THE EXPLOITATION OF INNOVATIVE ECO-PRODUCT DESIGN CAPABILITIES FOR FIRMS' SUSTAINABLE COMPETITIVE ADVANTAGE AND SUSTAINABILITY PERFORMANCE IN THE CIRCULAR ECONOMY: THE ROLE OF CUSTOMER INVOLVEMENT

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by

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Doctor of Philosophy

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To God be all glory.

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LIST OF ABBREVIATIONS

AVE	Average Variance Extracted
CA	Sustainable Competitive Advantage, see SCA
CB-SEM	Covariance-based Structural Equation Modelling
CE	Circular Economy
CMB	Common Method Bias
CMV	Common Method Variance
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalent
CR	Composite Reliability
CU	Customer Involvement
DC	Design Capabilities or Design or Exploitation of Innovative Eco-product Design Capabilities or Innovative Eco-product Design Capabilities
DfX	Design for X
EC	European Commission
EP	Environmental Performance
EMF	Ellen MacArthur Foundation
EU	European Union
f^2	Effect Size
FP	Economic Performance
HTMT	Heterotrait-Monotrait Ratio
IPCC	Intergovernmental Panel on Climate Change
MNC	Multinational Companies
MTBF	Mean Time Between Failure
NDC	Nationally Determined Contribution
NRBV	Natural Resource-based View
PLS-SEM	Partial Least Squares – Structural Equation Modelling
q^2	Predictive Relevance
Q^2	Predictive Relevance
RBV	Resource-based View
R^2	Coefficient of Determination
SCA	Sustainable Competitive Advantage, Interchangeable with CA

SDG	Sustainable Development Goal
SEM	Structural Equation Model
SP	Social Performance
TBL	Triple Bottom Line
TU	Delft University of Technology
UN	United Nations
UNEP	United Nations Environment Program
UNFCCC	United Nations Framework on Convention Climate Change
WBCSD	World Business Council of Sustainable Development
WCED	World Commission on Environment and Development

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PENGEKSPLOITASIAN KEMAMPUAN REKA BENTUK PRODUK-EKO INOVATIF UNTUK KELEBIHAN DAYA SAING DAN PRESTASI YANG LESTARI DALAM EKONOMI PEKELILING: PERANAN PENGLIBATAN PELANGGAN

ABSTRAK

Ekonomi linear menyebabkan kesusutan sumber, pengeluaran dan kemerosotan alam sekitar dan lain-lain menyebabkan kenaikan harga secara terus-menerus, pencemaran dan perubahan iklim. Penyelidikan ini mempertimbangkan faktor yang boleh menunjukkan faedah ekonomi pekeliling. Perkara ini berhipotesis secara spesifik bahawa eksploitasi kemampuan reka bentuk produk-eko inovatif dan penglibatan pelanggan (moderator) sebagai pembolehubah eksogen mempengaruhi kelebihan daya saing yang lestari dan seterusnya prestasi yang lestari termasuk alam sekitar, ekonomi dan sosial. Model penyelidikan dikurung dalam Pandangan Berasaskan Sumber (teori utama) dan diperlengkapkan dengan Teori Kapasiti Penyerapan. Data dikumpulkan sepanjang tempoh 12 minggu dengan menggunakan kajian soal selidik iaitu borang Google dalam talian dari firma Direktori FMM 2020 dengan pensampelan berstrata. Sebanyak 1416 e-mel telah dihantar dan 249 (17.58%) maklum balas diterima. Sebanyak 249 daripada maklum balas ini terdiri daripada 16 yang gagal memenuhi kriteria inklusif dari sektor Makanan, 17 jawapan “straight line” tidak terpakai dan akhirnya 216 dapat diguna pakai. Metodologi yang digunakan adalah *Partial Least Squares-Structural Equation Modelling* (PLS-SEM) menggunakan perisian SmartPLS v3.3.2 dan IBM SPSS v26. Ujian utama merangkumi statistik deskriptif, analisis faktor eksploratori, model pengukuran

reflektif dan model struktur. Hasil kajian menunjukkan bahawa kesemua 8 hipotesis telah disokong. Oleh itu, reka bentuk dapat mempengaruhi SCA dan dimoderasi oleh Penglibatan Pelanggan. SCA dapat mempengaruhi Prestasi Kelestarian. Hal ini memaklumkan syarikat bahawa pembolehubah eksogen dapat mewujudkan SCA untuk prestasi kelestarian yang berikutnya. EFA telah menghasilkan 3 faktor untuk penyelidikan masa depan. Mereka adalah Faktor 1 Reka Bentuk untuk Kitaran Semula, Faktor 2 Reka Bentuk untuk Pemakaian dan Factor 3 Reka Bentuk untuk Kualiti. Empat cadangan termasuk: Pertama, ekonomi pekeliling harus dilembagakan. Kedua, komuniti perniagaan mesti diberitahu bahawa kemampuan reka bentuk produk eko yang inovatif merupakan dasar yang mesra perniagaan. Ketiga, agenda tindakan iklim, kemakmuran ekonomi dan perhatian sosial yang lebih luas dan global dapat dicapai dengan kemampuan reka bentuk eko-produk yang inovatif. Keempat, penglibatan pelanggan harus diperkenalkan bagi tujuan SCA.

