so on. For instance, Goldberg and Velicer (2006) recommended a rating scale with five to seven response categories, which give advantages from the psychometric views.

There are various types of Likert measurement scales, as listed by Vagias (2006). It was initially a five-point scale ranging from strongly disagree to strongly agree with neither disagree nor agree at the middle (Likert, 1932). In this study, the five-point scale was used because changing or increasing rankings is not about improving the reliability but the measurement quality itself (Likert, 1932). Hence, the questions related to three aspects of the firm performance were asked using a five-point Likert scale, anchored from 1-extremely unsuccessful to 5-extremely successful. Such individual measures maybe fetch manager prejudice nonetheless are prevalently employed in empirical inquiries (Khazanchi et al., 2007). The underlying rationale for using such scales is that the organizations are disinclined to divulge detailed performance reports, and executives are less reluctant to share impartial performance information (Ward & Duray, 2000; Boyer et al., 1997).

On the contrary, top executives, who are well-informed of performance data, can give an accurate individual assessment (Choi & Eboch, 1998). Similarly, for measures of innovation types, respondents were asked to highlight a five-point Likert scale, anchored from 1-strongly disagree to 5-strongly agree to what extent the related innovation activities were implemented in their firms. In addition, the questions related to three Constructs of TOE were asked using a five-point Likert scale, defined from strongly disagree to strongly agree. Since the study relied on the adopted or not adopted stage of advanced technology, applied a binary scale (0, 1) for new milling technology adoption.

Product technological capabilities (RD) comprise R&D expenditure and R&D personnel that scaled as a share of employment and a percentage of sales. The variable is formulated as:

$$RD = 1/2[RDexp, RDper]$$

Where RDexp = R&D expenditure as a percentage of sales and RDper = R&D personnel.

Process technology (PT) includes the age of machinery and equipment (ME), inventory control systems (ICS), and process technology restructuring expenses that ranked in total sales (RE). As such, PT is formulated as:

PT = 1/3[ICS, ME, RE]

The ICS is ranked as a dummy variable (ICS=1 if each of the advanced inventory control system items of Total Preventive Maintenance (TPM), Statistical Process Control (SPC), International Standards Organization (ISO), Just-In-Time (JIT), a Roundtable on Sustainable Palm Oil (RSPO) used, ICS= 0 otherwise). The ME is ranked using a scale of fewer than 2 years; which is equivalent to 3; 3–5 years, which is equivalent to 1; and over 5 or more years, which is equivalent to 0. The variable PT is normalized using the following formula:

Normalisation score = (Xi- Xmin) / (Xmax -Xmin)

Where Xi, Xmin, and Xmax refer to the actual, minimum, and maximum value of the related proxy of firm i, respectively. To establish an equivalent index, normalization is needed.

Subsequently, the questions related to strategic alliances were asked using a five-point Likert scale, defined from strongly disagree to strongly agree. In contrast, the inquiries on factors TC (technology transfer mode and government support) using a five-point Likert scale, defined from lowest to highest levels. Since the study relied on the organization learning mechanisms of training and innovation strategy to absorb new technologies, applied a dummy scale (0, 1) for both of them. The summary of variables, scale, and items are depicted in Tables 3.3, 3.4, and 3.5.

Table 3.3: Summary of Variables, Scale, and Items of TC development

Variables	Scale	No. of Items
Organization learning mechanism	Dummy	5
Innovation strategy	Dummy	6
Technology transfer mode	Five-point scale	6
Strategy alliance	Five-point scale	5
Government supports	Five-point scale	5
R&D capability	R&D expenditure as a percentage of sales	2
	R&D personnel as a share of employment	
Process capability	Inventory control systems (ICS)- Dummy	5
	Age of machinery &equipment (ME)- multinomial	6
	Percentage of restructuring expenses in total sales	1

Table 3.4: Summary of Variables, Scale, and Items of innovation Types and Firm Performance

Variables	Scale	No. of Items
Organization Innovation	Five-point scale	5
Product Innovation	Five-point scale	6
Process Innovation	Five-point scale	6
Marketing Innovation	Five-point scale	5
Innovation performance	Five-point scale	5
Product performance	Five-point scale	5
Marketing performance	Five-point scale	3

Table 3.5: Summary of Variables, Scale, and Items of TOE Constructs

Variables	Scale	No. of Items
Adoption	Binary	6
Organizational constructs	Five-point scale	12
Technological constructs	Five-point scale	11
Environmental constructs	Five-point scale	8

The constructs and items of TC development are shown in Appendix B (Section B) of the survey questionnaire. The measurement instruments developed for the mill firms of this study were adapted from previous researchers and were conceptualized as the point of reference of development level on a set of strategic firm objectives. In terms of TC development, the study focuses on assessing RD and PT. The questions related to organizational learning mechanisms were inquired regarding training processes in order to develop skills to improve TC and firm performance. In addition, the innovation strategy questions were regarding the absorption and participation of new technologies in production processes. Transfer channel questions were associated with the incorporation of categorical modes such as Imports of capital goods, local R&D, contracts, and licensing agreements.

In terms of strategic alliances, the questions asked were related to the level of linkages developed with external actors to attain cooperation benefits. In contrast, the inquiries associated with benefits given to training and technology support and financial incentives to implement improvements in processes, machinery, and new products define the extent to which respondents are received from government support and incentives. The details of these items and the sources from which they were adapted are shown in Table 3.6. Moreover, some minor wording changes in the sentences by the author without changing its source meaning. The modification is purposely for adapting all the items appropriately into the context of current research.

Table 3.6: Variable Measurement of TC development

Variables	Items	Sources
Organization Learning mechanisms	Formal in-house training programs On the job training Outside Training Training from technology donor Patent acquisition	Sobanke et al. (2014) & Toyama et al. (2014)
Innovation Strategy	Technology process change1 Technology process change2 Technology process change3 Technology process change4 Technology process change5 Technology process change6	Hashim et al. (2012)
Technology Transfer Mode	Licensing agreements Imports of capital goods Local industry development &participation Contracts Local R&D	Chandra & Kolavalli (2006)
Strategy Alliances	Collaborate suppliers Collaborate educational institutes Collaborate financial institutes Collaborate standard institutes Collaborate MPOB Collaborate MPOA	Sobanke et al. (2014) & Iammarino et al. (2012)
Government Support	Government Taxes Government Grants Government ventures Government teach-programs Government trainings	Madanmohan et al. (2004) &Rasiah & Shahrin (2006)
R&D capability	R&D personal R&D expenditure	Chandran & Rasiah (2013)
Process capability	ICS-ISO 9000 ICS-RSPO ICS-JIN ICS-TPM ME1 ME2 ME3 ME4 ME5 ME6 RE. cost	Chandran & Rasiah (2013)

The constructs and items of innovation types and firm performance are shown in Appendix B (Section C) of the survey questionnaire. The measurement instruments developed for the mill firms of this study were derived from prior researchers and were conceptualized as the point of reference of development level on a set of strategic firm objectives, market and technology strategy, innovativeness efforts, market conditions, competitive priorities, in-firm atmosphere, and firm performance. In assessing the firm's performance, the study focused on three aspects: innovation, marketing, and product performances. The details of these adapted items and sources are presented in Table 3.7.

Table 3.7: Variable Measurement of Innovation Types and Firm Performance

Scales	Items	Sources
Product Innovation	Introduce new products and innovative products Capability to bring in new knowledge and technologies to develop new products Efforts to develop new products in terms of hours/persons, team, and training involved Capability to use new materials, new products functions, and new design Company's products are modified and improved Enhances the manufacturing technology of new products	Polder et al. (2010) & Guan & Ma (2003) & Wolff & Pett (2004)
Process Innovation	Has a pioneer disposition to introduce new processes Has the capability to adjust the processes at all levels concerning the production process, inventory, logistic, etc. Display clever response to new processes introduced by other firms Improve existing machinery and equipment Uses machinery adaptations and develops original processing solutions Decreases variable costs components in industrial processes, techniques, machinery and software.	Polder et al. (2010) & Guan & Ma (2003) & Wolff & Pett (2004)
Organization Innovation	Renewing the routines, procedures and processes employed to execute firm activities in innovative manner Renewing the production and quality management systems Renewing the organization structure to facilitate teamwork Renewing the organization structure to facilitate coordination between different functions such as marketing and manufacturing Renewing the organizational structure to facilitate strategic partnerships and long term business collaborations.	Gunday et al. (2011)& Jiménez-Jiménez & Sanz-Valle (2011)& Chiang & Hung (2010)& Reed et al. (2012)
Marketing Innovation	Renewing the design of the current and/or new products through changes Renewing the distribution channels without changing the logistics processes related to the delivery of the product. Renewing the product promotion techniques employed for the promotion of current and/or new products. Renewing the product pricing techniques employed for the pricing of the current and/or new products.	Johne & Davies (2000)

'Table 3.7, Continued'

Scales	Items	Sources
Product Performance	Product quality Cost advantage Market competitiveness Uniqueness of the product and/or process technology employed Average product concept-to-lunch time	Lo, Naidu & Yam (2001) & Fu & Shi (1995)
Innovation performance	Ability to introduce new products and services to the market before competitors Innovations introduced for work processes and methods Quality of new products and services introduced Percentage of new products in the existing product portfolio Renewing the administrative system and the mindset in line with firm's environment	Gök & Peker, (2017)& Gunday et al. (2011)& Stock & Reiferscheid (2014)
Marketing Performance	Market share Total sales Customer satisfaction	Gunday et al. (2011)

The constructs and items of critical factors to new technology adoption are shown in Appendix B (Section D) of the survey questionnaire. In the same way, the measurement instruments developed for the mill firms of this study were derived from past studies and were conceptualized as the point of reference of development level on a set of strategic firm objectives. In terms of adopting advanced milling technology, the study focused on assessing the critical factors adoption to three organizational, technological, and environmental aspects. The details of these items and the sources from which they were adapted are addressed in Table 3.8.

Table 3.8: Variable Measurement of TOE Factors

Scales	Items	Sources
Technological Constructs	Compatibility of new technology Complexity of new technology Cost	Rogers (1962); Moore & Benbasat, (1991) Madaki & Seng (2013a); Ngah, et al. (2017)
Organizational Constructs	Financial support & resources Top management support Managers' new technology knowledge Technical skills Size of firm	Wongsim (2013); Sulo et al. (2012); Sila (2013);Ghobakhloo et al., (2011a); Grandon & Pearson (2004); Grover (1999); Oh et al. (2009) & Jeon et al. (2006); Thong (1999); Abdullah et al. (2015) Zhu et al. (2006)
Environmental Constructs	Competitive Pressure Government policy	Abdullah et al. (2015) Abdullah et al. (2015)

3.5.2 Pilot Study

Validity generally specifies whether the measuring instrument is certainly measuring what it purports to measure where it is associated with measurement procedures (Hair et al., 2007; Kumar, 2011). It is critical to ensure the content validity of the questionnaires. The fact that measures were drawn from well-established empirical and conceptual works guarantees their validity (Bohrnstedt et al., 1983).

A pre-test was conducted to authorize the statement of complete and correct questions and to decide which items among those adopted and adapted from previous studies were most appropriate for the survey questionnaire. A pilot study is a process of judgment by experts of how a question accurately measures the concept it was projected to measure and to ensure for the quality of data. The researcher must then modified the survey instrument to enhance the possibility that the meaning of each item was clear (Krosnick, 1999). The pilot study cannot be determined statistically; it can only be determined by experts and by reference to the literature (Flynn et al., 1990; Gable, 1994). In addition to the deal with validity through extensive literature reviews, DeVellis (2003) suggested a response of input from both the experts in academia and industry to warrant the content validity. More so, it is highlighted that a questionnaire pre-testing must be conducted in advance by consulting experts for their recommendation before deploying it for the actual survey (Ghauri & Grønhaug, 2005).

For that purpose, six experts were invited to enhance and validate measures for each concept. The draft survey questionnaire was first passed to six senior academicians in the field of technology, innovation, and the palm oil industry. According to Julious (2005), the draft survey instrument was sent randomly to 12 operational and production managerial personnel of POMs in the Malaysian palm oil industry to determine whether the respondents clearly understand the phrasings and content.

In this way, some suggestions were offered to include their insights in the final revised version of the survey questionnaire. Finally, refined assessment items resulted in a well-structured survey, as enclosed in Appendix B.

3.5.3 Reliability and Validity

Factor and reliability analyses were directed to measure the validity and reliability of the variables in the study. The primary function of factor analysis is to reduce data by analyzing the bulky number of items variables whether there is a tendency for groups of them to be interrelated (Bryman, 2008; Hair et al., 2010).

It is also a statistical technique is utilized to recognize a smaller number of factors holding many observed variables (Gaur & Gaur, 2009). It is often used with multiple item measures to see if the items tend to gather to form one or more groups of objects. Items with a high connection between them and are widely independent of other subsets of variables are joined to factors. These groups of items are called factors and must then be given a name according to literature.

For this study, factor analysis was conducted to test the construct validity of the measurement instruments. A factor analysis determines the primary structure among the variables in the analysis (Hair et al., 2010). Based on the sample size proposed by Hair et al. (2010) and Coakes and Steed (2003), a minimum of five subjects per variable is required for factor analysis, more satisfactory for 10:1 ratio of the sample size for conducting the investigation (Hair et al., 2010). Besides, other researchers suggested less rigid regulations of 5:1 (Gorsuch, 1983) or 3:1 (Gorsuch, 1997). However, some studies indicate that such stringent regulations may be further simplified as good restoration of the actual population factor structure relies more on communities of the variables and the number of variables per factor (MacCallum et al., 1999, 2001; Velicer & Fava, 1998). If the data are well-conditioned, factor analysis can be legally conducted even on extremely smaller sample sizes (Preacher & MacCallum 2002; MacCallum et al. 1999, 2001). Therefore, With 27 variables, this study managed to obtain 54 samples, which are the acceptable required, and hence, the minimum needed for factor analysis was definitely satisfied.

A Principal Component Analysis (PCA) was applied to decrease the larger set of variables into a more compliant set of scales considering the primary number of variables is too large to explain individual relationships (Saraph et al., 1989; Benson et al., 1991; Flynn et al., 1990). PCA with a tetrachoric correlations matrix factor analysis was performed, owing to being the dummy variable.

Therefore, A PCA with varimax rotation is accompanied to determine the fundamental dimensions of the current study's independent and dependent variables. Also, PCA with a tetrachoric correlations matrix factor analysis was performed, owing to being the dummy variable. Factor analysis can identify whether a well-known factor or more than one factor exists in the responses to the items. In principle, factor analysis has been applied to understand the fundamental structure in the data matrix, recognize the closest set of variables, and ascertain the goodness of measures for examining the hypotheses (Hair et al., 2010). The purpose of PCA is to extract a comparably small number of components that can consider the variability obtained in a comparably large number of measures. This statistical method, which is also named data reduction, is commonly accomplished when a study does not need to embrace all of the primary measures in the analyses; however, it still needs to collaborate the information included in the measures. According to DeCoster (1998), data reduction aims to simplify by summarizing the variance associated using a smaller number of factors. PCA is commonly considered the best technique for the practical purposes of data reduction.

The suitability of factor analysis is subjected to the guidelines for factor analysis proposed by Hair et al. (2010), which include Bartlett's Test of Sphericity at 5% level of significance or less, the Overall Measure of Sampling Adequacy at a significant level 5% or more, and Kaiser-Meyer-Olkin (KMO) of over 0.60. Communalities give information on to what extent the variance in each item is explained. If values appear below the significant level of 5%, they could be removed; it shows that the item does not match correctly with other items in the components. Eliminating items with low communalities values lead to an increase in the total variance explained. In addition, a correlation matrix that is suitable for factor analysis should possess many sizable correlations greater than 0.3 (Hair et al., 2006). The value of significant factor loading proper for interpretation is determined by the sample size, where items tested on a smaller sample size require higher factor loading to ascertain practical significance. Hair et al. (2006) recommended that the factor loading of 0.40 or greater is considered very significant. Besides, factors with eigenvalues were offered for further analysis when they appear greater than one (Kim & Mueller, 1978).

The reliability test is purposely applied to test the internal consistency of the instruments used. A reliability analysis specifies whether the extent of variables is reliable to measure the constructs (Hair et al., 2010). It showed the instrument's consistency and stability in measuring a concept and aids in evaluating the goodness of a measure (Sekaran, 2000). Moreover, Cronbach's Alpha is proposed in determining the internal stability of the measurement items and has been generally utilized for the reliability coefficient (Cronbach, 1951). Therefore, reliability analysis has been carried out on the scale to determine the pertinence of the instrument by measuring the Cronbach's alpha coefficient values for each construct in this study. Nunnally (1978) suggested the minimum acceptable Cronbach's alpha value be set at 0.7, while Sekaran (2000) proposed the value 0.06 as the minimum sufficient reliability.

3.5.3.1 Validity and Reliability: TC Development and Its Determinants

To assessing the validity of the scale of the influencing factors and TC development, a principal component analysis was performed. There were originally 27 items for influencing factors of TC development scale under five dimensions; at least five items for each dimension. PCA with orthogonal varimax rotation was applied to find out the dimensionality of factors. The analysis showed that the 27 items formed 5 components, which equaled the initial structures. 9 items were omitted due to the low value of commonalities and cross-loading.

Based on table 3.9, the KMO measure of sampling adequacy value for influencing factors and TC development were 0.672 and 0.786, respectively, which exceeds the required value of 0.6. It indicates that the items were interrelated. Also, it means that the sample size ratio to the number of items is adequate for factorability. Besides, both Bartlett's sphericity tests significantly indicated the suitability for factor analysis (TC. Chi-Square = 348.855, Sig.=0.000; Determinants. Chi-Square = 352.402, Sig.= 0.000).

Results showed that five factors of determinants of TC development explained 66.15 percent of the total variance with initial eigenvalues greater than one. The first factor comprises four items, which covered innovation strategy. This factor accounts for 17.99 percent of the variance in the data, with loadings ranging from 0.773 to 0.912. The second factor has loadings ranged from 0.654 to 0.830, accounting for 13.52 percent of the total variance. This factor includes four items that indicated the respondents' perception of the participation in Technology Transfer Mechanisms. The third factor consisted of four items that are accounted for 13.42 percent of the total variance, with the loadings range from 0.681 to 0.772. These items are related to the strategic alliance with the external agents interested in the respondents' POMs. The fourth factor included three items that showed organizational learning, with loadings ranged from 0.602 to 0.849, which are accounted for 10.99 percent of the total variance explained. The fifth factor contained three items related to government support, accounted for 10.2 percent of variance with loadings ranging from 0.671 to 0.779.

TC development factor analysis showed that two items explain 68.88 percent of the total variance with original eigenvalues greater than one. The firm's process capability joined three items and was identified as the technological process capability component. The first factor loadings ranged from 0.662 to 0.925, accounting for 52.88 percent of the total variance. The second factor (RD capability) accounted for 16.01 percent of the total variance, with loadings ranging from 0.742 to 0.822. Moreover, five items, including the inventory control system (TPM and SPC), age of sterilizer, oil, and Kernel recovery types of machinery, were dropped because of the low communalities values and cross-loading.

In addition, all of the average variance extracted for measurements ranged from 0.522 to 0.704, surpassed the threshold of 0.5 (Bagozzi & Yi, 1988), which indicates that the study had sufficient levels of convergent and discriminant validity. In the same way, Cronbach's alpha values for all dimensions of the above factors ranged from 0.749 to

0.876 that more than 0.70, and confirmed a good reliability scale (Streiner, 2003; Hair et al., 1998; Nunnally, 1978; O'Leary-Kelly & Vokurka, 1998). Table 3.9 present the reliability and validity of the independent and dependent variables TC development.