THE EXPLOITATION OF INNOVATIVE ECO-PRODUCT DESIGN CAPABILITIES FOR FIRMS' SUSTAINABLE COMPETITIVE ADVANTAGE AND SUSTAINABILITY PERFORMANCE IN THE CIRCULAR ECONOMY: THE ROLE OF CUSTOMER INVOLVEMENT

ABSTRACT

The linear economy causes resource depletion, emissions and environmental degradation and respectively induces price spirals, pollution and climate change. This research considered factors which could instead reveal the benefits of the circular economy. It specifically hypothesized the exploitation of innovative eco-product design capabilities and customer involvement (the moderator) as exogenous variables influencing sustainable competitive advantage (SCA) and consequently sustainability performance - environmental, economic and social. The research model is grounded in Resource-based View (the primary theory) and supplemented with the Theory of Absorptive Capacity. Data was collected over a 12-week period using an online Google form questionnaire survey from firms of the FMM Directory 2020 with stratified sampling. A final total of 1416 emails attracted 249 responses (17.58%). These 249 responses (100%) comprised 16 (6.42%) which failed the inclusive criteria from the Food sector, 17 (6.83%) straight lines and finally 216 (86.75%) usable. The methodology used was Partial Least Squares-Structural Equation Modelling (PLS-SEM) deploying the SmartPLS v3.3.2 and IBM SPSS v26 software. Major tests included descriptive statistics, exploratory factor analysis, reflective measurement model and structural measurement model measurement. The results show all 8 hypotheses have positive relationships and are supported. Therefore, Design could influence SCA with large effect size and is moderated by Customer Involvement (weak effect size). The SCA could influence Sustainability Performance with large effect size for Social Performance and weak for both environment and economic. The SCA could positively mediate between Design and Sustainability Performance. These inform firms that the exogenous variables could create SCA for subsequent Sustainability Performance. The EFA yielded 3 factors for future research. They are Factor 1 Design for Recyclability, Factor 2 Design for Usage and Factor 3 Design for Quality. The four recommendations are: First, the circular economy should be institutionalized. Second, the business community must be informed that the innovative eco-product design capabilities are pro-business policy. Third, the greater and global agenda of climate actions, economic prosperity and social concerns could be met with innovative eco-product design capabilities. Fourth, customer involvement should be introduced for SCA.

CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter introduces the linear and circular economy and their impact on the environment, economy and society. This will be followed with the problem statement, research objectives and questions, significance of the study, the theoretical and practical contribution, and the list of glossary and definitions. The setting of linear economy and the circular economy are introduced in this immediate section while its next sub-sections will elaborate this setting. The linear economy is the take-make-use-throw practice (Korhonen et al., 2018a) or sometimes called the cradle-to-grave economy (Braungart, McDonough, & Bollinger, 2007). Firms harvest materials from the Earth, make them into products, sell to consumers, and have them thrown away when they are no longer useful (EMF, 2013).

The global economic system, from extractions, received about 65 billion tonnes of raw materials in 2010 and 82 billion tonnes are expected in 2020 (Figure 1.1) (EMF, 2013). The percentage change from 1980 to 2020 was 200% for metal ores, 116% non-metallic minerals, 81% fossil energy carriers and 67% biomass. The total compounded annual growth rate for these combined extractions was 1.8%. The first three relate to extractions of metals and non-metals while biomass relates to renewables. The biomass from plants and animals, and municipal solid wastes (also considered biomass) when burned would supply heat energy and release carbon dioxide (CO_2) or when left to decay emit methane (CH_4) (Leme, Rocha, Lora, Venturini, Lopes, & Ferreira, 2014; Powell, Chertow, & Esty, 2018) causing the greenhouse effect (GHG) (IPCC, 2013a). The annual per capita tonnes on a global basis were 9.1 (1980), 8.7 (2002), 9.5 (2010 forecasted) and 10.6 (2020 scenario). In terms of per capita consumption on a country basis, Malaysia's 16.6 tonnes per capita trailed behind Singapore (32.6 tonnes per capita) and the US (18.6) but ahead of Thailand (12.7) and Japan (8.9) (Figure 1.2) (OECD, 2019).

The consumption and accompanying wastage deplete resources, emit pollutants and degrade the environment (EMF, 2013). This physical exploitation of resources cannot go on forever with global population growth and the rise of middle-income consumers because the Earth has limited resources (Meadows, Meadows, Randers, & Behrens, 1972). A solution must be found which could persuade firms adopting it.

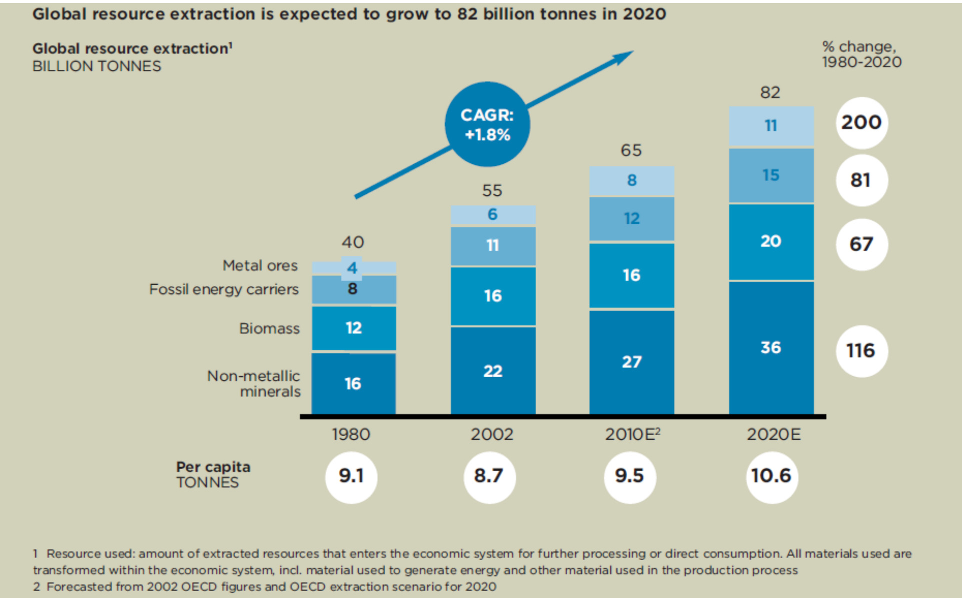


Figure 1.1 Global resource extraction
Source: EMF (2013)

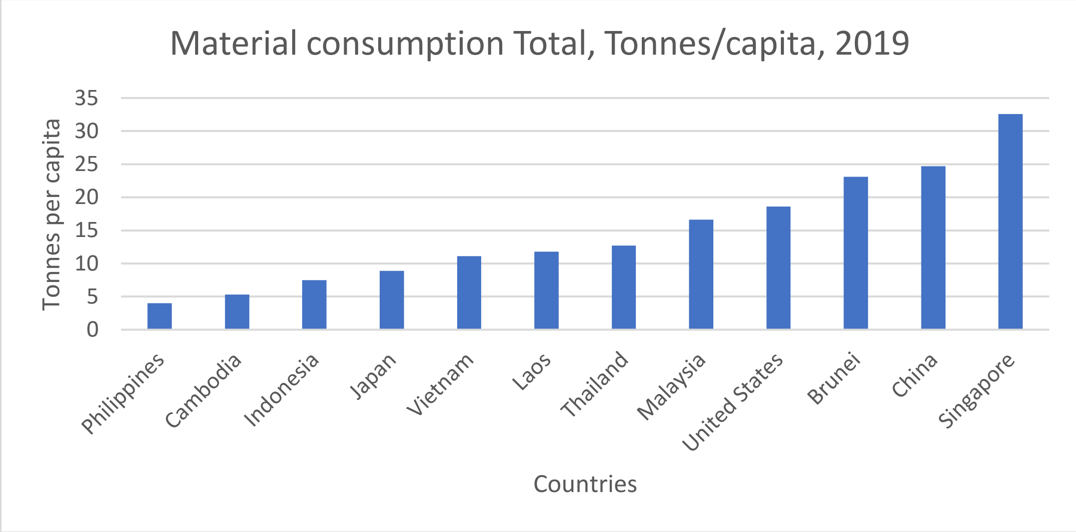


Figure 1.2 Material consumption Total, Tonnes/capita, 2019
Source: OECD material resources