Table 3.9: Validity and Reliability Analysis: TC Development and Its Determinants

Scale	Items	Factor Loading	Eigen-value	Cum. % variance explained	AVE	Cronbach alpha
Innovation Strategy	Technology process change1 (INN.S1)	.912	3.65	17.992	.704	.876
	Technology process change2 (INN.S2)	.863				
	Technology process change5 (INN.S5)	.802				
	Technology process change6 (INN.S6)	.773				
Technology .Transfer Mode	Imports of capital goods/inputs (TTM3)	.830	2.623	31.515	.522	.749
	Local R&D (TTM6)	.727				
	Local industry development &participation (TTM4)	.667				
	Contracts (TTM5)	.654				
Strategy Alliance	Collaborate suppliers (SA1)	.772	2.501	44.942	.545	.782
	Collaborate centers (SA4)	.751				
	Collaborate universities (SA3)	.746				
	Collaborate MPOB (SA5)	.681				
Organization Learning Mechanisms	Formal in-house training programs (OL1)	.849	1.659	55.935	.571	0.753
	On the job training (OL2)	.794				
	Training from MPOB (OL5)	.602				
Government Support	Government trainings (GS5)	.779	1.460	66.154	.533	.787
	Government Grants (GS2)	.736				
	Government Taxes (GS1)	.671				
Process Capability	ICS-ISO 9000 (ICS4)	.925	4.816	52.883	.679	.819
	ICS-RSPO (ICS5)	.693				
	ICS-JIN (ICS3)	.662				
	ME2	.883				
	ME4	.882				
	ME6	.786				
	RE. cost	.898				
R&D Capability	R&D personal (RD1)	.822	1.384	68.888	.613	.737
	R&D expenditure (RD2)	.742				
	KMO Determinates					
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.			.672			
Bartlett's Test of Sphericity	Approx. Chi-Square		352.402			
	df		153			
	Sig.		.000			
	KMO TC Development					
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.			. 786			
Bartlett's Test of Sphericity	Approx. Chi-Square		348.855			
	df		36			
	Sig.		.000			

3.5.3.2 Validity and Reliability of TC, Innovation Types, and Firm Performance

The validity of TC development, innovation types and firm performance scale was determined by using PCA. Initially, there were 34 items and five dimensions; six items for product innovation, six items for process innovation, five items for organization innovation, five items for marketing innovation, two items for R&D capability, and 12 items for process capability. In contrast, firm performances were 13 items divided into 5 items for innovation performance, five items for product performance, and 3 items for marketing performance. Results of factor analysis indicated that six factors are explained 72.92 percent of the total variance with initial eigenvalues, which surpassed the threshold one (Table 3.10).

The first factor was related to the organization's innovation, comprised of four items. This factor is accounted for 13.56 percent of the total variance, in which loadings range from 0.733 to 0.865. The second factor is covered process innovation with three items whose factor loadings ranged from 0.791 to 0.814, accounting for 11.84 percent of the total variance. Three items that comprised the items relating to product innovation showed the third factor. Its factor loadings ranged from 0.753 to 0.893, which was accounted for 9.7 percent of the total variance in the data. The fourth factor included four items, which indicated respondents' perceptions of the marketing innovation. Its factor loadings ranged from 0.661 to 0.779 and are explained for 9.5 percent of the total variance. The R&D capability with two items was accounted for 8.58 percent of the total variance, with loadings ranging from 0.852 and 0.870. Lastly, 19.5 percent of the total variance has been explained by the items of process capability.

In addition, the KMO measure of sampling adequacy for TC and innovation types and firm performances confirmed interrelated among items with a ranking of 0.616 and 0.779, respectively. In this regard, Bartlett's Test of Sphericity of both factor analysis results significantly indicates satisfactory factor analysis.

Table 3.10: Validity and Reliability Analysis: TC development, Innovation Types, and Firm Performance

Scales	Items	Factor Loading	Eigen -value	Cum. % variance explained	AVE	Cronbach alpha
Organization Innovation	Renewing the production and quality management systems (ORG.INN2)	.865	4.394	13.569	.654	.864
	Renewing the organization structure to facilitate teamwork (ORG.INN3)	.848				
	Renewing the routines, procedures and processes employed to execute firm activities in innovative manner (ORG.INN1)	.783				
	Renewing the organization structure to facilitate coordination between different functions such as marketing and manufacturing (ORG.INN4)	.733				
Process Innovation	Uses machinery adaptations and develops original processing solutions (PR.INN4)	.814	2.399	25.410	.647	.806
	Has a pioneer disposition to introduce new processes (PR.INN1)	.809				
	Has the capability to adjust the processes at all levels concerning the production process, inventory, logistic, etc. (PR.INN2)	.791				
Product Innovation	Capability to use new materials, new products functions and new design (PD.IINN4)	.893	2.019	35.104	.671	.748
	Company's products are modified and improved (PD.INN5)	.804				
	Capability to bring in new knowledge and technologies to develop new products (PD.INN2)	.753				
Marketing Innovation	Renewing the product promotion techniques employed for the promotion of current and/or new products. .(MKT.INN3)	.779	1.935	44.779	.503	.755
	Renewing the distribution channels without changing the logistics processes related to the delivery of the product.(MKT.INN2)	.682				
	Renewing the product pricing techniques employed for the pricing of the current and/or new products. .(MKT.INN4)	.661				
R&D Capability	R&D personal (RD1)	.870	1.587	53.380	.741	.737
	R&D expenditure (RD2)	.852				

'Table 3.10, Continued'

Scales	Items	Factor Loading	Eigen -value	Cum. % variance explained	AVE	Cron bach alpha
Process Capability	ICS-ISO 9000 (ICS4)	.522	1.211	72.924	.546	.819
	ICS-RSPO (ICS5)	.586				
	ICS-JIN (ICS3)	.651				
	ME2	.532				
	ME4	.567				
	ME6	.506				
	RE. cost	.687				
Innovation performance	Quality of new product or services (INN.PF3)	.878	4.450	37.340	.615	.837
	Renewing the administrative system and the mind set in line with firm's environment (INN.PF5)	.860				
	Innovations introduced for work processes and methods (INN.PF2)	.721				
	Ability to introduce new products and services to the market before competitors (INN.PF1)	.656				
Product Performance	Product quality (PRD.PF1)	.875	1.645	58.949	.620	.829
	Cost advantage (PRD.PF2)	.839				
	Market competitiveness (PRD.PF3)	.625				
Market Performance	Market share (MKT.PF1)	.890	1.028	71.224	.627	.711
	Total sales (MKT.PF2)	.798				
	Customer satisfaction (MKT.PF3)	.674				
KMO TC and Innovationns						
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.616				
Bartlett's Test of Sphericity	Approx. Chi-Square	443.130				
	df	231				
	Sig.	.000				
KMO Firm Performances						
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.779				
Bartlett's Test of Sphericity	Approx. Chi-Square	248.304				
	df	45				
	Sig.	.000				

Source: Computed data analysis

Two items from product innovation, three items from process innovation, one item from marketing innovation, and one item from organization innovation were eliminated due to the low value of commonalities and cross-loading. In addition to the above items, five items from process capability were dropped because of low communalities values and cross-loading.

Firm performance factor analysis showed that three items explain 71.22 percent of the total variance with original eigenvalues greater than one. The first factor comprises four items, which covered innovation performance. This factor is accounted for 37.34 percent of the variance in the data that has loadings ranging from 0.656 to 0.878. The second factor has loadings ranged from 0.625 to 0.875 accounted for 21.6 percent of the total variance. This factor includes three items that indicated the respondents' perception of participation in product performance. The third factor consisted of three items that accounted for 12.27 percent of the total variance, with loadings ranging from 0.674 to 0.890. Meanwhile, one item from innovation performance and two items from product performance were omitted due to the low value of commonalities and cross-loading.

Furthermore, all of the average variance extracted for measurements ranged from 0.503 to 0.741, surpassed the threshold of 0.5 (Bagozzi & Yi, 1988), which indicates that the study had sufficient levels of convergent and discriminant validity. In the same way, Cronbach's alpha values for all dimensions of the above factors ranged from 0.711 to 0.864 that more than 0.70, which is reflected as a good scale of reliability (Streiner, 2003; Hair et al., 1998; Nunnelly, 1978; O'Leary-Kelly & Vokurka, 1998).

3.5.3.3 Validity and Reliability Analysis: TOE Constructs

The validity of the critical factors of the TOE scale was determined by principal component analysis (Table 3.11). Technological constructs were originally 11 items with 3 aspects of compatibility, complexity, and cost. After performed varimax rotation, 3 items were eliminated because of cross-loading. Results of factor analysis showed that eight technological items are explained 67 percent of the total variance with original eigenvalues greater than one.

The first factor comprises three items, which covered respondents' perceptions of the complexity of new technologies, accounting for 24.73 percent of the variance in the data with loadings ranging from 0.736 to 0.802. The second factor has loadings ranged from

0.705 to 0.859, accounted for 23.97 percent of the total variance, which includes three items that indicated the respondents' perception of compatibility. Two items that comprised the items relating to the cost of new technologies showed the third factor. Its factor loadings ranged from 0.789 to 0.823, which explained 18.28 percent of the total variance in the data.

Organizational constructs were 12 items and 4 dimensions; three items for financial resource and support, four items for top management support, three items for technical skill, and two items for the managers' knowledge. Results of factor analysis indicated that four factors with initial eigenvalues greater than one are explained 66.1 percent of the total variance. The first factor comprises three items, which covered financial resources and support. This factor accounted for 22.69 percent of the variance in the data, with loadings ranging from 0.787 to 0.827.

The second factor has loadings ranging from 0.729 to 0.831, which explained 17.87 percent of the total variance. This factor includes three items that indicated the respondents' perception of the top management support. One item is omitted due to cross-loading. The third factor involved three items that were linked to technical skills. This factor is accounted for 15.25 percent of the total variance, with loadings ranged from 0.655 and 0.819 in the data. The last organizational element contained two items related to the managers' knowledge, with loadings ranged from 0.660 to 0.804, which accounted for 10.28 percent of the total variance.

Initially, environmental constructs were eight items in two dimensions, including competitive pressure and government support and policy. Results of factor analysis showed that six items are explained 68.26 percent of the total variance with original eigenvalues greater than one. The first factor comprises three items, which covered respondents' perceptions of the competitive pressure. This factor is accounted for 34.51 percent of the variance in the data that has loadings ranging from 0.770 to 0.882.

The second factor has loadings ranged from 0.737 to 0.887, explaining 33.75 percent of the total variance. This factor includes three items that indicated the respondents' perception of the government support. One item from each factor is omitted due to cross-loading.

Adoption scale were six items of new technology adoption, which one item is reduced because of the low value of communalities. The results indicated that 53.73 percent of the total variance in the adoption model is explained by 5 items of adoption.

The results in Table 3.11 confirm a satisfactory convergent validity parameter on the AVE of all constructs were greater than 0.5 (Bagozzi & Yi, 1988); the factor loadings were above 0.6 (Hair et al., 2010); and Chronbach's alpha values for all dimensions of factors are higher than 0.7 (Hair et al., 1998).

Moreover, the results reveal the KMO measure of sampling adequacy for the TOE constructs scale are 0.657, 0.635, and 0.645, respectively, which shows that the items are interrelated. Similarly, the KMO results for the adoption confirmed corresponding items with a ranking of 0.779. In this regard, Bartlett's Test of Sphericity of The TOE model results from factor analysis significantly indicates satisfactory factor analysis.

Table 3.11: Validity and Reliability Analysis: TOE Constructs

Scales	Items	Factor Loading	Eigen-value	Cum. % variance explained	AVE	Cronbach alpha
Complexity	New technology adoption process is complex. (CX1)	.802	2.394	24.735	.597	.701
	Learning to operate new technology is easy (CX3)	.778				
	New technology usage is understandable. (CX2)	.736				
Compatibility	New technology is compatible with the external environment of our organization.(CP3)	.859	1.881	48.711	.630	.729
	New technology is fit with current operational practices.(CP2)	.808				
	New technology is compatible with existing system of conducting organization's operation. (CP1)	.705				
Cost	New technology is expensive to install and maintain. (CO2)	.823	1.085	66.997	.649	.771
	New technology is expensive to acquire (CO1)	.789				
Financial resource and support	Our firm is facing lack of adequate capital. (FS3)	.827	2.816	22.690	.653	.802
	Our firm is facing lack of financial support (FS2)	.812				
	Our firm is facing lack of credits facilities (FS1)	.785				
Top management support	Our organization's top management involves decision-making on new technology adoption (TM2)	.831	1.970	40.565	.623	.830
	Our organization's top management is supportive of the use of new technology in the production operation. (TM1)	.805				
	Our organization's top management is likely to be interested in adopting new technology to gain competitive advantage. (TM4)	.729				
Technical skills	Our organization has insufficient capacity in time to pick-up technical knowledge. (TS3)	.819	1.451	55.825	.516	.721
	In our organization information related to new technology technical support is not available to management and employees. (TS2)	.670				
	Our organization is facing lack of technical knowledge and expertise relate to new technology. (TS1)	.655				

‘Table 3.11, Continued’

Scales	Items	Factor Loading	Eigen-value	Cum. % variance explained	AVE	Cronbach alpha
Managers’ knowledge	Our organization’s senior management has expertise in innovative technology practices(MK1)	.804	1.035	66.108	.541	.742
	Our organization’s senior management has adequate knowledge in new technologies like POME treatment (MK2)	.660				
Competitive pressure	In palm oil mill’s, a large number of mills adopt new technology. (CP4)	.882	2.538	34.508	.674	.718
	Our firm has experienced competitiveness pressure to adopt new technology.(CP1)	.807				
	In palm oil mill’s, most of our competitors use new technology.(CP3)	.770				
Government Support & Policy	Inadequate government's new technology policies to create awareness and promote uptake of the technology.(GP4)	.887	1.558	68.265	.658	.706
	Inadequate enforcement of environmental regulations by government officers for adopting new technology POME.(GP1)	.803				
	Inadequate subsidies for adopting new technology (GP2)	.737				
Adoption	Kernel recovery (AD4)	.864	2.687	53.734	.540	.762
	Sterilization (AD1)	.830				
	Boiler operation (AD5)	.672				
	Waste water treatment (AD6)	.639				
	Oil extraction (AD2)	.627				
	KMO Technological Factors					
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.657				
Bartlett's Test of Sphericity	Approx. Chi-Square	87.715				
	df	28				
	Sig.	.000				
	KMO Organizational Factors					
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.635				
Bartlett's Test of Sphericity	Approx. Chi-Square	139.978				
	df	55				
	Sig.	.000				
	KMO Environmental Factors					
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.645				
Bartlett's Test of Sphericity	Approx. Chi-Square	91.264				
	df	15				
	Sig.	.000				
	KMO Adoption					
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.729				
Bartlett's Test of Sphericity	Approx. Chi-Square	81.038				
	df	10				
	Sig.	.000				

Source: Computed data analysis

3.6 Models and Techniques of Analysis

The multivariate relationships assumed by the research model were used to test the collected data; thus, the data has experienced a series of analyses. Since the Statistical Package for Social Science (SPSS) software is one of the most reliable and prevalent packages used to analyze data (Cramer, 1998); therefore, the study deployed the IBM SPSS statistics version 22 to test hypotheses provide a descriptive explanation.

3.6.1 Data Cleaning and Screening

Data cleaning and screening is the process of the data where it begins after all the data have been collected and before starting any further statistical testing. After the data were obtained, each question in the survey form was coded and keyed in the SPSS. The data has been examined through primary descriptive and frequency distribution to identify any improperly coded or out-of-range data. Any missing responses were detected during the frequency test. There are three main steps in the screening and cleaning the data: inspection for errors, the discovery of errors in the data file, and finally, rectifying the errors in the data file (Pallant, 2013). The percentage of missing for each of the variables was checked by performing the descriptive analysis. The data set provided by the answers serves to be fulfilled without any missing data. Hence, to eliminate the problem of missing data in this study, no more procedures are needed.

3.6.2 Descriptive Analysis

Before conducting statistical analysis, it is necessary to ensure no infractions were detected during the assumptions created for the test. Data were analyzed mainly through descriptive statistics. Descriptive statistics is a term used to summarize a group of data

(Meier et al., 2015). The data will be analyzed using descriptive data analysis, which covered the frequency distribution to observe the characteristics of respondents, measures of central tendency of mean, and measures of dispersions of standard deviation (Pallant, 2013).

The descriptive analysis geographically indicates that Johore and Pahang accounted for the majority of respondents' returns (61.6%), which is also because of the concentration of oil palm acreage in these states of Peninsular Malaysia (Table 3.12). Furthermore, most respondents' mills (58%) were owned by Felda and Felda Global Ventures Holdings Bhd, as the largest Malaysian palm oil company (Ramasamy et al., 2005; Yacob et al., 2005). Following that, Sime Darby is accounted for 12% of the total respondents. Kuala Lumpur Kepong Bhd and Kulim Plantation (M) Sdn. Bhd and Southern Group from independent companies and sub-groups have been the rest of the POM respondents.

Table 3.12: Distribution of Locations by mill Respondents

Survey Respondents' Location	**Percentage %**
Johor	34.67
Pahang	27.1
Kelantan	8.24
N. Sembilan	8.24
Terengganu	7.6
Perak	7.3
Kedah	1.71
Melaka	1.71
P. Pinang	1.71
Selangor	1.71

Source: Computed data analysis

The Malaysian POMs were established in different years. Figure 3.5 shows 12.7% of mills were established between 1960 and 1979, while 59% were established during the years 1980 until 1989. From 1990 to 1999, the established mills were 20%, and 8.3% has been set up since 2000.

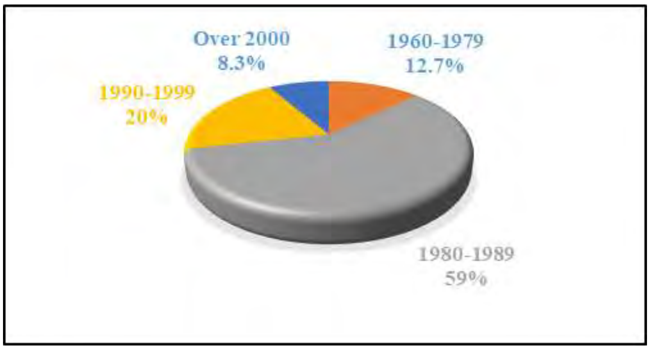

Figure 3.5: Years of Establishment of the POMs
Source: Computed data analysis

According to Figure 3.6, the positions retained by the respondents within their mills included mill managers (46%), assistant mill managers (23%), mill engineers (19%), and executives R&D (12%).

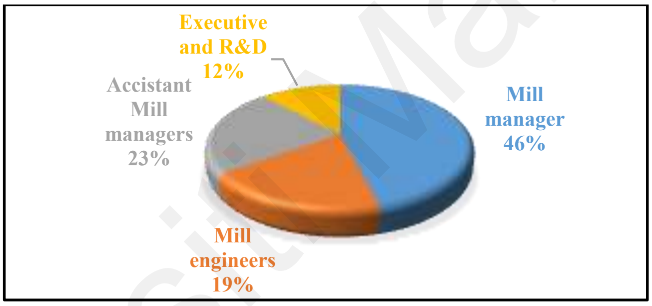

Figure 3.6: Position of POMs Respondents
Source: Computed data analysis

Figure 3.7 shows that most mills were privately owned (63%), whereas the rest was allocated to partially privatized ownerships.

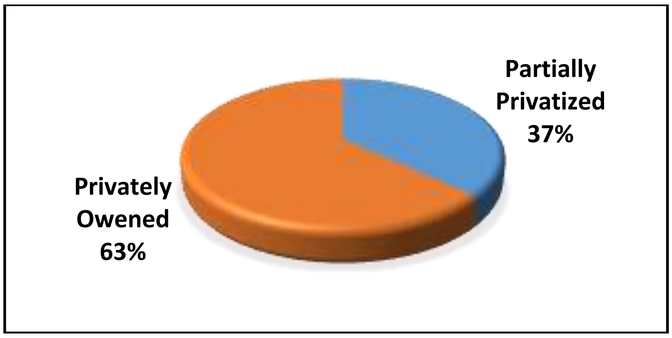

Figure 3.7: Type of Mill Ownerships
Source: Computed data analysis

3.6.3 Goodness of Measures

Based on Sekaran (2003), the goodness of measures is established by measuring the validity and reliability. Generally, a study has to ensure whether or not the tested measures do evaluate what it is to be measured (Validity) and assessed the coherency of the measurement outcomes (Reliability) (Cooper & Schindler, 2003). In this research, before multivariate analyses were undertaken, the goodness of measures was first analyzed through the factor analysis (validity) and the test of reliability (see Tables 3.9, 3.10, and 3.11).

3.6.4 Non-Response Bias

Non-response is an important issue for researchers who employed survey research. Typically, the unit and item non-response problems have been treated survey research by different influences on data quality, statistical assessments and adjustments, and various fundamental causes (Groves et al., 2000; Groves et al., 2004; Groves, Cialdini & Couper, 1992; Beatty & Herrmann, 2002). The considerable differences between respondents and non-respondents indicate that collected data cannot represent the target population of the research (Draugalis & Plaza, 2009).

Due to the significant portion of failed samples 43.15% (41/95) in the survey, it is essential to examine whether respondents are different from non-respondents, resulting in biases in the data collected and influencing the internal validity of the survey results (Atif, Richards, & Bilgin, 2012). Hence, this study applied the standard approach to testing for non-response bias using the linear extrapolation method based on the assumption suggested by Lahaut et al. (2003) and Armstrong and Overton (1977), which subjected to comparing between the early and late responses. This comparison method is mainly applied in quantitative research to distinguish non-response bias. According to

Lindner et al. (2001), If no significant differences are located between the groups of respondents, this indicates that non-response bias was not a paramount concern to impact the sample results.

Therefore, the study identified early and late respondents based on the recorded response time to evaluate non-response bias. From a total 54 of responses, the first 19 were considered early respondents as their responses were recorded in a short time. In contrast, the last 35 were deemed to be late respondents because of the forces applied to obtain them through reminder E-mails or phone calls.

The study employed a Pearson Chi-squared test to find the presence of any differences between early and late respondents via comparing them to the demographical information collected in the survey (Appendix D1). The findings indicated no difference between early and late respondents ($P>0.05$) regarding the size, age, and type of ownership of the POMs.

In addition, the study used a non-parametric method that covered the ordered nature of Likert scales as they possess distinct characteristics, such as continuous values and restricted range (De Winter & Dodou, 2010). Consequently, the Mann-Whitney U test was applied to the rest of the items to determine whether early respondents' answers differ significantly from late respondents (Appendix D2). The findings show that only two items (OR1 and RD1) from 62 items were significant at level 5%. Although this could indicate non-response bias, it can be affected by randomness because of the number of tested variables.

Furthermore, as most items were non-significant, this study concluded that no dissimilarities between early and late respondents were diagnosed. Thus, non-response bias is unlikely to impact the sample.

3.6.5 Model Specification

In Regression models, the dependent variables are continuous or categorical, and the independent variables can also be either continuous or categorical.

Hence, the Regression model treated the factors frim size, type of ownership, Organization learning mechanisms, innovation strategy, and inventory control systems as categorical. In this study, dummy variables contained within large firms (1) and small and medium-sized firms (0); partially privatized ownership (1) and privately owned (0); organization learning mechanisms (1) if used On-the-job training, Formal in-house training programs, Out-side training, Training from technology donor, and MPOB, otherwise (0); inventory control systems (1) if used SPC, TPM, JIT, ISO, and RSPO, if not (0); and innovation strategy (1) if participated in simple changes in new process technologies, otherwise (0). The other variables were considered continuous. According to p-values of 0.05 and 0.01, the study used the significance at 5% and 1% levels.

Furthermore, as the research frameworks of this study have a solid theoretical basis, the break-in method was completely proper for apply. This procedure places all independent variables into the regression model in one block and calculates parameter estimates for each block (Field, 2009).

3.6.6 Techniques of Analysis

Based on Hair et al. (2010), multiple regression analysis is a statistical method applied to analyze the relationship between one dependent variable and combine it with many independent variables or predictors (Meier, Brudney, & Bohte, 2015). Multiple regression analysis aims to utilize the independent variables reinforced to predict the s single dependent value.

Furthermore, as a dependence technique for hypothesis testing, the researcher should split the variables into independent and dependent variables to use multiple regression analysis. Through conducting multiple regression analysis, the study proceeded to investigate the first research framework (Figure 3.2) and test the direct relationship hypotheses between internal factors (organizational learning mechanisms, innovation strategy, firm size, and type of ownership), technology transfer mode, and external factors (strategic alliances and government support) and dependent variable TC development in Malaysian POMs.

With respect to the second objective, the study has employed a multi regression model to examine the association between TC development and firm performance. In addition to that, Linear regression analysis is applied to investigate the relationship between innovation types and firm performance.

In the same vein, the study examined the second research framework (Figure 3.3) and test the hypotheses by using a logit regression model to identify the drivers and barriers of new technology milling technology adoption among adopters and non-adopters by Malaysian POMs.

3.6.6.1 Model development

To determine the variables that influence TC development in POMs, the research applied multiple regression analysis using the following model:

$$TC = \beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \beta_3 X_{i3} + \beta_4 X_{i4} + \beta_5 X_{i5} + \beta_6 X_{i6} + \beta_7 X_{i7} + \varepsilon$$

Where the TC is the dependent variable, β0 is the value Y in cases where all variables are zero, Bi is the regression coefficient of Xi, Xi is the independent variable, and e is the error term.

The multiple regression model is interpreted by the regression coefficients, P-values, and R2 adjusted. The sign of a coefficient reveals the presence of a positive or negative relationship between each independent variable and the dependent variable. The R^2 adjusted is a new R^2 modified that has been altered for the number of predictors in the model. The adjusted R^2 can increase when a predictor improves the model excess predicted by chance. Linear relationships of factor coefficients were significant at 1%, 5%, and 10 % levels.

Besides, this study employed a correlational design, which is classified under non-experimental quantitative approaches. The correlational design allows the description, assessment, and measurement of statistical relations between two or more variables (Creswell et al., 2007). Hence, the Logit model was applied to define the correlation between the probability of the new technology adoption and its critical factors. Due to the focus on POM's adoption, the study employed the frequently utilized logit regression model as it conveniences various technology adoption studies (CIMMYT, 1993). In addition to that, the model provides the quantitative analysis of adopting agricultural methods innovations (Tene, Havard & Temple, 2013). The model derived n predictor variables that occur for the two particular responses, i.e., Y = 1 adoption of advanced milling technology; Y = 0 non-adoption of advanced milling technology. Ten independent variables were used in the regression. Based on Adéoti, Tamò, & Coulibaly (2002), the logit model is defined by the latent variable Yi as follows:

$$E(Yi) = P(Yi) = \frac{e^{\alpha+\beta xi}}{1+e^{\alpha+\beta xi}} \quad (1)$$

If the mill did not adopt new technology, the probability shift is denoted by:

$$E(no - adoption) = P(Yi) = \frac{1}{1+e^{\alpha+\beta xi}} \quad (2)$$

Where P (Yi) is the probability of a mill i to adopt the new technology; Yi=1 if the new technology is adopted and Yi=0 if the new technology is not adopted. Also, e is the exponential function, β is The path of the parameters to estimate whose sign allows interpreting the results, Xi is characteristic of the mill firm i, and α is the constant.

Founded mathematically on a linear model of the natural logarithm of the odds in favour of Yi = 1, subsequently, the logarithmic. Odds of adoption and non-adoption of advanced milling technology can be written as:

$$\text{Ln}\left[\frac{P}{1-P}\right] = \beta_0 + \beta 1X_{i1} + \beta 2X_{i2} + \beta 3X_{i3} + \beta 4X_{i4} +$$

$$\beta 5X_{i5} + \beta 6X_{i6} + \beta 7X_{i7} + \beta 8X_{i8} + \beta 9X_{i9} + \beta 10X_{i10} \quad (3)$$

Several tests were conducted to determine the efficacy of the logit regression model of the TOE factors. The key parameters were significant to allow interpretation of the results. Firstly, the Likelihood Ratio conducted to test the improvement of the new model was significant at the 5% level. Secondly, the Pearson Chi-Square test of goodness of fit of the model, i.e., the linear relationships of factor coefficients were significant at 5% level.

3.6.7 Normality, Multicollinearity, and Correlations

Normality is the first and foremost hypothesis. According to Hair et al. (2006), in multivariate analysis, normality outlines the dispersal of data for a metric variable and its relation to the normal distribution. A statistical test could become invalid if the collected data deviate extensively from the normal distribution shape. Normality has been considered by skewness level (distribution symmetry) and kurtosis level (the clustering of scores toward the distribution center) for all measured variables.

The normality test results are presented in Table 3.13. The value of the skewness and kurtosis are in the region of -0.918 to 0.552 and from -1.764 to 0.462, respectively. The results indicate that the skewness and kurtosis values for the variables are between ±2.00, respectively (Field, 2000; Gravetter & Wallnau, 2014; Trochim & Donnelly, 2006). In addition, the Kolmogorov-Smirnov and Shapiro-Wilk test of normality is applied for dependent variables (Appendix D3). The p-value from both tests should be greater than 0.05, indicating no serious departure from normality (Oztuna et al., 2006).

Table 3.13: Normality Analysis

Variable	Mean	SD	Skewness	Kurtosis
Influencing Factors of TC Development				
Organization learning Mechanisms	1.459	0.317	0.050	-1.188
Innovation strategy	.280	0.247	-0.918	-1.203
Technology transfer mode	3.595	0.357	-0.722	-0.571
Alliance strategy	2.771	0.311	-0.451	0.194
Government support	2.924	0.505	-0.654	0.462
Size of organization	2.296	0.717	-0.512	-0.890
Type of ownership	1.629	0.487	-0.552	-1.726
TC development				
R&D personal	**0.759**	0.612	0.180	-0.481
R&D expenditure	0.37	0.487	0.552	-1.764
Product technological capability	0.560	0.219	-0.189	-0.869
Inventory control system	0.444	0.198	-0.282	-0.207
Age of machinery	0.278	0.231	0.367	-0.519
Process technology restructuring expenses	1.09	0.652	-0.092	-0.569
Process technological capability	0.604	0.248	0.073	-0.729
Innovation Types				
Organization innovation	3.36	0.485	-0.117	-0.418
Product innovation	3.54	0.290	-0.129	-0.194
Process innovation	3.00	0.526	-0.225	-0.803
Marketing innovation	2.89	0.522	0.156	-0.576
Firm performance				
Innovation performance	3.32	0.427	-0.068	-0.587
Product performance	3.34	0.445	-0.317	-0.441
Marketing performance	3.38	0.491	-0.112	-0.424
Technological Constructs				
Complexity	3.53	0.451	-0.773	-0.123
Compatibility	3.09	0.432	-0.580	-0.650
Cost	3.49	0.655	-0.021	-0.589
Organizational Constructs				
Financial resource and support	3.32	0.642	0.032	-0.412
Top management support	3.34	0.599	0.281	0.107
Managers' knowledge	2.87	0.645	-0.094	-1.100
Technical skills	3.50	0.644	0.387	-0.149
Environmental Constructs				
Competitive pressure	3.13	0.645	-0.153	-1.048
Government support and policy	3.15	0.642	-0.403	-0.917
Adoption	0.39	0.231	0.101	0.325

Source: Computed data analysis

Also, having run the test, the results display the histogram and P-P Plot between the dimensions of the independent and dependent variables. The histogram graphically presents that the normality assumption is obtained because the bars form a normal curve. On top of that, the P-P Plot graph illustrations that all the points lie on a 45^0 diagonal line from bottom left to top right. The histogram and P-P Plot figures can be viewed in Appendixes D4, D5, and D6, respectively. It clarifies that there is no violation of the normality assumption, and instead, it completes the statistical assumptions. Thus, the normality assumptions are established and founded, which signifies the variables are ready for further analysis.

For this study, two multicollinearity tests were conducted using Pearson correlations and Tolerance Value and Variance Inflation Factors (VIF). The multicollinearity problem appears when the independent variables are highly correlated; it means that Pearson's r between each pair of variables should be less than 0.85 (Hair et al., 2010). Hence, the multicollinearity problem does not exist among the variables in the study as the inter-correlations being less than 0.85 (see Tables 4.12, 5.1, and 6.3).

In the second test, the Tolerance value and VIF were employed to seek the degree of multicollinearity among the variables. This method specified that serious multicollinearity is revealed when the VIF value above 2.50 and the tolerance value of each independent variable below 0.40 (Nawanir et al., 2013). The results presented in Tables 3.14, 3.15, and 3.16 showed none violated the recommended values of tolerance and VIF, thus prove multicollinearity is not a concern in this study. The regression analysis results exposed no multicollinearity problem in the regression models utilized in the current study.

Table 3.14: Tolerance and VIF Values: Independent Variables of TC

Independent Variable	Collinearity Statistics	
	Tolerance	VIF
Organisatinal learning	.885	1.129
Innovation strategy	.572	1.748
Technology transfer mode	.770	1.299
Alliance strategy	.811	1.233
Government support	.557	1.795
Size of organization	.728	1.373
Type of ownership	.479	2.087

Source: Computed data analysis

Based on table 3.14, the results of collinearity statistics from independent variables of TC development indicate that none violated the recommended values of tolerance (.479) and VIF (2.087). Thus it proves that multicollinearity is not a concern in this study.

Table 3.15 Tolerance and VIF Values: Independent Variables of Firm Performance

Independent Variable	Collinearity Statistics	
	Tolerance	VIF
RD	.491	2.035
PD	.548	1.824
Organization innovation	.763	1.311
Product innovation	.808	1.237
Process innovation	.487	2.052
Market innovation	.476	2.102

Source: Computed data analysis

Table 3.15 presents the results of collinearity statistics from the independent variable of firm performance. The results showed that none violated the suggested values of tolerance (.645) and VIF (1.585), thus prove multicollinearity is not a problem in the research.

Table 3.16 Tolerance and VIF Values: Independent Variables of Adoption

Independent Variable	Collinearity Statistics	
	Tolerance	VIF
Complexity	.654	1.529
Compatibility	.515	1.941
Cost	.621	1.611
Financial support and resource	.646	1.547
Top management support	.817	1.223
Managers' knowledge	.590	1.696
Technical skill	.635	1.576
Size of company	.532	1.879
Competitive pressure	.749	1.334
Government support	.540	1.852

Source: Computed data analysis

The results of collinearity statistics from independent variables of adoption in Table 3.16 prove that none violated the proposed values of tolerance (.515) and VIF (1.941). As a result, multicollinearity is not a challenge in this study.

Since the multicollinearity problem is tightly linked to discriminant validity, it is used as a commonly applied method for diagnosing the level of multicollinearity (Grewal et al., 2004). For this reason, the study employed this method to explore the degree of multicollinearity further. Discriminant validity is tested by assessing whether the square root of the AVE is greater than the association between variables (Agarwal & Karahanna, 2000). The results present that the AVE square root measures surpassed the inter-correlations of each variable with the other variables in the models (see Tables 3.17, 3.18, and 3.19). It indicates an acceptable degree of discriminant validity of all variables (Fornell & Larcker 1981), confirming no multicollinearity problem exists among the variables.

Table 3.17: Discriminant Validity of TC and its Determinants

	OL	INN.S	TTM	SA	GS	SIZ	OWN	RD	PT
OL	**.756**								
INN.S	.139	**.839**							
TTM	.141	.351	**.723**						
SA	.110	.315	.264	**.736**					
GS	.173	.586	.380	.299	**.730**				
SIZ	358	.543	.378	.373	.314	**.836**			
OWN	.323	.404	.277	.348	.223	.590	**.718**		
RD	.102	.379	.319	.341	.474	.694	.446	**.783**	
PT	.213	.683	.667	.338	.691	.634	.328*	.493	**.824**

Note 1: OL = organization learning, INN.S =innovation strategy, TTM = technology transfer mode, SA = strategy alliance, GS = government support, SIZ = size, OWN = type of ownership, RD = product technological capability, and PT = process technology capability.

Table 3.18: Discriminant Validity of TC, Innovations and Firm Performance

	RD	PD	PD.INN	PR.INN	MKT.INN	ORG.INN	INN.PF	PD.PF	MKT.PF
RD	**.860**								
PD	.641	**.739**							
PD.INN	.561	.214	**.819**						
PR.INN	.603	.156	.766	**.804**					
MKT.INN	.667	.247	.701	.604	**.709**				
ORG.INN	.650	.137	.541	.733	.615	**.808**			
INN.PF	.341	.141	.562	.398	.587	.369	**.784**		
PD.PF	.367	.247	.226	.403	.372	.616	.299	**.787**	
MKT.PF	.644	.124	.384	.512	.524	.474	.333	.296	**.792**

Note 1: RD= P&D capability; PD= Process Capability; PD. INN= Product Innovation; PR. INN= Process Innovation; MKT.INN=Marketing Innovation; ORG.INN= Organizational Innovation; INN. PRF= Innovative Performance; PRD. PF= Product Performance; MKT. PF= Marketing Performance.

Table 3.19: Discriminant Validity of TOE Factors and Adoption

	CX	CP	CO	FS	TM	MK	TS	SIZ	CP	GS	AD
CX	**.733**										
CP	-.250	**.794**									
CO	.437	-.237	**.803**								
FS	.516	-.287	.561	**.808**							
TM	-.022	.200	-.077	-.079	**.789**						
MK	.399	-.162	.024	.108	.085	**.735**					
TS	.531	-.340	.300	.227	-.030	.370	**.718**				
SIZ	-.676	.481	-.716	-.694	.129	-.227	-.520	**.860**			
CP	.192	.413	.146	.169	-.270	.196	.362	-.216	**.820**		
GS	.355	-.345	.216	.286	-.177	.272	.352	-.382	.146	**.811**	
AD	-.437	.227	-.365	-.639	.258	-.190	-.351	.544	-.223	-.444	**.735**

Notes: CX= complexity, CP= compatibility, CO= Cost, FSR= financial support and resources, TMS= top management support, MK= managers' knowledge, TS= technical skills, SF=Size of the firm, EP= environmental pressure, GSP= government support and policy, and AD= adoption.

3.6.8 Correlation Analysis

Correlation analysis was conducted to determine the association between the variables on the basis of this study. A correlation analysis recognized the strength and direction of the linear linkage between two variables (Gaur & Gaur, 2009). The results expose the correlation between the independent and dependent variables and multicollinearity before proceeding to multiple regression analyses (Pallant, 2013). The correlation coefficient (r) value ranges between ±1.0, with +1.0 describes an absolute positive linear relationship, 0 shows no linear association, and -1.0 shows a fundamental reverse relationship (Hair et al., 2010). There are three types of correlation coefficients available in the SPSS program: Pearson's, Spearman's, and Kendall's tau-b (Gaur & Gaur, 2009). However, Pearson's coefficient was used as it is generally applied for continuous data compared to the other two, used primarily for ranked data.

In explaining the values between 0 and 1, Davis (1971) had recommended guidelines for interpretation as follows:

"If r is 1.0, the magnitude is perfect

If r is 0.85 – 0.99, the magnitude is very high

If r is 0.70 – 0.84, the magnitude is high

If r is 0.50 – 0.69, the magnitude is substantial

If r is 0.30 – 0.49, the magnitude is moderate

If r is 0.10 – 0.29, the magnitude is low, and

If r is 0.01 – 0.09, the magnitude is negligible."

Pearson's method was related to the two-tailed statistical significance test at 1% and 5% significance levels. The results of the Pearson correlation are presented in Tables 4.12, 5.1, and 6.3.

3.7 Chapter Summary

This chapter presents the research methodology of this study—all stages of the research arrange in line with the research questions and the introduced conceptual frameworks in the earlier chapters. The study selected a quantitative research design and developed conceptual frameworks (Fig. 3.2 and 3.3.). In terms of sampling and data collection, It used the standard sample size determination formula for a finite population from a simple random sampling method, yielding 95 from a population of 450 POMs. In this vein, a structured mail questionnaire was formulated to collect data from the sampled mills and sent to managerial levels, including mill managers and assistants, engineer managers, and R&D managers. The study also conducted a face-to-face interview with some respondents who reported not receiving the mail questionnaire. The response rate was 56.8%, with only 54 respondents, while 9 of the survey are dropped due to incomplete answers.

The questionnaire was approved by the consulting professor and by palm oil mill experts. Various statistical tools were used to assess the research models and hypotheses. The study applied PCA to measure the validity and reliability of the variables by factor analyses, KMO test, Cronbach alpha (see Tables 3.9, 3.10, and 3.11). Data cleaning and screening were performed by descriptive analysis.

A multi regression model is used to examine the model and assumptions regarding the first research framework. The study also applied a logit regression model for the second research framework to identify critical factors of new technology adoption by POMs in Malaysia. Moreover, the normality tests were conducted using the skewness and kurtosis values for the variables, and Kolmogorov-Smirnov and Shapiro-Wilk test, confirming no serious departure from normality. The multicollinearity tests were conducted using Pearson correlations and Tolerance Value and Variance Inflation Factors (VIF), and discriminant validity, which proved the presence of any multicollinearity problem. Lastly, the study was performed correlation analyses to assess each variable's inter-correlations with the other variables.