1.1.1 Linear Economy – Symptoms and Consequences

First, the symptoms of the linear economy are the price spirals (Figure 1.3), price volatility (Figure 1.4), resource scarcity (EMF, 2013), waste and the associated landfills (Seadon, 2010; WCED, 1987; Zaman & Lehmann, 2013); marine and coastal plastic waste (Figure 1.5), climate change typically about global warming (EMF, 2013; Lieder & Rashid, 2016; WCED, 1987) emanating from GHG such as CO_2 and CH_4 (De los Rios & Charnley, 2017), and rising sea levels (Begum, 2017). Figure 1.6 shows a sharp increase of CO_2 between 1985-1995 with a spike in 1995 which further took a sharp climb between 2000-2016. The sharp trend would follow through for Malaysia unless counter measures are taken. Meanwhile in the Malaysian context, it aims to reduce emissions of 13,113 million tonnes CO_2e by year 2030 as its nationally determined contribution (NDC) in the Paris Agreement (2016) (MITI, 2017). In terms of climate change, Table 1.1 shows it has come to the Malaysian shores. Temperature increase ranges from 0.6 to 1.2°C between (1969-2009) and is expected to touch the limit of 2°C in 2050. This limit is prescribed in the Paris Agreement for 2030. While rainfall shows unappreciable differences, its intensity in terms of heavy pouring has increased by 17% for 1-hour duration and 29% for 3-hour and these have brought severe flooding (Shaaban, 2013). Further to this dismal scenario, extreme weather is expected by 2050. On a global scale, sea level is expected to rise 0.5m in a worst case scenario (Begum, 2017).

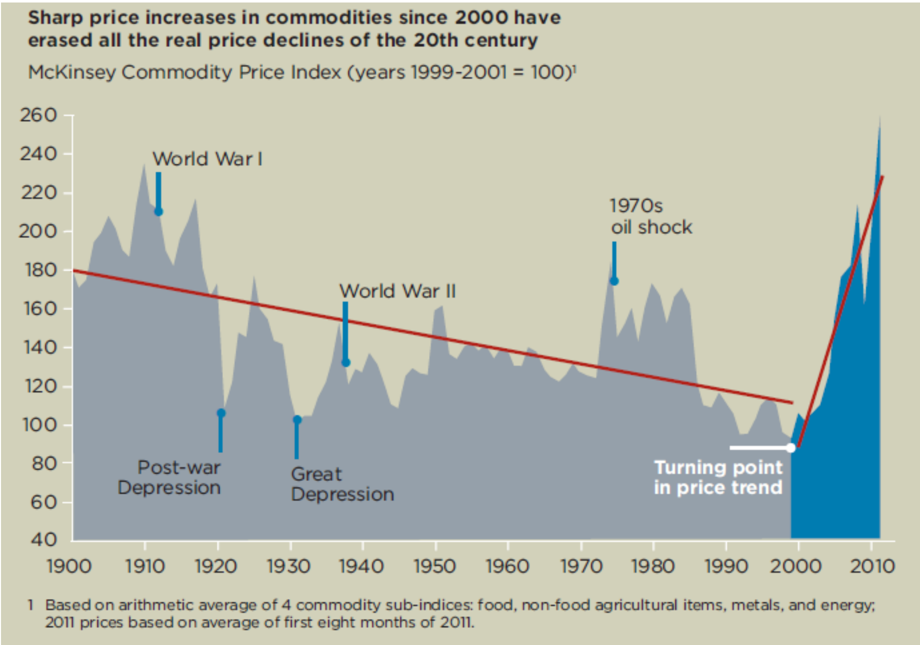


Figure 1.3 Price increases in commodities
Source: EMF (2013)