CHAPTER 4

TECHNOLOGY CAPABILITY DEVELOPMENT AND ITS DETERMINANTS IN MALAYSIAN PALM OIL MILLS

4.1 Introduction

This chapter presents related factors that are assumed to support the development of TCs in Malaysian POMs significantly. The chapter provides the framework and technique of analysis briefly. It indicates the state of TC and organizational learning, innovation strategy, TTM, strategy alliance, size of the firm, and type of ownership in the palm oil mills. The state of government support for the palm oil mills is also determined. In the following, the chapter presents determinants of TC development and discusses the findings. Lastly, it ends up with the conclusion of the study.

4.2 Framework and Technique of Analysis

Figure 3.2 in chapter 3 presents the conceptual framework for the study grounded on the RBV and evolutionary theories to analyze organizational learning, innovation strategy, TTM, strategic alliances, government support, age, and size of the mills are suggested as influencing factors that stimulate the firm-level TC development.

The study is deployed SPSS 22 to conduct data analysis using the Multi regression model to examine the research framework and test hypotheses. The coefficients, P-values, and R2 adjusted interpret the multiple regression model with seven independent variables. Besides, the correlation analysis is applied to determine the association between the internal and external factors as well as TTM with the TC development.

4.3 State of TC development in The Palm Oil Mills

The palm oil milling industry has grown tremendously during the past decades. There are currently 452 operational mills with a capacity of 112.91 million tonnes of fresh fruit bunches (FFB). This industry mainly depends on using machinery and equipment for multi-purpose functions, problem-solving, and creating value (Jin, 2002; Karlsson et al., 2010; Mat & Razak, 2011). Although POMs need to develop TCs to raise efficiency and productivity, the remaining firms have yet to do so due to their challenges (Madaki & Seng, 2013a). The evidence showed that only 58% of palm oil mills in Malaysia operated with moderate efficiency, and another 18% were only efficient (Hassan et al., 2012).

To evaluate the level of TC among POM firms, Table 4.1 indicates the number of mill firms that have personnel qualified for R&D and their TC group. Significantly, the majority of the POMs categorized in the intermediate TC levels possess the head of R&D. For POMs that are stimulated to achieve an advanced level of TC, finding emphasized the significance of investing in the personnel involved in R&D activities. This result is in sync with Freeman and Soete's (2009) argument, who highlighted that more focus is needed to contribute to knowledge generation to attain innovation. In the same way, Bell and Pavitt (1995, p.87) discussed that "*R&D capabilities are directly linked to the engineering capabilities, and strategic decisions are taken by management about the incorporation of new technological processes in projects involving a significant investment*."

It implies that knowledge and technology acquired by the POMs and their managers' skills are significantly correlated to the level of investment and performance of R&D, i.e., "*the level of technical expertise of managers is an important factor influencing the commitment of a company with activities that create change*." (Bell & Pavitt, 1995, p.92).

Table 4.1: Level of TC

Technology capability	Head of R&D		Total
	Yes	NO	
Basic	1	5	6
Intermediate	29	16	46
Advanced	2	1	3
Total	32	22	54

Source: Computed data analysis

In addition to the above discussion, a closer assessment (Table 4.2) shows most POMs have invested less in their R&D and development activities (below 0.2%). Even though there was some learning, managers believed that TC could have been improved much further if they had engaged in research activities increasing beyond insignificant changes in product or process and technology (Madanmohan, Kumar, & Kumar, 2004). These results imply that the presence of a small R&D budget devoted to adaptive R&D does less or no influence on the development of the TC (Table 4.2).

Table 4.2: R&D Expenditure % Sales

R&D Investment	0-2%	3-5%	6-8%	More than 9%
Mills	28 (51.9%)	18 (33.3%)	5 (9.3%)	3 (5.6%)

Source: Computed data analysis

4.4 Organizational learning Mechanisms, Innovation Strategy, TTM, Strategies Alliances, Firm Size, and Type of Ownership in The Palm Oil Mills

Qualified human resources such as scientists, engineers, and highly educated entrepreneurs have been recognized as a vital firm-specific asset enhancing capability accumulation (LeBlanc et al., 1997; Sobanke et al., 2014). The knowledge and skills of employees brought into the companies through their earlier training and formal education form its capability base. Hence, firms prefer to hire highly educated personnel due to less training required, particularly when experiencing rapid technological progress. In Malaysian POMs, the descriptive analysis shows that 44.6 % of the respondents have had managers posted at a mill for between 6 and 10 years. The operations age showed 12.5% over 10 years, while 42.9% have operated for between 2 and 5 years (Table 4.3).

Table 4.3: Work Experience.

Experience	No experience	2-5 years	6-10 years	More than 10 years
Managers	-	22 (42.9%)	25 (44.6%)	7 (12.5%)

Note: Figures in parentheses are percentages (n=54)

Source: Computed data analysis

In terms of the managerial educational level, 66.1% of the managers have had bachelor's degrees. In contrast, 21.4% have had master's degrees and 12.5% technical school academic level (Table 4.4).

Table 4.4: Educational Background.

Education	High school	Technical School	Bachelor Degree	Master Degree	PhD
Managers	-	7(12.5%)	35(66.1%)	12(21.4%)	-

Note: Figures in parentheses are percentages (n=54)

Source: Computed data analysis

Besides, more than half of the mill firms applied learning mechanisms in the shaps of on-the-job training and formal in-house training mechanisms regarding the continuous improvement in processes, products, quality, machine management, and teamwork (Table 4.5). Although training from technology donors is one major practical method to obtain technological skills, mill firms receive fewer train on behalf of their technology donors. Similarly, mill managers have not received noticeability outside training (20.4%) and training from MPOB (31.5%). In Malaysian POMs, the accumulation of TCs through on-the-job training and formal in-house training seems to be prevalent because of the inadequate training from technology donors and MPOB and external training costs.

Table 4.5: Organizational learning Mechanisms

Training	Yes	No
On- the- job training	40 (74.1%)	16(25.9%)
Formal in house training programme	34 (63%)	20(37%)
Out-side training	11(20.4%)	43(79.6%)
Training from technology donor	25(46.3%)	29(53.7%)
Training from MPOB	17 (31.5%)	37(68.5%)

Source: Computed data analysis

In addition to such organizational learning, innovation strategies can also be contributed to the accumulation of TCs. Innovation technologies in terms of participation in simple technology changes by POMs indicate that 55.6% of mills participated in oil extraction process technology (double pressing) to increase their OER, resulting in decreased CPO cost of production (Table 4.6). Vertical sterilizer systems were accounted for 29.6% of the process changes to improve temperature and sterilization, easy to separate fruit bunches, and stop enzymatic decomposition from avoiding high levels of free fatty acids.

Subsequently, POMs upgraded kernel recovery machinery (24.1%) to assure the high yield recovery process of palm kernel, whereas 16.7% of mills selected new boiler operations to change greater heater and apply fuel-feeding systems. Lastly, only 13.1% of mills were interested in wastewater treatment to decrease palm oil mill effluents. None of the mills have tended to change the oil recovery process in the new machinery recommended (Table 4.6).

Table 4.6: Firms' Technological Tools: Milling process Changes.

Process	2nd generation (changes)	Yes	No
Sterilization	Continuous sterilizers Vertical/tilting/inclined/spherical sterilizers	16 (29.6%)	38 (70.4%)
Oil extraction	Double pressing	30 (55.6%)	24 (44.4%)
Oil recovery	Two-phase decanters	-	54 (100%)
Kernel recovery	Multi-stage winnower Clay bath/hydro cyclone	13 (24.1%)	41 (75.9%)
Boiler operation	Fuel feeding system Moving grate furnace	9 (16.7%)	45 (83.3%)
Wastewater treatment	Faster rate anaerobic process Tertiary treatment for BOD-20 ppm	7 (13.1%)	47 (86.9%)

Source: Computed data analysis

Technology transferred through formal and informal organizational mechanisms and various TTMs also enable mill firms to develop their TCs. The specific channel selected determines the amount of TC transferred. It seems that the accumulation of TCs through import capital goods among POMs has received more attention due to the improvement in producing CPO and OER. A close evaluation of TTMs in Table 4.7 reveals that local R&D (57.1%), local industry development and participation (44.4%), and contracts (33.9%) had medium to low levels of importance for POMs.

Table 4.7: Firms' Technology Transfer Mode

TTM	Lowest	Low	Medium	High	Highest
Licensing	14 (25%)	31 (55.45%)	9 (12.5%)	-	-
Import capital goods	-	5 (12.5%)	13 (23.2%)	36 (64.3%)	-
Contracts	9 (16.1%)	21 (37.5%)	19 (33.9%)	5 (12.5%)	-
Local R&D	-	21 (42.9%)	32 (57.1%)	-	-
Local Industry development &participation		10 (25.9%)	24 (44.4%)	16 (29.6%)	

Source: Computed data analysis

Strategic alliances in terms of R&D collaborations and technology training with external actors can also contribute to the TC development among POMs in Malaysia. Contracts of post-sale technological support (57.1%) lead to an essential collaboration between POMs and suppliers (Table 4.8).

Table 4.8: Firm Collaboration with External Actors

Actors	Lowest	Low	Medium	High	Highest
Suppliers' Association	-	5 (12.5%)	17 (30.4%)	32 (57.1%)	-
Research Institutions	18 (34.2%)	30 (57%)	6 (8.8%)	-	-
Universities (local/aboard)	16 (28.6%)	30 (53.6%)	8 (17.9%)	-	-
Research Centers (public/private)	15 (26.8%)	31(55.4%)	8 (17.9%)	-	-
Government agency-MPOB	-	20 (35.7%)	24 (42.9%)	10 (21.4%)	-

Source: Computed data analysis

The cooperation between the POMs and MPOB (64.3%) has aimed to design collaborative strategies or implement technological development. For instance, most POMs developed linkages to understand their basic principle needs, technological development, and implement product and process improvements. The POMs and research institutions, research centers, and universities have maintained moderate alliances. It seems that even though some interactions are existing between POMs and external actors but these collaborations are not strong enough for the cultivation of their TCs.

Past researchers have emphasized the importance of the firm size in stimulating firm-level TCs (Iammarino et al., 2012; Parhi, 2005; López-Salazar et al., 2014; Katrak, 1991). Typically the financial reach of large firms has offered them the capacity to invest in risky and uncertain R&D activities (Schumpeter, 1934; David, 1975; Davies, 1979; Nelson & Winter, 1982; Dewar & Dutton, 1986; Alpar & Reeves, 1990). In Malaysian POMs, the size breakdown showed 44.4% large mills, 40.7% medium mills, and 14.8% small mills (Table 4.9).

Table 4.9: Size of POMs

Size of company	**Small**	**Medium**	**Large**
Mills	8 (14.8 %)	22(40.7%)	24(44.4%)

Note: Figures in parentheses are percentages (n=54)

Source: Computed data analysis

Firms' TC Index (TCI) is evaluated by the mean and standard deviation to assess the linkage between the size of the firm and the variables of TCI (Table 4.10). The result of their relationship revealed an R2 value of 0.684, showing a moderate-strong association. Large firms indicated the highest average level of the TC (0.6678), while small and medium firms were placed at low levels of 0.2491 and 4454, respectively. The mean variations were at a 5% level of significance.

It suggests the presence of the different capabilities among the three categories of the firms. Generally, large POMs are better endowed than small firms to allocate capital for developing their TCs. Large POMs also have easier access to financial resources required for hiring better-qualified employees and buying and installing new technology. Large mills also have the human capital and requisite skills, and other resources to accumulate of TCs. Compared to the small mills, large mills prefer to invest more in advanced technologies and seldom go until the international market to gain utilized machinery (Sobankea et al., 2014). It seems that large POMs enjoy economies of scale to amortize the investment in new technologies quickly.

Table 4.10: TCI Descriptive Statistics with RD (Tukey HSD).

No. of employees (I)	Mean	S.D	No. of employees (J)	Difference (I-J)	S.E
1-50	.2491	.13285	51-100	-.14927	.0615
			>100	-.35033*	.0608
51-100	.4454	.15212	1-50	-.14927	.0615
			>100	-.20106*	.0440
>100	.6678	.16538	1-50	.35033*	.0608
			51-100	.20106*	.0440

*. The mean difference is significant at the 0.05 level.

Source: Computed data analysis

Corporate ownership plays a significant role in explaining innovative activities within the firm (e.g., Gu & Lundvall, 2006; Choi, Park, & Hong, 2012). The firm's type of ownership may be the main factor when the R&D activities in a firm. In Malaysian POMs, the lowest-cost producers in terms of the cost of maintenance and repairs belong to partnerships and private limited firms (Noor et al., 2004). Also, privately owned plantation firms are more cost-effectively managed than partial privatization among palm oil plantations in Malaysia (Ramasamy et al., 2005). The type of ownership breakdown showed 63% privately owned mills and 37% partially privatized ownership mills in Malaysia. It seems that private mills are further interested in having their own plantation in decreasing delivery times of FFB, which influences the quality of CPO.

In Malaysian POMs, the accumulation of TCs through privately owned mills seems to be prevalent because of the lowest cost of maintenance and repairs and the high quality of CPO produced.

4.5 State of Government Support for the Palm Oil Mills

The palm oil milling sector has grown rapidly following government efforts to diversify agricultural exports since the 1970s. Given the exhaustion of arable land in Malaysia, the focus by the government and firms must shift towards the use of advanced technologies in order to develop firm-level TC. To underwrite uncertainties and risks, the Malaysian government implemented various incentives for encouraging POMs to upgrade their technologies. It made significant expenditures into such support while launching the IMP2 in 1996 and the IMP3 in 2006 (Rasiah & Shahrin, 2006). In addition, more efforts are being promoted by the government to develop different treatment methods to produce POME that conforms to the regulatory discharge limits (Taha & Ibrahim, 2014).

Government support and incentives in terms of Tax incentives and technology development loans moderately have contributed to the accumulation of TCs (see Table 4.11). The level of satisfaction regarding receiving government aids by venture capital supports among mills has captured a medium-low level. Similarly, Malaysian POMs consider that existing policies and incentives on government technology support and assistance programs (42.4%), training supports (64.6%) predominantly from government agents, are moderately sufficient to convince them to accumulate TCs.

Table 4.11: Government Support

Government support	Lowest	Low	Medium	High	Highest
Tax incentive	3 (5.4%)	15 (26.8%)	28 (50%)	8 (17.9%)	
Technology development loans	-	38 (67.9%)	14 (25%)	2 (7.1%)	-
Venture capital supports	24 (42.9%)	23 (41.1%)	7 (16.1%)	-	-
Technology support & programs	-	30 (57.6%)	21 (37.1%)	3 (5.3%)	-
Training supports (R&D personal)	-	20 (35.4%)	25 (47.5%)	9 (17.1%)	-
Others	-	-	-	-	-

Source: Computed data analysis

4.6 Determinants of the TC development

Determinants of the TC development in this study derived from the proposed framework included the internal factors (organizational learning, innovation strategy, size of the firm, and type of ownership), external factors (strategy alliance and government support), and TTM. Hence the study sought to investigate the critical factors mentioned to determine a milling firm's ability to develop TC, mainly through TTMs.

Regarding the correlation indicators are involved, Table 4.12 reveals that the correlation between independent variables is not so high; hence, they should not bias the statistical significance and disprove the model. The results indicate that the strong correlations were the relationships between size of the firm and RD ($r = 0.694$, $p < 0.01$), innovation strategy and PT ($r = 0.683$, $p < 0.01$), government policy and PT ($r = 0.691$, $p < 0.01$), size of the firm and PT ($r = 0.634$, $p < 0.01$), and technology transfer mode and PT ($r = 0.667$, $p < 0.01$).

Table 4.12: Correlation Analysis Between TC development and Its Determinants

	OL	INN.S	TTM	SA	GS	SIZ	OWN	RD	PT
OL	1								
INN.S	.139	1							
TTM	.141	.351**	1						
SA	.110	.315*	.264	1					
GS	.173	.586**	.380**	.299*	1				
SIZ	358**	.543**	.378**	.373**	.314*	1			
OWN	.323**	.404**	.277*	.348*	.223	.590**	1		
RD	.102	.379**	.319*	.341*	.474**	.694**	.446**	1	
PT	.213	.683**	.667**	.338*	.691**	.634**	.328*	.493*	.

**P-value significant at the 0.01 level. *P-value significant at the 0.05 level.

Note 1: OL = organization learning, INN.S =innovation strategy, TTM = technology transfer mode, SA = strategy alliance, GS = government support, SIZ = size, OWN = type of ownership, RD = product technological capability, and PT = process technology capability.

Source: Computed data analysis

The innovation strategy has a strong and positive correlation with the size of the firm ($r = 0.543$, $p < 0.01$). Moreover, another strong and positive relationship occurred between the government policy and innovation strategy ($r = 0.586$, $p < 0.01$). The variable strategy alliance has a positive and significant association with PT ($r = 0.548$, $p < 0.01$). Correspondingly, the linkage between the size of the firm and the type of ownership is considerable ($r = 0.590$, $p < 0.01$).

The results show that all the hypotheses are confirmed concerning correlations except for H1a. Therefore, this study can generally infer that innovation strategy, mode of technology transfer, government policy, size of the firm, and type of ownership factors are associated with the increased ability of the POMs to developing TCs.

Although the problem of multicollinearity examined (see Tables 3.14 and 3.17 in Chapter 3) proves that it no concern in this study, Durbin-Watson also has been applied to check auto-correlation, which suggested no auto-correlation when values are above 1.5 and below 2.5 (Statistics Solutions, 2017). The results of both models (dI = 1. 841 and dII= 1.828) were been between the two significant values of $1.5 < d < 2.5$. As a result, the research can assume that first-order linear autocorrelation in the multiple linear regression data does not exist.

Besides, the Breusch-Pagan test was applied to evaluate linear regression homoscedasticity (Black, Hashimzade, & Myles, 2009). Although this test is not part of SPSS, macros exist online that can be imported into SPSS to do so. The macro used was developed by Daryanto (2013) and also included the Koenker test. According to the macros' result developed by Daryanto, the homoscedasticity assumption has been violated if the Sig value below 0.05. The results in Table 4.13 confirmed that homoscedasticity has not existed in this study.

Table 4.13: Breusch-Pagan and Koenker on TC development

	LM	**Sig.**
Breusch-Pagan	5.668	.579
Koenker	6.961	.433

Source: Computed data analysis

This study proceeds to examine the research framework and test hypotheses by using a multi regression model. Table 4.14 indicates the two models. In the first model, all of the variables are analyzed. The findings of the R^2 adjusted explain that 63.6% of the variation in the TC model I is defined by the innovation strategy, TTM, government support, and size of the firm. In the second model, a stepwise method has been applied. The findings of the R^2 adjusted shows that 65% of the variation in the TC model II is explained by innovation strategies, TTM, government support, and the size of the firm.

Table 4.14: Multiple regression analysis

Variables	**Model I**	**Model II**
Organization learnings	.026 (.285)	
Innovation strategies	.329 (2.809)***	.279 (2.615)**
Technology transfer mode	.267 (2.816)***	.249 (2.745)***
Strategies alliance	.068 (.736)	
Government supports	.270 (2.331)**	.317 (2.924)**
Size	.260 (2.029)**	.212 (2.024)**
Ownership	.101 (.905)	
Constant	.155(1.135)*	.112 (.942)*
F	14.216	25.66
Prob >F	.000	.000
R^2 adjusted	.636	.650
Durbin-Watson	1.841	1.828

*Significance to the 10% level; ** Significance to the 5% level;*** Significance to the 1% level.

Source: Computed data analysis

4.6.1 Hypothesis Testing

This study investigates the influence of the internal (organizational learning, innovation strategy, size of the firm, and type of ownership), external (strategic alliances, government policy) factors, and TTM on the dependent variable TC development by POMs in Malaysia.

In the model I and II results, organization learning is statistically insignificant at the 5% alpha level, and hence, it calls for the rejection of hypothesis H1a. Innovation strategy and firm size were the results of the internal influencing factors of TC development that were significant at p-Value<0.05, which support the hypotheses H1b, and H1c, respectively. Type of ownership was not statistically a significant factor in the development of TC, and hence, H1d should be rejected.

The results in Table 4.14 show that strategic alliance is statistically insignificant at the 5% alpha level, and hence, call for the rejection of hypothesis H1e. In contrast, government support has a positive and significant influence on TC development at the 5% level, which lends support for hypothesis H1f.

Lastly, TTM was a significant influencing factor of the development of TC, and hence, H1g should be supported. The results allows the pursuit of the following multi regression equation model I & II:

$$TC\ I=0.155+ .329\ (INN.S) + .267(TTM) + .270(GS) + .260(SIZ) +1.135$$

$$TC\ II=0.112+ .279\ (INN.S) + .249(TTM) + .317(GS) + .212(SIZ) +1.118$$

4.7 Discussion

The conceptual framework produced interesting and statistically significant results for explaining the ability of POMs to develop their TCs. This study found that internal and external factors significantly contribute to the TC development of the recipient POMs. The findings of Madanmohan et al. (2004) who used the conceptual framework in the manufacturing firms in Indian and Indonesia, which concur with the importance of TTMs, also found both factors more important to cultivate TC through imported technology.

4.7.1 Internal Factors

Organizational learning, innovation strategy, size of the firm, and type of ownership were the influences captured in the internal factors of TC development.

Hypothesis H1a was not be supported as organizational learning showed a statistically insignificant relationship with the development of TC, which is not in sync with the findings of several studies that argue that the development of TC depended on the ability of the firm to choose the appropriate method for acquiring new technologies (Narayanan, 1998; Chesbrough, 2006; Madanmohan et al., 2004; Wignaraja 2002; Egbetokun et al., 2010; Börjesson & Löfsten, 2012; Sobanke et al., 2014; López-Salazar et al., 2014; Hansen & Ockwell 2014; Toyama et al., 2014; Akinwale et al., 2018; Ofoka & Nwalieji, 2019). A possible explanation for this result is that externally mediated learning dependent on how knowledge is obtained and internalized into the organization from resources external to the firm (Bell & Figueiredo, 2012). Interviews show that a few numbers of POMs have trained their managers through outside training. Furthermore, the high cost of external training for small and medium milling firms that experience a lack of financial support can explain this result.

However, POMs need to provide their managers with opportunities to participate in government tech programmes and courses, those relating to various aspects of their organization product and process technology to promote manager advancement and meet their specific firm needs, to enhance their TC and competitiveness. Therefore, milling firms should benefit from the campaigns of research, training, and conferences by MPOB (Cramb & Curry, 2012; Rasiah & Shahrin, 2006) to increase their knowledge levels that lead to their TC development.

Innovation strategy showed a significant relationship with the ability of the mill firm to develop TCs (Hypothesis H1b). This result concurs with several findings (Contractor &

Sagafi-Nejad, 1981; Gunday et al., 2011; Hervas-Oliver et al., 2014; Karabulut, 2015) who argue the importance of product and process innovation strategies to improve internal firm processes and learning and growth. Interviews with mill managers show that the oil extraction process change through a double pressing technology generates a considerable contribution to TC development than other processes. Milling firms modify or adopt milling technology processing with the aim of increase OER, decrease oil losses, and develop productivity and efficiency, staying competitive in their marketplace.

Firm's size was an influencing factor in POMs' TC development and substantially supported hypothesis H1c, which confirms previous findings that found firm size as a significant influence on the cultivation of TC (Panda & Ramanathan, 1996; Wignaraja, 2002; Parhi, 2005; Iammarino et al., 2009; Iammarino et al., 2012; Chandran, & Rasiah, 2013; López-Salazar et al., 2014; Akinwale et al., 2018). Larger mills are attempted to increase R&D activities than smaller mills. This means that firms with more employees had higher advanced R&D programs. Most large firms moved toward inclusive quality management by adopting ISO 9000 quality management standards and sustainable oil palm products by RSPO certification to enhance their quality of CPO and reduce environmental impact, hence remain and develop competitively. In addition, the majority of the large mills had regular maintenance and repairing of equipment, a maintenance store, and expert maintenance human resources. Compared with large mills, small mills seem likely to take on repairs only when machinery breaks down and operation is stopped. Finally, interviews show that large mills had a higher collaboration with other actors such as MPOB, universities, and R&D research institutes than small mills.

Type of ownership was not significant (Hypothesis H1d), which is not in line with many previous findings (Boubakri & Cossets, 1998; Gu & Lundvall 2006; Hill, 2007; Choi, Park, & Hong, 2012; Talaja, 2013). This result might reveal the fact that few partially privatized ownership mills are in the sample of the study for this result to appear.

Moreover, partially privatized ownership mills may have more investment in training managers and technical employees. They may have accumulated TCs and better develop new products and processes, specifically those with partners equipped with R&D labs, R&D center research, and a higher level of collaboration with other actors. Private Mills prefer to invest in their own R&Ds. Although some partially private mills enjoyed joint ventures such as Sime Darby, the rest have a lack of investment in R&Ds. Also, both types of POMs' ownership (privately owned and partially privatized) were the lowest-cost producers (Noor et al., 2004); this highlights that type of ownership has not been involved in cost-saving among mills.

4.7.2 External Factors

Strategic alliance insignificantly impacts TC development (Hypothesis H1e). The results of this part are not supported by other researchers who revealed R&D collaboration between the firms and various actors positively influence on developing the firm's TCs (Urata & Kawai, 2002; Amara et al., 2008; Massa & Testa, 2008; Kaminski et al., 2008; Boujelben & Fedhila, 2010; Iammarino et al., 2012; Börjesson & Löfsten, 2012; Hinkkanen et al. 2012; Sobanke et al., 2014; López-Salazar et al., 2014; Hansen & Ockwell 2014: Egbetokun et al., 2012; Madaki & Seng, 2013b; Akinwale et al., 2018). A possible justification for this result is that there are constraints, for instance, the level of obligation of the universities, delivery objectives, the lack of trust, disinclination to share secret firm information, rules in the achievement of purposes, and service stability. When Firms attain a higher level of TCs, collaboration with universities may obtain more important because they may not be interesting partners to cooperate with until that point (López-Salazar et al., 2014). Interviews with the managers show that mill managers should take the initiative to collaborate with research institutes and universities in and outside Malaysia and suppliers to involve in the R&D of new technology and make the machinery user-friendly and simplify the maintenance procedures.

Another explanation for this result is that mills generally recognized ‘us-they’ conditions among themself and MPOB (Baluch, 2012), which discourage milling firms from collaboration with MPOB. It seems MPOB requires improving its relations with POMs; hence more innovative techniques and proactive methods will be necessary to increase partnerships between the engineering mills, universities, and government research institutes in this industry.

Government support showed a significant relationship with mill firms’ ability to develop TC (Hypothesis H1f), which strengthens several past findings (e.g., Lin & Ho, 2010; Veugelers, 2012; Lee et al., 2014: Ismail et al., 2003). This result implies that cooperative R&D ventures among POMs and public research institutes often experienced financial aid from the government. Private research in companies and educational institutes were enjoyed government supports (Chandra & Kolavalli, 2006). In addition, the Malaysian government should provide more financial support and incentives and selectively target the specific learning process to stimulate TC development in the palm oil milling industry.

4.7.3 TTM

The importance of selecting a proper channel is demonstrated by the significant relationship between TTM and the accumulation of TC (Hypothesis H1g), which is consistent with the findings of past studies (e.g., Contractor & Sagafi-Nejad, 1981; Iammarino et al., 2009; Urata & Kawai, 2002; Madanmohan et al., 2004; Kumar et al., 2002; Akinwale et al., 2018). This result indicates that milling firms that selected the import capital goods to acquire technology significantly contributed to TC development than other channels.

Interviews show that imported capital goods, especially advanced oil extraction machinery have been purchased and installed from some owned Malaysian suppliers such as Boilermech, Hur Far Engineering Works companies. It indicates the recipient's mill firms enjoyed great absorptive capacity where imported capital goods were selected. A possible justification for this result is that in-house product and process developments or R&D activities were insignificant and still in progress in milling firms. Thus, imported capital goods were considered to obtain the needed technology and operate production facilities.

4.8 Conclusion

This study sought to investigate the influencing factors of TC development by developing a 7-factor model through a conceptual framework to establish its determinants.

The hypothetical factors accompanied by significant coefficients include innovation strategy, firm size, TTM, and government support have been significant determinants of TC development. It is noteworthy that both internal and external factors had more impact on the development of TC, mainly through TTMs.

The study tested and validated the proposed framework, which showed statistically significant relationships between internal and external factors as well as factor TTM and the development of TC. Consequently, the results offer a solid conceptual basis for the development of TC in the palm oil milling industry in Malaysia. It also replicates past findings on the influence of the TTM factor in the accumulation of TCs. Whereas innovation strategy, firm size, TTM, and government support were the most important affecting factors for enhancing the ability of POMs, organizational learning mechanisms, strategic alliances, and type of ownership were not significant. Since innovation strategy drives absorptive capacity, milling firms need to invest in continuous changes and evaluate the modified process.

The findings show evidence of operating expenditure thinking that the recipient firms pursue investing and taking distinct benefits of their technical knowledge and skills (Williamson, 1985). Consequently, firms tend to select the modes of technology that guarantee their knowledge sources are effectively utilized with the TC internalized fully.

Although technology transfer projects improve product quality and/or production capacity, they had a low contribution to the TC as milling firms were not skilled. Hence, POMs need to support sustained technical skills and training efforts to ensure that the adopted technologies meet their expected operational needs. This justification is supported by Harun et al. (2015), who argue that some of this new technology faced malfunction and Irregular maintenances.

Furthermore, the study's evidence suggests that the size of the firm is associated with the development of TCs. Large mills seem to have accumulated the required competitive capabilities to produce the CPO with high-quality standards by imported capital goods and modifying their processes. However, small and medium milling firms have lagged behind in the development of their TCs. Thus, these milling firms should link to technology suppliers to fully understand the technology acquiring capability potential in themself. The research has also highlighted the vital role of government support in the development of TC among POMs. Lastly, the study provides several implications for policymakers, mills' CEO and managers, and practitioners, presented in Chapter 7.

4.9 Chapter Summary

This chapter details the relationship among internal (organizational learning, strategy innovation, size of the firm, and type of ownership), external (strategy alliance and government support) factors, and mode of technology transfer with the development of TC among Malaysian POMs. The descriptive analysis is applied to explain the basic tables of the data and provide simple reviews on the factors. The correlation analysis is used to investigate the inter-relation between determinants of TC. Moreover, a multi regression analysis is applied to discover paths among variables. More specifically, it was measured the extent of the milling firm's ability to develop TCs through internal and external factors as well as TTMs. The hypotheses are tested, and then the results are carefully discussed. The results have emphasized that TC development is significantly dependent on the innovation strategy, mode of technology transfer, government support, firm size, and type of ownership in the POMs. Lastly, the conclusion of the findings is presented.

CHAPTER 5

THE IMPACT OF TC DEVELOPMENT AND INNOVATIONS ON FIRM PERFORMANCE IN MALAYSIAN POMs

5.1 Introduction

This chapter presents the impact of TC development and innovations on the performance of POMs in Malaysia. The chapter provides the framework and technique of analysis briefly. The relationship between TC, innovations, firm performance, and linkage among innovation types are also presented. Next, the chapter details the links among TC, innovation types, and firm performance in the POMs, discusses the findings, and ends with the study's conclusion.

5.2 Framework and Technique of Analysis

Figure 3.2 in chapter 3 presents the conceptual framework for the study grounded on the RBV and evolutionary theories to examine the relationship between TC development and innovation types, including product, process, marketing, organizational innovation, and firm performance in Malaysian POMs.

The study deployed SPSS 22 to conduct data analysis using the multiple and linear regression models to examine the research framework and test hypotheses. A multiple regression model is employed to explore the linkage between TC development and firm performance. In contrast, the association among innovation types and their impact on firm performance have been examined in a linear regression model. The coefficients, P-values, and R^2 adjusted interpret the regression models. Also, the correlation analysis is applied to determine the association between the TC and innovations with the dependent variables firm performance.

5.3 TC and Firm Performance

It is clear from past studies that TC will have to play a positive and significant role in firm performance. Lestari & Ardianti (2019) concluded that TC directly affects performance and indirectly impacts firm performance through innovation. TC can be considered as a critical factor in enhancing firm performance and obtaining firms' competitive advantages in the highly competitive market. Firms can manage to accumulate organizational resources and skills and participate in strategic activities with high TC, achieving competitive advantages and enhancing firm performance (Hobday & Rush, 2007; Lin & Lai, 2020). Most studies investigating the link between TC and firm performance were involved R&D investments and/or patents (e.g., Hall, 1995; Acha, 2000; Chen et al., 2009). The importance of R & D's role as a core of innovation in affecting a firm's innovative ability was highlighted by Cozzarin (2006) and Yam et al. (2004). The correct exploration and combination of R&D resources could bring enormous economic performance for firms (Peteraf, 1993). Past research pointed at the positive impact of R&D investments on enhanced productivity and innovation performance (e.g., Hall, 1995; Wakelin, 2001; González & Gascón, 2004; Kafouros et al., 2008; Hashi & Stoji, 2013; De Fuentes et al., 2015). Contrarily, several researchers considered other aspects of TC, including technological shifting, acquiring, and operating capabilities (e.g., Guifu & Hongjia, 2009; Wang et al., 2006). However, empirical studies have shown that TCs significantly impact firm performance (e.g., Madanmohan et al., 2004; Martín-Rojas et al., 2013; Lestari & Ardianti, 2019).

Despite the development models of TC and the substantial research in different industries, limited studies investigated the TC-firm performance relationship with product and process capabilities (e.g., Chandran & Rasiah, 2013), especially in the Malaysian palm oil milling industry. Therefore, this study examined this linkage based on R&D capability and process capability among POMs in Malaysia.

5.4 Innovations and Firm Performance

Innovations can enhance the firm performance in several aspects. Notably, four different performance dimensions are employed in the literature to represent firm performance (Narver & Slater, 1990; Barringer & Bluedorn, 1999; Antoncic & Hisrich, 2001; Hornsby et al., 2002; Hagedoorn & Cloodt, 2003; Yilmaz et al., 2005). These dimensions are innovative performance, production performance, market performance, and financial performance. This research is investigated three aspects of firm performance, including innovative performance, production performance, market performance.

Innovation is considered a vital driver for firms' long-term success in highly competitive markets (Darroch & McNaugton, 2002; Baker & Sinkula, 2002). The innovation ability is the introduction of new products and processes and modification of existing products, and opening new markets, which can lead to an increase in both the number of product variations and the firm performance. Since successful innovation is closely linked to effective performance, firms should focus on external and internal factors to develop new products to increase their performance (Sheng, 2017). Innovative firms can respond to the challenges faster, introduce new products, and better market prospects than non-innovative firms.

Varis and Littunen (2010) investigated the relationship sources of information, different types of innovation, and firm performance among SMEs in Finland. They found that the innovation process and introduction of the products' novelty significantly influenced its growth but did not impact its profitability. Similarly, several empirical studies have proved that the higher level of innovation capabilities resulted in improved firm performance (e.g., Gunday et al., 2011; Wu, Mahajan, & Balasujbramanian, 2003; Ul Hassan et al.,2013; Yıldız et al., 2014; Rajapathirana & Hui, 2018; YuSheng, & Ibrahim, 2020).

Innovation performance is initially associated with the non-financial aspects of firm performance, such as customer aspects, satisfaction, and subsequently enhanced financial performance (Gunday et al., 2011). Even though innovation in a short period might cause possible loss (Visnjic et al., 2016), it might positively affect the market, production, and financial performance during the long term (Damanpour & Evan, 1984). Wei and Morgan (2004) found that innovation performance by making greater value to customers can lead to a sustainable competitive edge, resulting in higher market performance and profitability. However, many past researchers recognized a positive linkage between the innovation-market performance (Cheng & Krumweide, 2010; Gunday et al., 2011; Stock & Reiferscheid, 2014; Gök & Peker, 2017; Rajapathirana & Hui, 2018).

Market performance can be obtained from how firms profit market-related results than their competitors in terms of new customer acquisition, customer satisfaction, loyalty, and so on (Oh et al., 2014). Firm market and financial performances can only be reached with superior judgmental/innovation performance (Agrawal et al., 2003). Therefore, innovation performance can enable firms to create market performance in various ways through identifying TC with improving product and service quality and superior value products to the customer can help gain new customers.

Furthermore, process innovations can influence the TQM efforts of the organizations (Lo´pez-Mielgo, Montes-Peón, & Vázquez-Ordás, 2009). Sadikoglu and Zehir (2010) found that innovation performance and operative performance moderately mediate the TQM practices-firm performance link and suggested that firms need to improve innovativeness to become competitive in the face of marketplace changes. Successful renewal efforts, particularly in new products, production processes, and administrative mechanisms, can significantly disseminate knowledge and coordination efficiency within the organization, which are required to operational flexibility and reduce costs-related (Koufteros & Marcoulides, 2006). Besides, Liu et al. (2009) confirmed that operational flexibility positively affects new product success. Consequently, the firm innovative performance improvement causes higher production performance improvement (Gunday et al., 2011).

Furthermore, production performance indicates organizational success concerning improving quality, cost reduction, production flexibility, and speed to market, which logically directs the organization to improve market position and cost-effectiveness (Gunday et al., 2011). However, Past scholars confirmed that the stimulant of setting and implementing such operations aims, including increasing speed for dependability, quality for customer satisfaction, flexibility for external adaptation, and cost reduction for profitability, is to effort to improve inclusive firm performance in the end (Ul Hassan et al., 2013; Gunday et al., 2011; Alpkan et al., 2002, 2003).

5.5 Linkage among Innovation Types

Typically, firms possess various levels of innovative capabilities. Therefore, creative activities must be focussed on several facets simultaneously, such as new process technologies, new products, new marketing, and organizational practices or administrative mechanisms (Azadegan & Wagner, 2011; Drejer, 2002; Lin & Chen, 2007; Johannessen et al., 2001; Garcia & Calantone, 2002). A balanced adoption rate of organizational and technological innovations helps firms sustain and increase their performance level than implementing them only (Damanpour & Evan, 1984). Walker (2004) decided that innovations impact each other and should be implemented jointly. Organizational restructuring in predicting process innovation indicates the link between organizational-process innovation (Germain, 1996). However, there is limited empirical literature regarding the linkage among innovation types (Ul Hassan et al., 2013; Gunday et al., 2011), and future research has been suggested clarifying these associations better (Walker, 2008).

5.6 Links among TC, Innovation types, and Firm Performances in the Palm Oil Mills

By investigating innovation capability and innovations in the Nigerian palm kernel processing industry, Ilori et al. (2017) categorized innovations based on technological development, marketing activities, and organizational characteristics. They revealed that Marketing innovation is associated with pricing strategies, credit facilities to customers, product package design properties, and promotion activities. In Malaysian POMs, innovation in palm oil processing is crucial to improving quality and increasing the quantity of CPO and CPKO, which in turn leads to increased productivity in POMs. Generally, the CPO extraction process is operated with low process losses and simple operating maintenance. Since these processes' technologies still appear to be staying stagnant, they need far-reaching changes tailored to the present technological innovations that are taking place in the industry. Moreover, the industry should go beyond the current products into expanding the range of CPO products and palm kernel to embrace the innovative added value in using by-products that meet the unique needs (Hashim et al., 2012). Therefore, it can be stated that this new value added can only be obtained through innovation practices.

The results in Table 5.1 indicates that the strongest correlation were the association between process-product innovations(r= 0.766, p<0.01), organizational innovation and process innovations (r = 0.733, p< 0.01), market-product innovations (r = 0.701, p< 0.01), marke innovation and R&D capability (r=0.667, p<0.01), organizational innovation and R&D capability (r = 0.650, p < 0.01).

As shown in table 5.1, the correlation coefficients between the independent variables R&D capability, product innovation, process innovation, marketing innovation, organizational innovation, and dependent variable innovation performance are 0.341, 0.562, 0.398, 0.587, and 0.369, respectively, and all significant at the p<0.01, except for R&D capability is at 5% level of significance. Thus, it provides evidence that higher innovation capabilities are related to increased innovation, product, and market performance. Similarly, the results show that greater R&D capability is associated with greater marketing performance (r=.644, P<0.01). However, process capability has not shown any correlation with other variables.

Table 5.1: Correlation Analysis Between TC, Innovation Types and Firm Performance in POMs

	RD	PD	PD.INN	PC.INN	MKT.INN	ORG.INN	INN.PF	PD.PF	MKT.PF
RD	1								
PD	.641**	1							
PD.INN	.561**	.214	1						
PC.INN	.603**	.156	.766**	1					
MKT.INN	.667**	.247	.701**	.604**	1				
ORG.INN	.650**	.137	.541**	.733**	.615**	1			
INN.PF	.341*	.141	.562**	.398**	.587**	.369**	1		
PD.PF	.367**	.247	.226	.403**	.372**	.616**	.299	1	
MKT.PF	.644**	.124	.384**	.512**	.524**	.474**	.333*	.296*	1

**significant at the 0.01 level. *significant at the 0.05 level.

Note 1: RD= P&D capability; PD= Product Capability; PRD. INN= Product Innovation; PRC. INN= Process Innovation; MKT.INN=Marketing Innovation; ORG.INN= Organizational Innovation; INN. PRF= Innovative Performance; PRD. PF= Product Performance; MKT. PF= Marketing Performance.