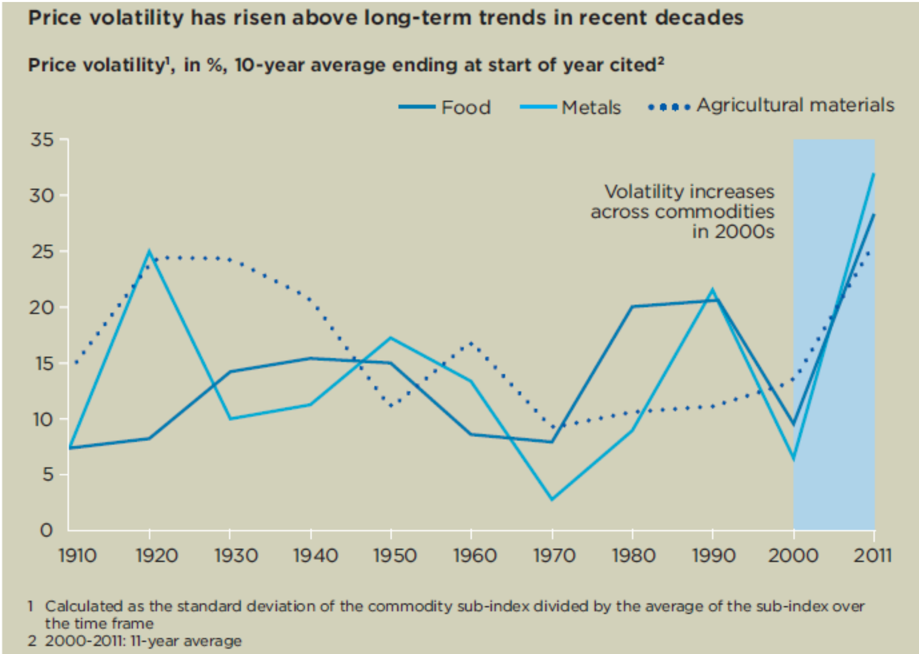


Figure 1.4 Price volatility for food, agriculture and metals.
Source: EMF (2013)

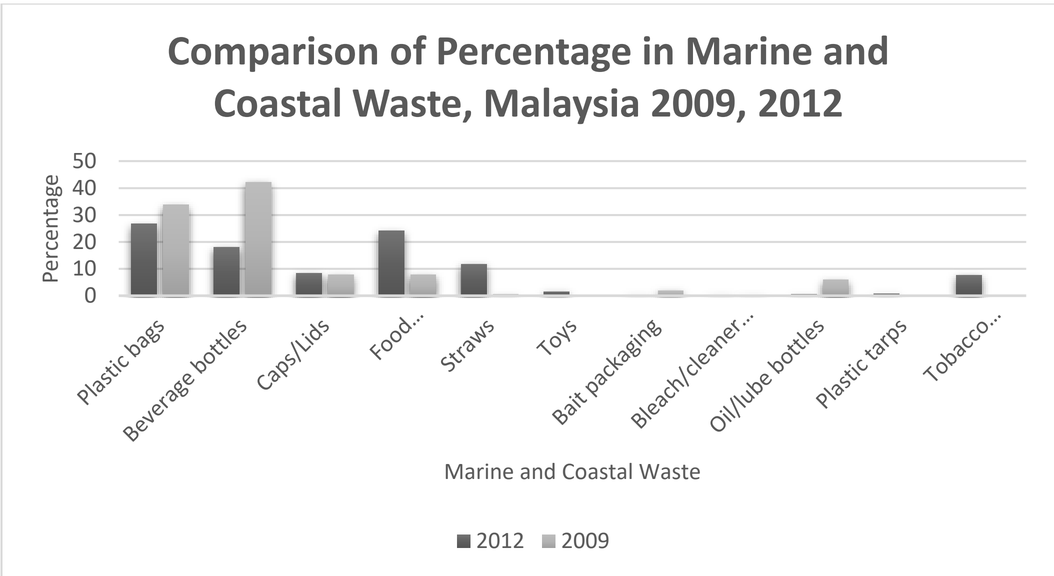


Figure 1.5 Comparison of percentage in marine and coastal waste in Malaysia in 2009 and 2012
Source: ICC (2010, 2012)