Source: Computed data analysis

Moreover, the correlation coefficients between innovation performance and product performance with the factor marketing performance were significant at $p<0.05$, implying that higher innovation and product performances are linked to increased marketing performance. Thus, it can be generally concluded that the higher innovation types are correlated with increased firm performance in innovation, production, and market aspects.

Although the problem of multicollinearity examined (see Tables 3.15 and 3.18 in Chapter 3) proves that it no concern in this study, Durbin-Watson also has been applied to check auto-correlation, which suggested no auto-correlation when values are above 1.5 and below 2.5 (Statistics Solutions, 2017). The results of first model (dI = 2. 280 and dII= 2.185) were been between the two significant values of $1.5 < d < 2.5$. As a result, the research can assume that first-order linear autocorrelation in the multiple linear regression data does not exist. To assess and examine the path coefficients, the study has used the samples bootstrapping method.

This study proceeds to examine the research framework and test hypotheses by using two regression models. Table 5.2 indicates the three models. In the model I, the R^2 adjusted shows that the R&D capability and process capability accounted for 54% and 42.2% of the variation in innovation and marketing performances.

In model II, organizational innovation explains 27.9%, 52.8%, and 36.7% of the variance in product innovation, process innovation, and market innovation, respectively. In addition, marketing innovation accounted for 48.2% of the variation in product innovation. In model III, innovation performance is explained by innovations of process, product, and organizational 14.2%, 30.3%, and 33.1%, respectively. Marketing innovation indicates 12% of the variation in innovation performance. Meanwhile, market and product performances are accounted for 9.3% and 3.4% of the variation in innovation performance. Product performance shows only 7% of the variation in marketing performance.

Table 5.2: Regression Analysis

Hypothesis		P-value	t-value (bootstrap)	Path Coefficient (β)	R^2 adjusted
Model 1					
H2a	R&D Capability→ Innovation Performance	.003	3.159	.640	.540
	Process Capability → Innovation Performance	.562	.584	.118	
H2b	R&D Capability →Marketing Performance	.032	2.206	.998	.422
	Process Capability →Marketing Performance	.431	.794	.511	
Model II					
H3a	Organizational Innovation → Product Innovation	.000	4.642	.541	.279
H3b	Organizational Innovation →Process Innovation	.001	7.763	.733	.528
H3c	Organizational Innovation →Marketing Innovation	.000	5.628	.615	.367
H4	Process Innovation → Product Innovation	.000	8.595	.766	.579
H5	Marketing Innovation → Product Innovation	.000	7.092	.701	.482
Model III					
H6a	Process Innovation → Innovation Performance	.003	3.128	.398	.142
H6b	Product Innovation → Innovation Performance	.001	4.905	.562	.303
H6c	Organizational Innovation → Innovation Performance	.001	5.223	.587	.331
H6d	Marketing Innovation → Innovation Performance	.004	2.867	.369	.120
H7a	Innovation Performance →Marketing Performance	.014	2.542	.333	.093
H7b	Innovation Performance →Product Performance	**.096**	1.697	.229	.034
H8	Product Performance → Marketing Performance	.030	2.223	.296	.070

Source: Computed data analysis

5.6.1 Hypothesis Testing

This study examines the impact of TC development and innovation types on various aspects of firm performance among POMs in Malaysia.

Although in model I (Table 5.2), process capability is statistically insignificant at the 5% alpha level, the results show that R&D capability has a significant influence on innovation and marketing performances at the 5% level, which supports the hypotheses H2a and H2b.

From model II, the findings indicate that organizational innovation significantly affects product innovation, process innovation, and marketing innovation at p-Value<0.000, which supports the hypotheses H3a, H3b, and H3c, respectively; however, its impact on process innovation was greater than the other innovation types.

Process innovation and marketing innovation directly affected product innovation at p-Value<0.000, which lends support for hypotheses H4 and H5.

The results of model III show that process, product, organizational, and marketing innovations have significant impacts on innovative performance at the 5% alpha level, which supports the hypotheses H6a, H6b, H6c, and H6d, respectively (Table 5.2).

Furthermore, the results indicate that innovative performance significantly affects marketing performance at p-Value<0.05 while is statistically insignificant at the 5% alpha level with product performance, and hence, H7a is supported, but H7b should be rejected.

Lastly, production performance has a positive association with marketing performance at a 5% level of significance; consequently, H8 should be supported.

5.7 Discussion

The conceptual framework produced interesting and statistically significant findings for examining the impact of TC development, innovation types on firm performance among POMs in Malaysia. This study found that R&D capability and innovation efforts, directly and indirectly, influence innovative performance; furthermore, the innovative performance makes toward a higher level of market performance, whereas R&D capability and product performance lead to higher market performance.

Two components were captured in the TC development construct, namely, R&D capability and process capability. R&D capability showed significant influence on innovation and marketing performances and lent support to H2a and H2b. This result indicates that mills engaged in R&D activities can better gain innovation performance, which in turn, to obtain more market performance. Indeed, the supply of R&D personnel, team researchers, engineers, and R&D expenditures has been found by POM firms to be important in enhancing performance on innovation and market. R&D activities in POM sectors concentrated on derived product value additions, biogas (productivity, trapping, and use as an energy), wastewater management (POME discharge standards of RSPO), and biodiesel production from palm oil through non-traditional methods (Kushairi et al., 2018). These results are in sync with previous findings who found R&D capability as an indicator contributes to assessing the performance of firms (Nerkar & Paruchuri, 2005; Ehie & Olibe 2010; Coombs & Bierly III, 2006; Wang, 2007; Anuar et al., 2011; Jegede et al., 2012; Sun & Anwar, 2015).

On the other hand, process capability statistically insignificant relationship with innovation and marketing performances. A possible justification for these results is that mills still prefer to use conventional process technologies as modern technologies malfunctions in milling firms because of irregular maintenance support and the complexity of second and third-generation milling technologies (Harun et al., 2015). Interviews with mill managers show that mill managers should take the initiative to coordinate with large firms who engaged in-process R&D activities in coordination with the supplier to modify machinery to make them user-friendly. These results are not consistent with the findings of past studies that found TC as a significant influence on the performance of the firm(e.g., Lee et al., 2001; Wang, Zhang, & Xue, 2006; Isobe, Makino, & Montgomery, 2008; Ortega, 2010; Kylaheiko et al., 2011).

Besides, process, product, organizational, and marketing innovations had direct influences on innovative performance and substantially supported the hypotheses H6a, H6b, H6c, and H6d, respectively. Meanwhile, organizational innovation is perceived to be the essential driver of innovative performance. This result shows that improved innovation activities of the firms resulted in better innovation performance. Simultaneously, organizational innovations make an appropriate environment for the other innovation types and directly influence innovative performance. Interviews indicate that mill managers should be focused more on organizational innovation that owing to its essential role in innovative capabilities to enhance their innovation performance. The findings are in line with the previous researchers who indicated that innovations are positively associated with innovation performance (e.g., Rajapathirana & Hui, 2018; Chiang & Hung, 2010; Karabulut, 2015; Ul Hassan et al., 2013; Gunday et al. 2011; Reed, Storrud-Barnes, & Jessup, 2012).

The results among innovation linkages shown that organizational innovation had a robust impact on process innovation (hypothesis H2b) and affected product and marketing innovation (hypotheses H2a and H2c). Marketing innovation significantly led to product innovation (hypothesis H4), while product innovation was a significant factor for process innovation (hypothesis H3). In addition, the results show that process innovation and marketing innovation significantly affected product innovation, lent support to hypotheses H4 and H5. Indeed, POMs with successful process innovation efforts contribute to developing the product quality and marketing activities within the milling firms. Interviews indicate that mill managers tend to be focused on their process innovation activities to alter the development of a new CPO and kernels extraction process from a cost-consuming process to one that will cause profits, thereby reducing oil losses and increasing the OER. These results are supported by previous researchers' findings, who found organizational, marketing, and product innovations significantly to be interconnected (e.g., Ul Hassan et al., 2013; Gunday et al. 2011; Walker, 2008).

Hypothesis H7b was not be supported as innovation performance showed a statistically insignificant relationship with product performance, which is not in sync with the findings of several studies (e.g., Langerak et al., 2004; Wei & Morgan, 2004), who argue that the product performance depended on the innovation performance. This unusual finding could be a consequence of innovation between what firms possibly lose in a short period (Visnjic et al., 2016) and what firms expect in long period expedite into a significant impact on the production and market performances, and consequently financial performance (Damanpour & Evan, 1984).

Furthermore, the results revealed that innovation performance significantly impacted marketing performance, and hence, hypothesis H7a should be supported. Other researchers supported this result, who found a significant association between innovation-marketing performance (Stock & Reiferscheid, 2014; Gunday et al., 2011; Gök & Peker, 2017). Lastly, product performance had a significant positive link with marketing performance and substantially supported hypothesis H8, which confirms previous findings that found production performance significantly influenced marketing performance (Li, 2005; Alpkan et al., 2002, 2003; Gunday et al., 2011; Ul Hassan et al., 2013). Interviews with mill managers show that they need to identify and manage innovations with the aim of improving their effective performance.

Thus, the study can state that there is a resulting innovativeness path, which starts with R&D capability and/or organizational innovations, ultimately directing greater market performance. Overall findings of the study that can be summarized as follows; to achieve innovation performance, POM firms need to develop their capability to bring new knowledge, technologies, and practice to improve knowledge share in their mills, uses machinery adaptions, and create original processing solutions. Mill firms can leverage know-how and technology to carry out better innovation outcomes and performance. Lastly, the findings suggest that the innovation outcomes and performance might be extremely high when a firm enjoys strong innovation efforts.

5.8 Conclusion

This study sought to examine and understand the impact of TC development, innovation types, and three dimensions of performance through a conceptual framework to determine their relationships in POM firms in Malaysia.

The study tested and validated the proposed framework, which indicated statistically significant relationships between TC development, innovation types, and three aspects of firm performance. Consequently, the findings offer a solid conceptual basis for improving firm performance in the Malaysian palm oil milling industry. Whereas R&D capability was associated with innovation and marketing performances, process capability was insignificantly related to the performances of innovation and marketing.

The results also indicate that innovation efforts were important in improving the POM firms' innovation performance. Innovations (Process, product, organizational, and marketing) had direct and indirect influences on innovative performance through product innovation. There are also different relationships among the four types of innovation. Organizational innovation appeared to be the key driver for innovation performance. This result implied that enhancing the innovation capacity of the firms, resulting in better innovation performance. Simultaneously, the strong correlation between product innovation-innovation performances suggested that effective process innovation efforts improve the quality and quantity of the product CPO and marketing activities within the POM firms.

The analysis results also exposed that marketing performance was an outcome of innovative and production performances. However, the association between innovation-product performances was not found to be significant. Therefore, improved innovation performance is subject to the level of implementation of innovations. POM firms that are possessed resources (R&D capability) to develop their innovation capabilities could anticipate a more substantial improvement in their production and market performances, provided that they foster and implement a higher degree of innovation activities. However, the lack of capabilities and skills is one of the top barriers to innovation efforts, especially in small and medium POM firms.

In addition, innovation types have more or less positive and significant associations with firm performance in some aspects. Organizational innovation was also observed that plays an important role in innovative capabilities seeing that it has the most significant regression coefficient with innovation performance. This finding is also in agreement with that by Gunday et al. (2011) and Lin and Chen (2007).

Product innovation was observed as an important driver for innovative performance, which is become a bridge to transfer the positive effects of process innovations on innovative performance. It calls for more investments in R&D capability and supports new efforts to introduce each type of innovation, particularly advanced process milling innovations. The hub role of innovative performance is also highlighted in carrying positive impacts of innovation types and conveying them to production and market performances.

However, to observe the actual firm performance, a specific amount of time lags between innovations and financial performance (Teece, 1988) is needed. This fact clarifies that why top managers often criticize, saying that they do not achieve a sufficient amount of positive outcomes of their innovative efforts. At the same time, some of the mills try to increase spending on their R&D and innovation activities. Gunday et al.'s study (2011) also confirmed that even though innovation stays the best strategic focus for most firms and the innovation expenditures have increased annually, a large number of managers were unsatisfied about the financial results of their firm's investments in innovations.

The study can infer that R&D capability and innovations have been important to improving innovative performance and that innovative performance plays a mediator role in transferring positive effects of innovations to market performance in POMs. It is expected that increased market performance happens as a consequence of increased innovative and production performances, which depend on acquiring greater innovative capabilities.

Briefly, the research found that TC development in terms of R&D capability and innovations are positively associated with firms' innovation performance. This means that these essential factors facilitate POMs' path to achieving innovation performance.

In conclusion, the findings provide a better understanding of TC development and innovations as key strategic dimensions for the Malaysian POMs to drive long-term growth and essential to stay competitive. It is more significant for mill managers in a highly competitive environment, which emphasizes developing and executing innovation together with the firm's business strategy and possessing a clear picture of innovations required where purposely explains themselves to implement through the strategic plans.

5.9 Chapter Summary

This chapter details the relationships between TC development, innovation types, and firm performance in Malaysian POM firms. The correlation matrix is applied to investigate the inter-relation between the TC development, innovation types, and firm performance. Moreover, multiple and linear regression models are employed to find paths among variables. The hypotheses are tested, and then the results are carefully discussed. The results have highlighted the importance of TC development and innovation types, especially organizational innovation, to improve innovation performance, which in turn led to product and marketing performances. Lastly, this chapter ended with the conclusion of the findings.

CHAPTER 6

BARRIERS OF NEW MILLING TECHNOLOGY ADOPTION BY PALM OIL MILLS IN MALAYSIA

6.1 Introduction

This chapter presents the critical adoption or non-adoption factors of advanced milling technologies by POMs in Malaysia. The chapter provides the framework and technique of analysis briefly and indicates the state of technology adoption in POMs and then barriers and drivers of technology adoption. The chapter discusses the impact of barriers and drivers on the adoption of advanced technology and concludes the findings.

6.2 Framework and Technique of Analysis

Figure 3.3 in chapter 3 presents the conceptual framework for the study that combines the TOE and DOI models to adopt advanced milling technologies by Malaysian POMs. To examine the research framework and test hypotheses, the study deployed SPSS 22 to conduct data analysis using the logit regression model. It derived n predictor variables that occur for the two particular responses, i.e., Y=1 adoption of advanced milling technology; Y = 0 non-adoption of advanced milling technology. Ten independent variables were used in the regression. Moreover, the correlation analysis is applied to determine the association between the technological barriers, organizational barriers, and external environmental barriers with the adoption of new milling technology.

6.3 State of Technology Adoption in Palm Oil Mills

Although the utilization of advanced milling technologies is widespread across the Malaysian palm oil milling industry, mill firms show a low level of advanced milling technology adoption, ranging from none (0) in oil recovery to 64.8% in oil extraction (Table 6.1). Also, wastewater treatment (e.g., Faster rate anaerobic process), boiler operation (Fuel feeding system and Moving grate furnace), and kernel recovery (e.g., Multi-stage winnower) showed a low incidence of advanced milling technologies adoption.

Table 6.1: Level of Adoption by POMs

Process	Frequency	Mean	Percentage (%)
Sterilization	26	.48	48.1
Oil extraction	35	.65	64.8
Oil recovery	0	0	0
Kernel recovery	18	.33	33.3
Boiler operation	15	.28	27.8
Waste water treatment	11	.20	20.4

Source: Computed data analysis

Furthermore, the evaluation of the adoption of advanced technologies by the size of POMs highlight that large mills (61.1%) adopted more than small and medium mills (38.9%) adopted advanced milling technologies in their operations (Table 6.2).

Table 6.2: Adoption of New Technology by Size of POMs

Adoption of new milling technology		SME	Large	N
YES	1	14(38.9%)	21(61.1%)	35
NO	0	16(84.2%)	3(15.8%)	19
		30	24	54

Source: Computed data analysis

6.4 Drivers and Barriers of Technology Adoption

Investigating the critical factors that drove the adoption of advanced milling technologies and the barriers that have discouraged POMs will be important to address why so many mill firms have not adopted advanced technologies. Based on the frequency analysis (Figure 6.1), financial supports and resources (86.7%), government support and policies (83.4%), costs (79.6%), technical skill resources (77.9%), competitive pressure (68.5%), and complexity (64.8%) are believed to be the drivers of advanced milling technology adoption. On the contrary, the mill firm size (85.2%), top management support (72.2%), and manager's knowledge (69.9%) are critical factors in stimulating to adopting new milling technology in mill firms.

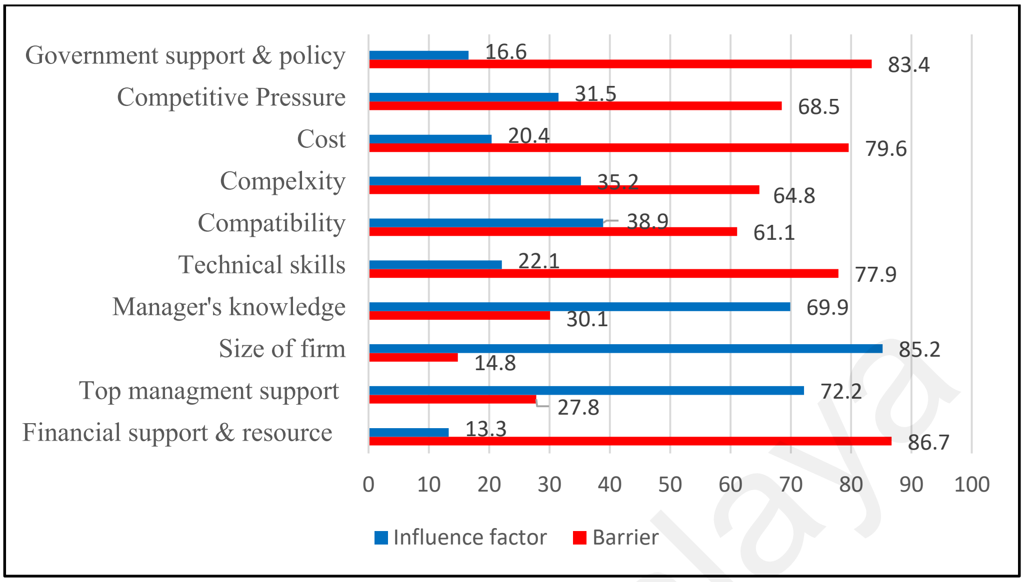

Figure 6.1: Distribution of critical factors and barriers of new milling technology adoption by POMs
Source: Computed data analysis

The results from the correlation analysis in Table 6.3 present that the majority of dimensions were significant at P<0.01, and only a few were significant at p < 0.05. In the case of technological barriers, the strongest correlation is the relationship between the cost and size of the firm (r= - 0.71, p< 0.01). The following strongest correlations are the association between complexity and size of the firm (r= - 0.67, p <0.01). Besides, the correlation coefficients between barriers complexity and lack of technical skills and complexity and cost of new technology are 0.53, p< 0.01 and 0.44, p<0.01, respectively; thus it evidence that complexity and high cost are associated with reducing the level of advanced milling technology adoption in POMs.

For organizational barriers, the strongest correlation is the relationship between the lack of financial support and the firm's size (r= -0.69, p < 0.01). Other strong coefficients correlations among barriers are lack of financial support and adoption (r = 0.63, p < 0.01), lack of financial support and cost (r= 0.56, p < 0.01), size of the firm and adoption (r= 0.54, p < 0.01), lack of technical skill and size of the firm (r= -0.52, p < 0.01). Therefore, it presents that a higher lack of financial support and lack of technical skill lead to reducing the level of new technology adoption; in contrast, greater top management supports and large firms are associated with increasing advanced milling technology adoption.

Table 6.3: Correlation Analysis Between TOE Constructs and Adoption

	CX	CP	CO	FS	TM	MK	TS	SIZ	CP	GS	AD
CX	1										
CP	-.25	1									
CO	**.44****	-.23	1								
FS	**.52****	**-.28***	**.56****	1							
TM	-.022	.20	-.077	-.08	1						
MK	**.39****	-.16	.024	.11	.085	1					
TS	**.53****	**-.34***	**.30***	.22	-.030	**.37****	1				
SIZ	**-.67****	.48**	**-.71****	**-.69****	.12	-.22	**-.52****	1			
CP	.19	**.41****	.14	.17	-.27	.19	**.36****	-.21	1		
GS	**.35****	**-.35****	.21	**.28***	-.17	**.27***	**.35****	**-.38****	.14	1	
AD	**-.43***	.23	**-.36****	**-.63****	**.26***	-.19	**-.35****	**.54****	-.22	**-.44****	1

*P-value significant at the 0.05 level, **P-value significant at the 0.001 level.

Note: CX= complexity, CP= compatibility, CO= Cost, FS=lack of financial support, TM=lack of top management support, MK=lack of manager's knowledge, TS=lack of technical skills, SIZ=Size, CP= lack of competitive Pressure, GS=lack of government support and policy, and AD= Adoption.

Source: Computed data analysis

In the context of environmental barriers, the strongest correlation is the relationship between lack of government support and adoption of advanced technology (r= -.444, p< 0.01). Also, the correlation coefficient between lack of government support and size of the firm is considerable (r= -0.38, p < 0.01). Consequently, it indicates that the level of advanced milling technology adoption depends on the lack of government support and the firm's size in POMs in Malaysia.

6.4.1 Hypotheses Testing

This study proceeds to examine the research framework and test hypotheses by using a logit regression model. Regarding overall discriminating, the results indicate a prediction accuracy of 78.3% to the overall discriminating power based on the logistic regression model (Table 6.4). Since this study includes 35 adopters and 19 non-adopters, calculating the adoption by random selection would lead to $(35/54)^2 + (19/54)^2 = 54.4\%$, which is considerably fewer than what is required for the researcher model. As a result, the logistic regression model is given priority over the random selection model due to its much greater discriminatory power.

Table 6.4: Classification

	Observed total	Predicated		Percentage Correct
		Adaptor	Non-adaptor	
Adapter	35	29	6	82.9
Non-adapter	19	5	14	73.7
Overall				78.3

Source: Computed data analysis

Table 6.5 indicates that the likelihood ratio test statistic (Chi-Square = 14.45, df = 3, and p=0.002) in the adoption model with the technological predictors fits the data significantly better than the restricted model. The results of the Nagelkerke R^2 explain that 31.4% of the variance in the adoption model is explained by the three technology attributes factors of complexity, compatibility, and cost. The -2Likelihood test value was 60.11, which indicates a strong correlation between the components of technology attributes and new milling technology adoption. The Hosmer-Lemeshow test reports a value $\chi 2 = 4.01$ and the p-value (p = 0.675), thus confirming an overall good fit for the adoption model at a significant level of 5%.

The statistical significance of the hypothesized technology attributes variables together with their regression coefficients and Wald statistics indicate that the critical factors of complexity and cost with p-values of 0.013 and 0.011 respectively are significant predictors for the adoption of advanced milling technologies at the 5% level, which therefore support the hypotheses H9b and H9c. The negative value of factors of complexity (-1.705) and cost (-1.780) in Table 6.5 show that mill managers who recognize that advanced milling technologies were complicated and costly with odds ratios of 0.182 and 0.169, respectively, are not significant predictors of adoption of advanced milling technologies. Compatibility (p-value > 0.05) is an insignificant predictor of advanced milling technology adoption with a coefficient of 0.976, and hence, H9a should be rejected.

Table 6.5: Logistic Regression analysis models of Technological Factors

Predictor	**B**	**S.E**	**Wald**	**df**	**Sig.**	**Odds Ratio**	**95% C.I. for Odds Ratio**	
							Lower	**Upper**
Compatibility	.976	.640	2.326	1	.127	2.653	.757	9.294
Complexity	-1.705	.686	6.182	1	.013	.182	.047	.697
Cost	-1.780	.698	6.498	1	.011	.169	.043	.663
Constant	1.532	.717	4.570	1	.033	4.627		
Overall Model Evaluation								

Test	**Chi-Squared**	**df**	**p-value**
Likelihood Test	14.449	3	.002
Goodness-of-Fit Test			
Homer & Lemeshow Test	4.013	6	.675
−2 Logistic likelihood		60.115	
Cox and Snell's R Squared		0.235	
Nagelkerke R Squared		0.314	

Source: Computed data analysis

Therefore, the logistic regression model was presented in the form of the logarithmic equation (Equation 6.5.1) and the logistic response function E (Y1) (Equation 6.5.2) for the adoption of advanced milling technology affected by the technology barriers where X1=complexity and X3=cost.

$$Y1 = 1.532 - 1.705\,X1 - 1.780\,X3 \qquad \text{(Equation 6.5.1)}$$

$$E(Y1) = e^{Y2} / (1 + e^{Y2}) \qquad \text{(Equation 6.5.2)}$$

The logistic response function E(Y1) (Equation 6.5.2) is used to calculate the probability of Y1 occurring of advanced milling technology adopted by a firm; for instance, in the case that a milling firm has complexity [X1(1) = 1], and cost [X3(1) = 1] E (Y1) equals to 0.124, which is close to 0.

From $Y1 = 1.532 - 1.705\ X1(1) - 1.780\ X3(1)$

$Y1 = 1.532 - 1.707 - 1.780$

$Y1 = -1.955$

$E(Y1) = e^{-1.955} / (1 + e^{-1.955})$

$E(Y1) = 0.141 / 1.141$

$E(Y1) = 0.124$ close to 0

It implies that a milling firm having these characteristics has a 12.4% probability of adopting new milling technology.

The results of the Likelihood ratio test statistic (Chi-Square =19.87, df =5 and p = 0.001) in Table 6.6 presents that the adoption model of advanced milling technology with organizational determining barriers is significantly more reliable than the fixed model alone. The results Nagelkerke R^2 model shows that the five organizational barriers explained 41.1% of the variation in the adoption model of advanced milling technologies. At -2Log likelihood= 54.69, the adoption model satisfactorily fits the investigation data. Moreover, Hosmer and Lemeshow's chi-square tests statistic (Chi= 4.980, p = 0.662) shows that the data fits the model well.

Financial support, top management support, human capital with technical skills, and size of the firm were the results of the organizational critical factors of advanced milling technologies that were significant at p-Value<0.05, which support the hypotheses, H10a, H10b, H10d, and H10e respectively (Table 6.6). The negative values of factors of financial support (-1.860) and technical skills (-1.823) in Table 6.6 show that mill managers who recognize that advanced milling technologies needed high capital and more demanded technical skills discourage from adopting advanced milling technologies. Lack of Managers' knowledge was not statistically a significant predictor of advanced milling technologies, which calls for the rejection of the hypothesis H10c.

Table 6.6: Logistic Regression analysis models of Organizational Factors

Predictor	**B**	**S.E**	**Wald**	**df**	**Sig.**	**Odds Ratio**	**95% C.I. for Odds Ratio**	
							Lower	**Upper**
Financial support	-1.860	.841	4.886	1	.027	.156	.030	.810
Top management support	1.778	.881	4.070	1	.044	5.920	1.052	33.311
Managers' knowledge	-.979	.694	1.987	1	.159	.376	.096	1.465
Technical skills	-1.823	.763	5.704	1	.017	.162	.036	.721
Size of the firm	1.647	.758	4.720	1	.030	5.189	1.175	22.920
Constant	1.004	.738	1.850	1	.174	2.728		
Overall Model Evaluation								
Test	**Chi-Squared**				**df**		**p-value**	
Likelihood Test	19.868				5		.001	
Goodness-of-Fit Test								
Homer & Lemeshow Test	4.980				7		.662	
−2 Logistic likelihood					54.696			
Cox and Snell's R Squared					0.308			
Nagelkerke R Squared					0.411			

Source: Computed data analysis

Consequently, the study proceeded with the logistic regression model in the form of logarithmic equation 6.6.1, and the logistic response function E (Y2) (Equation 6.6.2) on organizational barriers for the adoption of advanced milling technology:

$$Y2 = 1.004 - 1.860X1 + 1.778X2 - 1.823X4 + 1.647X5 \quad \text{(Equation 6.6.1)}$$

$$E(Y2) = e^{Y2} / (1 + e^{Y2}) \quad \text{(Equation 6.6.2)}$$

Where: X1= lack of financial support & resource, X2= Top management support, X4 = Lack of technical skills, and X5 =size of the firm.

The logistic response function E (Y2) (Equation 6.5.2) is used to calculate the probability of Y2 occurring of advanced milling technology adopted by the key concept organizational barriers in a firm; In the case that a mill firm enjoys a lack of financial support and resources [X1(1) =1], top management support [X2(1) = 1], lack of technical skills [X4(1) = 1] and is a large mill [X5(1) = 1], E (Y2) shall equal 0.678, which is close to 1.

From $Y2 = 1.004 - 1.860X1(1) + 1.778X2(1) - 1.823X4(1) + 1.647X5(1)$

$Y2 = 1.004 - 1.860 + 1.778 - 1.823 + 1.647$

$Y2 = 0.746$

$E(Y2) = e^{.746} / (1 + e^{.746})$

$E(Y2) = 2.108 / 3.108$

$E(Y2) = 0.678$ close to 1

It means that a mill endowed with these characteristics has a 67.8% probability of adopting advanced milling technology. Similarly, when mill size is small [X5(1) = 0], E (Y2) is accounted for 0.288, which implies that a small mill with all these specifications has a 28.8% probability of adopting advanced milling technology.

From $Y2 = 1.004 - 1.860X1(1) + 1.778X2(1) - 1.823X4(1) + 1.647(0)$

$Y2 = 1.004 - 1.860 + 1.778 - 1.823 + 0$

$Y2 = -0.901$

$E(Y2) = e^{-.901} / (1 + e^{-.901})$

$E(Y2) = 0.406 / 1.406$

$E(Y2) = 0.288$ close to 0

The Likelihood ratio test statistics (Table 6.7) shows that the adoption model with the environmental factors fits the data significantly better than the fixed only model (Chi-Square =7.10, df =2, and p = 0.029). The Nagelkerke R2 model results show that 16.5%

of the variation in the advanced milling technologies adoption models is accounted for by the two environmental factors. The -2Log likelihood value was 67.46, indicating that the model fits well the study data. The Hosmer-Lemeshow test ($\chi2$ = 1.54, p-value= 0.464) indicates that the adoption model by the two determining factors is a suitable model fit at a 5% level of significance.

Table 6.7: Logistic Regression analysis models of Environmental Factors

Predictor	B	S.E	Wald	df	Sig.	Odds Ratio	95% C.I. for Odds Ratio	
							Lower	Upper
Environment pressure	-.333	.585	.323	1	.570	.717	.228	2.257
Government support	-1.473	.604	5.948	1	.015	.229	.070	.749
Constant	1.193	.551	4.686	1	.030	3.296		
Overall Model Evaluation								
Test	**Chi-Squared**			**df**		**p-value**		
Likelihood Test	7.104			2		.029		
Goodness of-Fit Test								
Homer & Lemeshow Test	1.536			2		.464		
−2 Logistic likelihood					67.459			
Cox and Snell’s R Squared					0.123			
Nagelkerke R Squared					0.165			

Source: Computed data analysis

The results in Table 6.7 show that environmental pressure is statistically insignificant at the 5% alpha level, and hence, call for the rejection of hypothesis H11a. In contrast, government support has a negative and significant influence on adopting advanced milling technologies at the 5% level, which lends support for hypothesis H11b.

Therefore, the results allow the pursuit of the following logistic regression model in the form of logarithmic equation 6.7.1 and the logistic response function E (Y3) (Equation 6.7.2) on environmental barriers for the adoption of advanced milling technology.

Y3 = 1.193 -1.473 X2 (government support) (Equation 6.7.1)

$E(Y3) = e^{Y3} / (1+ e^{Y3})$ (Equation 6.7.2)

The logistic response function E (Y3) (Equation 6.7.2) is used to calculate the probability of Y3 occurring of advanced milling technology adopted by a firm. In case that a mill has government support (-1.473), E(Y3) is equivalent to 0.430, which implies that a mill with lack of government support has 43% probability of adopting a new milling technology.

From $Y3 = 1.193 - 1.473\ X2(1)$

$Y3 = 1.193 - 1.473$

$Y3 = -0.28$

$E\ (Y3) = e^{-.28} / (1 + e^{-.28})$

$E\ (Y3) = 0.755 / 1.755$

$E\ (Y3) = 0.430$ close to 0

6.5 The impact of barriers and drivers on Technology Adoption

The TOE-DOI framework produced interesting and statistically significant results for explaining the rationale behind why some POMs adopted advanced milling technologies while others did not. This study found that critical organizational factors have a stronger influence on the adoption of advanced milling technologies by Malaysian POMs than technology attributes and environmental barriers. The findings of Henriksen (2006) who used the TOE framework in the Danish steel and machinery industry, which concur with the importance of the organizational factors, it also found the environmental factors as more important than technology attributes.

6.5.1 Technological Barriers

Three components were captured in the technology attributes construct, namely, compatibility, complexity, and cost. Complexity and cost showed significant negative coefficients and lent support to H9a and H9c. A possible justification for these results is that when compared to conventional milling technologies, modern technologies (such as multiple screw presses) have caused malfunctions in POMs owing to irregular maintenance support, and complexity of advanced milling technologies (Harun et al., 2015), especially among POMs that have installed complex milling technologies. These findings are in sync with previous findings who found complexity and cost barrier in the adoption of advanced technologies (e.g., Ngongo et al., 2019; Yeh & Chen, 2018; Ngah et al., 2017; Thomas, 2016; Gangwar et al., 2015; Risselada et al., 2014; Ugwu, 2009; Agwu, 2006).

Interviews with the managers show that mill managers should take the initiative to coordinate with suppliers to make the machinery user-friendly and simplify the maintenance procedures. Indeed, mills equipped with managers and skillful technicians play a key role in shortening downtime in the use of advanced milling technologies. Indeed, large firms, such as Sime Darby, have highly qualified technical personnel who, in addition to solving problems, are also engaged in minor process R&D activities in coordination with the supplier to modify machinery to make them user-friendly.

Hypothesis H10b was not be supported as compatibility showed a statistically insignificant relationship with the adoption of advanced milling technology, which is not in sync with the findings of several studies (Thong, 1999; Ramdani et al., 2013; Awa et al., 2016; Chiu, Chen, & Chen, 2017; Ngongo et al., 2019), who argue that the adoption of technology depended on the degree of compatibility perceived. This abnormal finding could be a consequence of a disjuncture between what managers perceive and actual decisions made on acquiring advanced milling technologies, suggesting that a more extensive and rigorous study is essential.

6.5.2 Organisational Barriers

Financial support and resources, top management support, managers' knowledge, technical skills, and size were the influences captured in the organizational construct. Financial support and resources showed a significant and negative relationship with adoption of new milling technology (Hypothesis H10a), which concurs with several findings (Ngongo et al., 2019; Chandra & Kumar, 2018; Ogada et al., 2014). Milling machinery require heavy capital investment, and hence, it is not in the range of firms that lack sufficient finances. Consequently, some small POMs have overcome this barrier by pooling resources through collaboration with integrated plantation companies and small private millers (Dompok, 2010; Rasiah, 2018).

Top management support was statistically significant in the adoption of advanced milling technology (Hypothesis H10b), which strengthens several past findings (e.g., Chandra & Kumar, 2018; Chiu, Chen, & Chen, 2017; Ramdani et al., 2009). Managers' knowledge of advanced milling technologies was not significant (Hypothesis H10c), which is likely as top management make key decisions when involving lumpy investments. This finding is not in line with many previous findings (e.g., Madaki & Seng, 2013a, 2013b; Abdullah et al., 2015; Chandra & Kumar, 2018) that emphasize that managers' knowledge significantly influences technology adoptions. Managers and engineers tend to focus on processes and production matters, such as extraction efficiencies, product qualities, product losses, and process energy efficiencies. Also, interviews show that mill managers and technicians tend to be focused on their day-to-day tasks of operating and maintaining existing machinery (see also Bhattacharya & Wamba, 2015).

The importance of technical personnel is demonstrated by the significant relationship between human capital with technical skills and adoption of advanced milling technologies (Hypothesis H10d), which is consistent with the findings of Abdullah et al. (2015), Hölzl & Janger (2014), Baluch (2012), Silva et al. (2008) and Perron (2005).

Organized training, including specialized skill development training and external training that involves both technical personnel and management, can be a solution for improving the technical skills required to support advanced milling technologies. Milling firms reported enjoying access to free education programs, training, and workshops provided by machinery suppliers.

Firm's size was a critical factor in POMs' adoption of advanced milling technologies and substantially supported hypothesis H10e, which confirms previous findings that found firm size as a significant influence on the adoption of new technology (Ahmad et al., 2020; Ngongo et al., 2019; Awa, Ukoha, and Emecheta, 2016; Gallego et al., 2015; Ramdani et al., 2009; Jeyaraj et al., 2006; Thong, 1999). Small firms tend to lack the requisite resources, including financial funds, assets, and in-house technical skills, and hence, often avoid investing in complex and expensive machinery (Canepa & Stoneman, 2005; Zhu & Kraemer, 2005; Zhu et al., 2003). This finding is also in sync with the argument of the pioneer of the concept of innovation (Schumpeter, 1943), who argued that larger firms are more likely to engage in risky and uncertain activities than small firms.

6.5.2 Environmental Barriers

The environmental construct examined the relationship between environmental pressures driven at protecting the environment and subsequent government involvement in supporting the installation of greening measures by milling firms. Environment pressures had an insignificant negative coefficient, and hence, hypothesis H11a was not supported. Three reasons explain why environmental pressures have had little impact on the adoption of advanced milling technologies. Interviews show that the adopters were largely motivated by yields offered by the new technology as there have been little efforts to enforce these pressures in firms, especially when the output is directed at Asian and

African markets. In fact, most of these firms are still using second-generation milling technologies. Also, crude palm oil prices were generally low over the period 2015-17, which did not justify investment in new technology. Only the large integrated firms largely sought to introduce new technologies as it offered them technological benefits (see also Zailani et al., 2019; Awa, Ukoha, & Emecheta, 2016).

Unlike environmental pressure, government support had a significant negative coefficient, which supports Hypothesis H11b, which implies that government incentives and financing mechanisms are insufficient to encourage Malaysian mill firms to venture into advanced technologies, especially among non-adopters than among adopters. Generally, the most critical obstacle to taking environmental protection action is a lack of financial support (Johari et al., 2015). Therefore, the Malaysian government should provide more financial support and incentives in the forms of subsidies, low-interest loans, tax exemption, cost of funds for using advanced milling technologies, and to also more tighten controls and pressures for firms to comply with POME discharge standards of RSPO. This finding concurs with several other studies that found a lack of government support to have affected the adoption of technology (e.g., Zailani et al., 2019; Dennis & Romanus, 2018; Onwude et al., 2016; Abdullah et al., 2015; Madaki & Seng 2013b; Runhaar et al., 2008).

6.6 Conclusion

New milling technologies are second or third-generation milling technologies that were developed and introduced to the palm oil milling industry; adoption occurs after many factors have been carefully considered. Advanced milling technologies are complex and varied such that a single adoption framework will not be effective. These technologies are costly, require high maintenance expenditure, and are part of integrated mechanisms that offer POMs a competitive advantage if they are carefully identified and managed.

Technologies in advanced palm oil milling comprise a variety of aspects, including advanced oil extraction and recovery machinery, high-efficiency boilers, and high rate anaerobic digestion processors for raising oil extraction yields, CPO quality, and lowering oil losses, POME pollution, which are critical in increasing mill productivity while addressing climate change issues.

This study sought to examine the barriers and drivers of new technology milling technology adoption by developing a 10-factor model through an integrated TOE/DOI framework to establish its determinants.

The hypothetical constructs accompanied by significant negative coefficients include complexity, cost, financial support and resources, technical skills, and government support have been critical adoption factors. However, these variables have hindered adopters less than non-adopters. Top management support and firm size were significant determinants of adoption. Consequently, organizational constructs had more impact on the adoption of advanced milling technology than technological and environmental constructs.

The study tested and validated the proposed framework, which showed statistically significant relationships between T-O-E factors and the adoption of advanced milling technologies. Consequently, the results offer a strong theoretical basis for the adoption of advanced milling technologies in the palm oil industry in Malaysia. It also replicates past findings on the influence of cost factors in the installation and maintenance of new milling technologies. Whereas complexity, top management support, technical skill, and firm size were the most critical factors for adopters, government support was not significant, though firms unanimously noted that it was only because of a lack of coordination between government authorities (including incentives) and firms.