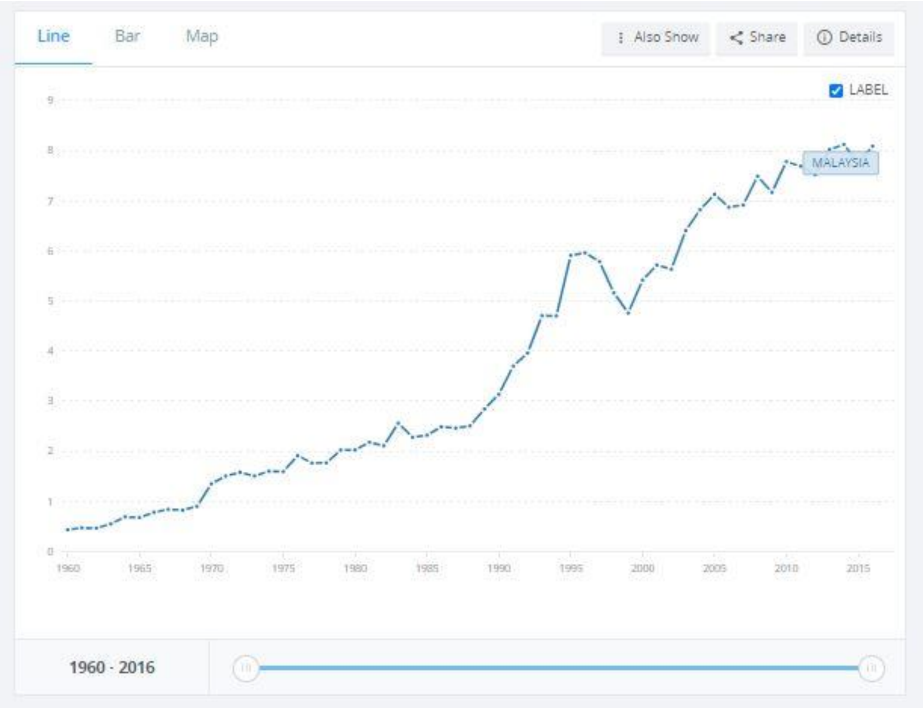


Figure 1.6 Malaysia CO_2 emissions from 1960-2016
Source: World Bank (2016)

Table 1.1 Observed and Projected Climate Change in Malaysia

Items	Observed	Projected (by 2050)
Temperature	0.6°C to 1.2°C over 50 years (1969-2009)	1.5-2°C increase
Rainfall (amount)	No appreciable difference	(-)5% to (+)9% change in regions within Peninsular Malaysia
		(-)6% to (+)11% change in regions within Sabah and Sarawak
Rainfall Intensity	Increased by 17% for 1-hour duration and 29% for 3-hour duration (2000-2007 compared to 1971-1980)	Increase in extremes within wet cycles
		Increase in frequency of extreme weather
Sea Level Rise (SLR)	1.3mm/yr (1986-2006, Tanjung Piai, Johor)	0.5m rise (Global high worst case at 10mm/yr)

Source: Malaysia Second National Communication (NC2) Begum (2017)

The woes of the linear economy were recorded with the advent of the industrial age (1776 – 1880) (Heizer & Render, 2016; Smith, 2000). The resources or materials were used to feed and produce an economy with GDP growing at 20-fold between 1900 and 2000 encouraged by voracious consumption and increased in income (Crainer, 2013). However, emissions were unbridled, solid waste generation with unsightly littering and landfills increasingly dotted the landscape (Lieder & Rashid, 2016). These phenomena continued with unrecycled waste of 60% in Europe (Crainer, 2013) and 95% in Malaysia (Sreenivasan et al., 2012), and rising GHG emissions (IPCC, 2013a). The GHG emissions cause climate change affecting the poor and vulnerable (Begum, 2017; UNFCCC, 2015). These all add up to the linear economy as unsustainable development (Bocken, Short, Rana, & Evans, 2014; Crainer, 2013; EMF, 2013; Frosch & Gallopoulos, 1989; Jacobs, 2018; WBCSD, 2010). The consequences of the linear economy are depicted in the following Figure 1.7.

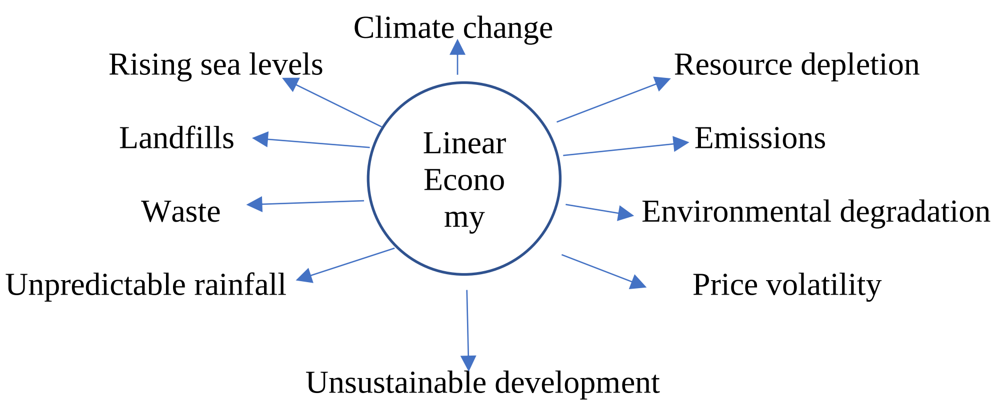


Figure 1.7 Consequences of a linear economy

1.1.2 Circular Economy – the Antidote

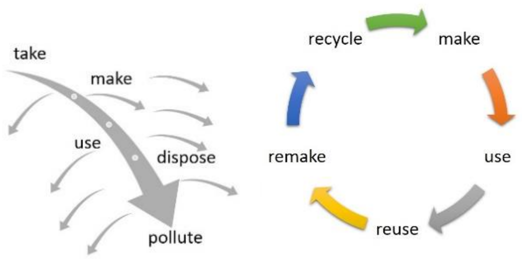
Instead, the circular economy is suggested as an approach to foster an SCA and to forge sustainable development or sustainability performance (Carter & Rogers, 2008; Elkington, 1997; Korhonen et al., 2018a; Montabon et al., 2016; Sikdar, 2003; WBCSD, 2017). The SCA is expected to yield superior firm performance according to RBV. Therefore, in the sustainable development context, it is superior sustainability performance. The term superior sustainability performance is used interchangeably with sustainability performance to avoid verbosity.