Also, the results provide important implications for policymakers, mill CEOs and managers, and practitioners that will be presented in the next chapter.

6.7 Chapter Summary

This chapter fills the study gap by testing several critical hypotheses on the drivers and barriers explaining the adoption and non-adoption of advanced milling technologies in POMs in Malaysia. The state of technology adoption is determined. The critical factors of advanced technology adoption by POMs are identified based on the logistic regression model. Also, the impact of barriers and drivers on the adoption of new technologies are discussed. Lastly, this chapter is finished with the conclusion of the findings.

CHAPTER 7

DISCUSSION, IMPLICATIONS, AND CONCLUSION

7.1 Introduction

This chapter presents all the discussions, conclusions, and implications of the quantitative research study. The chapter aims to offer a comprehensive review of the research effort. The significance of this final chapter rests in providing the contributions and implications of the study and suggesting ways for future research.

The first part of this chapter provides a discussion of the key findings of the research briefly. The next part focuses on the implications of the results based on policy, theory, and managerial perspectives. Later presents suggesting areas for future study. The last part ends the research with a conclusion.

7.2 Discussion of Key Findings

This section presents a review of the key findings regarding the research questions, based on the quantitative approach results presented in Chapters 4, 5, and 6.

7.2.1 Research Question One

The first objective aimed to investigate factors that significantly influence the TC development of oil palm mill firms in Malaysia. This study sought to examine the influencing factors of TC development by internal and external factors and the TTM factor through a conceptual framework to establish its determinants. The research results support the title that a higher development of TC can be achieved greater by increased influencing factors among POM firms. The descriptive analysis showed an intermediate level of TC development by having the head of R&D. Large mills indicated the highest average level of TC (0.6678) compared to small and medium mills at 0.2491 and 0.4454, respectively.

In respect of the internal factors, the results from regression analysis indicated that the organizational learning factor in training shapes was not a significant factor in mill firms' ability to develop TCs. The result is somewhat surprising given the strong indications in the literature that organizational learnings are made the most progress in TC among firms in developing countries (Madanmohan et al., 2004; Hansen & Ockwell, 2014). The findings also showed that innovation strategy as an internal factor in the shapes of technology process changes influenced the ability of mill firms to develop TCs.

In other internal factors, larger mill firms were more likely to work on R&D activities than the smaller mill firms. In other words, POM firms with more employees showed more advanced R&D programs. Moreover, large mills had linkages with external actors more than small and medium mills. Compared with large mill firms, small mill firms more outsource maintenance in their process milling technologies. Furthermore, the type of ownership did not influence the mills' ability to improve their TCs, especially partially privatized ownership mills. Considering to necessity of high investment for product development, it seems private POM firms prefer to invest in their R&Ds than their collaboration R&D activities with other actors.

Followed by internal factors, the study also found that mill firms choosing imported capital goods as one of the TTM contributed significantly to their ability to develop TC.

In the case of external factors, strategy alliance in the sense of R&D collaborations with external actors such as suppliers, universities, research institutes, research centers, and government agencies (mainly MPOB) was not significant about the ability of TC development.

Conversely, government policies and programs have been effective in developing mills' TCs. In this regard, the Malaysian government has followed this principle by supporting firms' private research and academic organizations (Chandra & Kolavalli, 2006) and also promoting research, training, and conferences to improve the industry's level of knowledge and networks (Cramb & Curry, 2012; Rasiah & Shahrin, 2006).

7.2.2 Research Question Two

The goal of the second objective is to examine the impact of TC development and innovations on oil palm mill firms' performance in Malaysia. This study sought to investigate the impact of TC development and innovation types on the performance of mill firms through a conceptual framework to establish their relationships. The study results confirm that a higher level of performance can be reached more incredibly by developing TC and innovativeness in POM firms. The innovation ability of the POM firms mainly depends on the R&D personal and expenditure.

The research results demonstrated R&D capability is associated with innovation and marketing performances, which highlights the importance of the supply of R&D personnel, team researchers, and engineers, as well as R&D expenditures for POM firms in enhancing the performances of innovation and market. It implies that R&D capability enables mill firms to explore different ways of handling technical hitches and identifies better technologies to produce and supply new products to satisfy the customer needs more than competitors to increase profitability and market share. Thus, mill firms that undertake TC through R&D activities more achieve innovative performance and competitive advantages.

The findings confirmed that innovation performance is reflected by innovations performed in POM firms directly and indirectly through product innovation. Moreover, among innovation types, organizational and product innovations appeared as critical drivers of innovative performance. It hints that a higher level of innovation performance is reached by developing the innovation activities, mainly organizational and product innovations within the POM firms. Also, the strong correlation between product innovation-innovation performances suggested that process innovation efforts improve the quality and quantity of the CPO and marketing activities within the POM firms.

Based on the findings, the effect of organizational innovations on process innovation was more robust than other innovations. The study showed that process innovation explained 58% of the variation in product innovation, while marketing innovation plays a critical role in product innovation. Hence, mill firms with successful process innovation efforts have improved the CPO product and marketing activities within the POMs. This result leads mill firms to promote the new oil extraction process from a cost-intensive process to one profitable by increasing the oil extraction rate and decreasing oil losses.
The research results also exposed that marketing performance is an outcome of innovation and production performances; nonetheless, the association between innovation-product performances is not found to be significant.

Briefly, the vital role of innovation performance is highlighted in this framework. It performs like a core that collects the positive impacts of innovations and transfers them to the production and market performances. These findings support that innovation strategy is a substantial driver of firm performance and needs to be developed and implemented as a central part of the business strategy.

7.2.3 Research Question Three

The third objective aimed to identify barriers and overcome them for the adoption of advanced technologies in POM firms in Malaysia. This study sought to examine the critical factors of new technology milling technology adoption by developing a 10-factor model through an integrated TOE/DOI framework to establish its determinants. The research results support the title that higher adoption of new technology can be achieved greater by decreasing barriers to adoption in POMs. The descriptive analysis showed a low level of advanced milling technology adoption with an average mean of 0.39. Also, large mills (61.1%) adopted more than small and medium mills (38.9%) adopted advanced milling technologies in their operations.

The technological constructs accompanied by significant negative coefficients include complexity and cost have been critical adoption factors. Lack of Financial support and resources and lack of technical skills were organizational barriers that impacted POMs' decisions to adopt advanced milling technologies. Regarding the external environmental obstacles, the lack of government support showed a significant relationship with the adoption of new milling technology. However, the above variables have hindered adopters less than non-adopters.

Moreover, the findings indicated that top management support and firm size were significant determinants of new milling technology adoption by POM firms. The study also found that compatibility, managers' knowledge, and competitive pressures were not significant regarding advanced technology adoption. Consequently, to overcome these barriers, the study provides implications for managers and policymaker, which could help to remove the obstacles facing the non-adopters, and effective strategies to stimulate the adoption of advanced milling technologies.

7.3 Implications

These results provide important implications for policymakers, mill CEOs and managers, and practitioners.

7.3.1 Policy Implications

The research results claimed that although the Malaysian government implemented various incentives for encouraging POMs to upgrade their technologies, the performance of many POMs has still not been effective. Hence, the results provide important implications for policymakers, which are as follows:

1) To increase the adoption of advanced milling technologies, policymakers should focus on eliminating barriers by taking a stand against inappropriate strategies and by providing supportive subsidies that motivate investment in advanced milling technologies, especially for small and medium mills as size and related factors pose significant adoption challenges. Small and medium mills, especially private POMs seldom leverage the strengths of extended functions of second-generation milling technologies since they lack the financial muscle to absorb the risks of adopting innovative and complex milling technologies.
2) Policymakers, mill CEOs and managers, advanced milling and technology investors, and suppliers must collaborate to cocreate a sustainable innovative technology economy that motivates both the demand- and supply-side of the advanced milling technologies. However, to achieve sustainable development objectives in Malaysian POMs, demand for advanced milling technology would require stringent policy measures. Sufficient investment is needed to support mill firms to obtain technical support to improve the capability of their technicians and to enhance the probability of POMs to adopt advanced milling technologies. For advanced milling technologies to act as a catalyst to achieve sustainable

development, the government has to prioritize tax incentives, such as the investment tax allowance), for mill firms that invest in costly advanced milling technologies.

3) Since the mill firms commonly perceive the ‘us-they’ syndrome, and there is a discriminatory between the taxation policies of the Malaysian government and the regulatory practices of MPOB, hence MPOB needs to improve its relationships with POMs by creating friendly-circumstances, resulting in powerful R&D alliances.
4) The Malaysian government should provide more financial support and incentives in the forms of subsids, low-interest loans, tax exemption, cost of funds for using advanced milling technologies and also to tighten more controls and pressures for firms to comply with POME discharge standards of RSPO.
5) Moreover, to increase the adoption of new technologies such as successful zero discharge concepts in Malaysia, awareness campaigns through POM firms like RSPO are required in stimulating the mills' owners and managers towards the advanced POME treatment technology.

7.3.2 Theory Implications

This study has been among the premier research designs to develop an innovative conceptual framework with respect to TC development and firm performance. This study contributes to a deep understanding of POM firms in the Malaysian palm oil milling industry and the process of their TC development. Moreover, this research investigates POM firms from a new perspective. Although some of the influencing factors of TC development have been significant, the study showed that the four influencing factors explained 65% of the variation in the development of the TC model. The study explained this balance by the postulates of the RBV theory and Evolutionary theory of the firm.

Hence, the research findings provide insightful knowledge and contribute further information towards understanding the role of TTM in the development of TC and firm competitiveness. Consequently, this study contributes to the literature by providing theoretically and conceptually developed data and empirical data, highlighting the role of the Malaysian government support and other factors affecting the development of TCs of POMs. Besides, the study suggests how the Malaysian oil palm milling industry can develop a TC strategy by recognizing the factors involved according to data acquired from the mill managers of POMs.

Regarding the second research gap, the study investigated the impact of TC development and innovative factors on firm performance in Malaysian POMs. From a theoretical perspective, prior studies on the relationship between TC and the firm's performance were conceptual (e.g., Walker, 2004). This study explains the role and importance of the innovation types completing the restricted resources on studies of firms located in developing countries (e.g., Bowen et al., 2009), particularly in Malaysia. Hence, this research is the empirical evidence of several prior conceptual studies that suggested that innovation types are significantly related to firm performance and fills the research gap in this particular area in Malaysian POM sectors.

Furthermore, the research results contribute to the existing knowledge on RBV in strategic business by explaining the relationship between TC development, innovations, and firm performance. It is important to note that the findings are relevant within the scope of the Malaysian POMs and other emerging countries, especially POMs in other palm oil milling industries, which offer to develop their TCs through creating a suitable strategy. The experience of Malaysian POM firms provides new understandings of TC development and technology transfer theories in developing countries.

Research results formulated from Malaysian POMs indicate that there is no model proper for all organizations, industries, or nations due to the diversity of the backgrounds and environments that affect a certain development way of a firm. This finding is in sync with the results of Iammarino et al. (2012), who recognized the social and economic structures of the various regions and policies that succeed in one specific area have not automatically been impressive in other perspectives. Therefore, the research suggested that government administrators and managers cannot consider the experiences of others directly into making their technology development strategies.

Regarding the third research gap, this study seeks to fill the gap by testing several critical hypotheses on the drivers and barriers explaining the adoption and non-adoption of advanced milling technologies in Malaysia's POMs. Technology adoption by firms depends on the technology's characteristics and other factors related to inter-organizational and environmental features. It is for these reasons the study deploys the technology–organization–environment (TOE) framework (Tornatzky & Fleischer 1990) and the Diffusion of Innovation (DOI) (Rogers, 2003) to investigate the adoption and non-adoption of advanced milling technologies by Malaysian POMs.

However, because of the TOE framework's limitations on providing specific characteristics of technological innovations in advanced milling technologies, this study absorbed elements of DOI theory by Rogers (2003) to investigate the critical technological adoption factors of advanced milling technology. The TOE-DOI integrated model explains better technology adoption (Awa et al., 2011; Ochola, 2015) and its competitive advantages (Mata et al., 1995; Ngongo et al., 2019), which provides a higher level of reliability and validity (Ramdani et al., 2009; Ngongo et al., 2019). Although this integrated framework has been deployed at the organizational level to investigate the adoption of new technologies, it has yet to be applied for studying the adoption of advanced milling technology by Malaysian POMs.

The research results contribute to the existing knowledge on technology adoption by identifying the barriers and drivers of advanced milling technology adoption through an integrated TOE/DOI framework to establish its determinants. Therefore, the results offer a strong theoretical basis for the adoption of advanced milling technologies in the palm oil milling industry in Malaysia. First, this study applied a combined TOE/DOI framework, expecting to have a broad view and comprehensive insights into organizational and environmental elements in addition to the technology attributes. Second, It also replicates past findings on the influence of cost factors in the installation and maintenance of new milling technologies. Third, the proposed framework could guide decision-makers in identifying the factors that could affect the adoption of new milling technology and help them draw road maps and plan strategies.

Finally, researchers and academics can benefit from understanding and analyzing the influencing factors of TC development, adopting new technology adoption, and improving firm performance by the conceptual model presented in this study.

7.3.3 Managerial Implications

The research results provide the following important implications for mill CEOs and managers, and practitioners.

1) Mill owners and managers should place more attention to evaluating the internal and external barriers that can influence their decision to adopt particular milling technologies and to implement proper strategies. The evidence on internal barriers to advanced milling technology adoption also provides a rationale for collaboration with industry, MPOB, and universities to generate commercial data

to help address gaps that create uncertainties associated with new technology adoption.

2) Mill managers should take the initiative to coordinate with suppliers to make the machinery user-friendly and simplify the maintenance procedures. Indeed, mills equipped with managers and skillful technicians play a key role in shortening downtime in the use of advanced milling technologies. Indeed, large firms, such as Sime Darby, have highly qualified technical personnel who in addition to solving problems are also engaged in minor process R&D activities in coordination with the supplier to modify machinery to make them user-friendly.
3) Milling machinery required heavy capital investment, and hence, it is not in the range of firms that lack sufficient finances. Consequently, some small POMs can overcome this barrier by pooling resources through collaboration with integrated plantation companies and small private millers (Dompok, 2010; Rasiah, 2018).
4) Organized training, including specialized skill development training and external training that involves both technical personnel and management, can be a solution for improving the technical skills required to support advanced milling technologies. Milling firms reported enjoying access to free education programs, training, and workshops provided by machinery suppliers.
5) Given that advanced milling technologies are incredibly diverse compared to conventional technologies in terms of innovation intensity and complexity and their effective utilization, POMs need to support sustained efforts in technical skills and training to ensure that the adopted technologies meet their expected operational needs. Such efforts need enormous support from top management.
6) Although advanced milling technologies have the potential to raise strongly milling efficiency, these technologies come with unique challenges, which include

adaptation to meet local conditions. Hence, mill managers should be aware of these problems to undertake the changes required.

7) Malaysian POMs should attach R&D activities in their annual business plans. Taking help from outside specialists or technicians is essential, especially for newly established POMs. Top managers should create a firm culture of innovative thought, and all employees should be part of this development. During the long period, R&D departments should utilize the knowledge generated in the mill and transform it into innovations and enhancements in processes and products.
8) When the POMs have attained intermediate levels of TCs, they should collaborate more with universities (local/aboard) and R&D research institutes and centers (public/private) to obtain the specific benefits of networking.
9) To reach highly effective organizational learning, the mill owners who cooperate with oil palm institutes and agencies, such as MPOB, should provide a trainer to help managers, specialists, and workers to improve their technological skills.
10) Mill managers should focus more on training, monitoring and checking, authorization, and knowledge to increase the effective implementation of transfer training from technology donors, total quality management, and total productive maintenance.
11) In the case of new machinery maintenance, the specialists of the maintenance department should be more concentrated on upgrading operators to operator-maintainers in total productive maintenance, or external experts should be employed to train members of the contract for the outsourcing of maintenance work (Baluch, 2012). Nonetheless, the training should embrace technical skills and knowledge required for optimizing perform functions and embrace problem-solving techniques, team working, and facilitating skills.

12) As the palm oil industry competes with other vegetable oils, POMs should emphasize types of innovation, especially product and process innovations, due to the importance of these innovations for reaching sustainable competitive power and increasing mill firm performance.

13) Considering the organizational innovations provide a proper environment for the other innovations and directly impact innovative performance, mill managers must focus on organizational innovations, which have an essential role in innovative capabilities.

14) Managers of POMs should invest further in innovative capabilities, especially R&D capability, and support new efforts to introduce each type of innovation, particularly advanced process milling innovations, to improve the quantity and quality of CPO produced and enhance organizational performance.

15) Moreover, mill managers should identify their crucial role in managing or creating innovation engagement and ensuring the mill structure is entirely in place to execute a well-structured innovation strategy.

16) Mill managers ought to identify and manage innovations with the aim of enhancement in their operational performance. Possessing a clear insight into the nature of innovations will assist POM firms to prioritize their production, market, and technology strategies to be led by a proper succeeding action plan.

17) The study could contribute to the experience of Malaysian POMs of new technology development by providing a confirmed image of the mills' critical factors to improve effective changes, resulting in enhanced industry productivity and stay competitive.

18) Studying the environmental barriers can lead to recognizing the competitive environment in the palm oil milling industry that can impact the advanced technology adoption by POMs.

19) Identifying the critical obstacles of the advanced milling technology adoption can eliminate the uncertainty of adopting new technology. It also leads to a higher technology practice to obtain benefits, including better milling efficiencies, the higher OER, the better CPO quality, less air pollution, and minor dependency on fossil fuel.

20) The significant effect of new technology practices on TC development and firm performance can help mill managers to convince mill owners to invest in new milling technologies. It would be helpful for decision-makers who are interested in expanding their business and gaining more benefits by utilizing different new milling technologies.

21) However, POMs cannot eliminate all barriers simultaneously; hence should prioritize them according to the degree of their importance and must be ready to manage the time to remove them one after another.

22) Lastly, the research efforts made by this thesis would help the other developing countries to plan and implement advanced technologies and increase the adoption rate, particularly POMs in developing countries that are involved in improving the process of production.

7.4 Further Research

As with any research, this study suggests the following directions for future research in the area as some areas relevant to this study required to be more investigated.

First, the study relied on a binary approach (adopted or not adopted). Hence, future studies should address the stages of adoption or adopted, rejected, and post-adoption to strengthen the dynamics of adoption.

Second, other critical decision factors, which may impact the adoption of advanced milling technologies should become important areas to focus on in the future.

Third, a panel study may be needed to strengthen the causality relationships established in this study. Moreover, a comparative analysis of the TC development, critical factors of the new technology adoption, and the various aspects of the firm performance may be needed among POMs in different developing countries. It can add useful knowledge into how government policies, strategies, implementations, competitive marketplace, and level of completion make similar or various situations for the development of TC and the adoption of new milling technology compared with those in the research. Therefore, the implications of this research may be generalized to other POMs in developing countries and their relative technologies.

Fourth, future research can extend this study through SME companies and various industries in different countries. Besides, researchers could focus the TC development on downstream sectors in the Malaysian palm oil industry to produce and extend the value-added products that can assist the industry.

Fifth, this study used the quantitative research methodology to respond to research objectives. Future investigation may be applied a case study to comprehensively examine the role of TC on firm performance in Malaysian POMs that engage in the process development of TC by adopting specific technologies.

Sixth, considering a larger sample size may be needed to contribute a more obvious understanding of the associations between dependent and independent variables in future studies.

7.5 Conclusion

This thesis has significantly contributed to the understanding and insufficient knowledge of TC development, advanced technology adoption, and firm performance in developing countries. It has investigated the role of TC on firm performance using a quantitative research method in POMs in the Malaysian palm oil milling industry.

The research has employed RBV and Evolutionary theories and the TOE-DOI integrated model to better understand the determinates of TC development, critical factors of new technology adoption, and the linkages between TC, innovations, and firm performance by POMs. Since the development of TC in improving firm performance and creating competitive advantages highlight among organizations and utilizing advanced milling technologies is widespread across the palm oil milling industry, it is believed the study into this area gain importance. Therefore, it could be stated that this research is a step in this regard because it aimed to generate a comprehensive image regarding the role of TC on firm performance among POMs in Malaysia.

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