The sustainable development is anchored in the development and sustenance of the three dimensions of environment, economy and society (Brundtland, 1987; Elkington, 1997). The measurement of these three dimensions is sustainability performance (Sikdar, 2003; Singh, 2012). This research also uses sustainable development and sustainability performance interchangeably.

The circular economy would be designed or pre-designed (used interchangeably) to enable materials from parts and products be recycled back into the economy (EMF, 2013) because a) the materials would reduce further resource extraction, reduce use of further energy in manufacturing as the embodied energy of the parts or products are retained, b) reduction of energy use from fossil fuels would reduce carbon dioxide emissions, and c) the recycling would have the parts and products avoid open dumpsites, sanitary and unsanitary landfills and incinerators. Together, they are anti-resource depletion, anti-emission and anti-environmental degradation (EMF, 2013; McCarthy, Dellink, & Bibas, 2018). These make the circular economy sustainable leaving virgin resources, cleaner air and environment for the future generations.

In order to attain this three-dimensional sustainable performance, firms must first position themselves as competitively advantageous (Barney, 1991; Grant 1991; Newbert 2007, 2008). Particularly, the exploitation of firms' innovative eco-product design capabilities would engender these positional advantages (EMF, 2013; Newbert, 2008). The competitive advantages arising could include low cost, differentiation, first-mover advantage and future positions (Hart, 1995; Porter, 1985) which would be dealt with further in Chapter 2. The circular economy should forge an SCA a position supported by scholars (Carter & Rogers, 2008; Elkington, 1997; EMF, 2013; Korhonen et al., 2018a; Montabon et al., 2016; WBCSD, 2017).

The circular economy is offered as a replacement to the linear flow of products and materials of the older industrial age, one that is designed or pre-designed and cyclical-enabled for competitive advantage and sustainability performance (EMF, 2013, 2015). It restores and regenerates the economy by prolonging product use (EMF, 2013; Lieder & Rashid, 2016) (Figure 1.8). The unequivocal importance of customer involvement (EMF, 2013) is required to incorporate user-friendly designs and facilitate the returns of used or broken parts for recycling, reuse, refurbishment, repairs, remanufacturing or upgrading (Rashid et al., 2013; Lai et al, 2013). This would also be dealt with further in Chapter 2.



(Left) The linear economy, (Right) circular economy
Figure 1.8 Difference between the linear economy and the circular economy
Source: Weetman, Catherine (2016).

1.2 Background of the Study

This section will further elaborate on the linear economy and the circular economy. Since this research is about resource depletion, emissions and environmental degradation, the narrative will focus on the manufacturing sector (De los Rios & Charnley, 2017). This sector is prioritised because it produces tangible goods which depletes resources unless they are recyclable for reuse, refurbishment, remanufacture or upgrading. The service economy are intangible processes and not recyclable yet though admittedly the service economy of logistics transport is the largest contributor to fossil fuel usage and hence emissions (Stead, 2006).

1.2.1 Manufacturing and Emissions

The CO_2 emission is contributed in no small way by the linear economy resulting from manufacturing because more fossil fuel energy would be deployed in resource extraction and the production processes. They emit CO_2 causing higher temperature affecting climate change (Mønster, Kjeldsen, & Scheutz, 2019; OECD, 2018; Powell, Chertow, & Esty, 2018; Unnikrishnan & Singh, 2010) further damaging human health. Manufacturing industries such as in Italy making leather goods, pulp and paper, and fabric and garment contribute harsh impact to its environment (Tukker et al., 2006). Municipal solid waste or commonly called MSW come from homes and could be easily traced to manufacturing sources as well. If unmanaged, this waste provides challenges to the economy because its disposal directly affects the environment with its CO_2 and CH_4 (Loureiro et al., 2013; Cândido et al., 2011). In Malaysia, manufacturing industries such as cement, steel, paper, textiles and chemicals have been identified as energy intensive but if better managed could provide 5 – 34% energy savings (MPC, 2010) which could curtail emissions. In the area of recycling and substitution of materials, manufacturing is by default involved (McCarthy, Dellink, & Bibas, 2018). In fact, about 50% of manufacturing CO_2 emissions come from the production of steel, cement, paper, plastic, and aluminium (FMEAE, 2015).

In contrast to the manufacturing linear economy, literature pointed out a remanufactured product could comprise as much as 85% of used components without compromising quality and yet also utilize 50-80% less energy in its production processes. In this manner, they could save 20-80% in production costs of customary manufacturing (Lund, 1996). Effectively, the manufacturing activities in the circular economy directly support resource, emission and social management.

1.2.2 Service Economy and Users

The general population consumes more tangible goods from manufacturing compared to the service sectors. Wastes are collected daily as they are visibly thrown away after use. However, they should be restored and regenerated. Services provided by cars and trucks, airplanes and ships still use fossil fuels and emit soot and CO_2. In contrast to consumer goods, these soot and CO_2 cannot be restored and regenerated by consumers unless users abandon such services. Until and unless there are accessible and cost effective renewable energy for each of these transportation modes, their major waste is still CO_2 emissions but which could not be recycled by consumers. Consumers and users are not in a position to recycle CO_2 from the planes or cruises they take. Services are processes not recyclable either. Hence the focus is on the tangibles of the circular economy of manufacturing.

1.2.3 Linear Economy and Unsustainability

Noting the above, the linear economy produces things from the raw materials extracted from the environment. The process of extraction, manufacturing and use phases require fossil fuel energy transformed into usable kinetic, electric or heat energy. As described earlier, the extraction depletes resources, the use of fossil fuel energy emits GHG chief of which is CO_2 destabilizing the Earth's radiative balance causing climate change (IPCC, 2013a), and the throwing away of broken parts and used products as waste would continually require landfills and see indiscriminate littering. The raw material extraction would eventually disrupt material supply because of material loss and therefore diminished supplies along the value chain (EMF, 2013). Landfills use up land and the unsanitary ones produce leachate to undermine underground water quality (Maiti, Hazra, Debsarkar, & Dutta, 2016).

Unsanitary landfills which produce GHG would contribute to climate change such as global warming, rainfall intensity, drought and rising sea levels (Begum, 2017). These climate changes affect agricultural yields, displace population, and wreck the natural habitats of animals and plants (Stern & Rydge, 2012). Further to environmental consequences are the endangerment of species, unavailability of potable water, deprivation of clean air, and reduction of arable land because of soil contamination, and as such the gross and reckless land use are increasingly threatening the earth's natural system to support life (Rockström et al., 2009; Jackson, 2009; Meadows, Randers, & Meadows, 2004; WWF, 2014). They directly affect the poor and vulnerable such as women and children (UNFCCC, 2015). Humanity is then threatened, and social equity at stake as the affluent who live in air-conditioned space either ignores or are indifferent towards climate change while the poor deteriorate into abject poverty and would be further exploited (UNFCCC, 2015).

Noting these, the current and traditional linear economy of take-make-use-throw material and wasteful energy model inherited from the industrialization era is unsustainable development (Bocken, Short, Rana, & Evans, 2014; Crainer, 2013; EMF, 2013; Frosch & Gallopoulos, 1989; Jacobs, 2018; WBCSD, 2010) because of shrinking resources and climate change (WBCSD, 2010). Consequently, the world would require 2.3 planet Earth in 2050 to sustain the pattern of production and consumption (referring to 2010) (WBCSD, 2010). This threatens civilization (Ceballos, Ehrlich, & Dirzo, 2017).

1.2.4 Circular Economy and Sustainability

The circular economy is about achieving sustainable development from a position of competitive advantage (EMF, 2013; EC, 2015; Lieder & Rashid, 2016; Kalmykova, Sadagopan, & Rosado, 2018; Rashid, Asif, Krajnik, & Nicolescu, 2013) to sustain natural resources (Nobre & Tavares, 2021), to nuture and safeguard life forms in their eco-system and curtail climate change (WBCSD, 2010). Essentially an effective circular economy is directed at anti-resource depletion, anti-emissions and anti-environmental degradation. These are supported by the eco-product design capabilities of firms (EMF, 2013). Embarking on a circular economy with UN-based *Vision 2050* will ensure the sufficiency of ecological resources for sustaining all life forms as is while holding on to the linear economy would require an enormous 230% of current resources (WBCSD, 2010). This is because the circular economy decouples economic growth from the socio-economic consequences of resource depletion and environmental degradation (Kalmykova et al., 2018; Moreau, Sahakian, van Griethuysen, & Vuille, 2017). This huge benefit is derived from the circular economy which is based on its three principles which are: (1) controlling stocks and use of non-renewables and ensure the recycling is balanced; (2) optimizing production and the circulation of products with maximum product utility; (3) designing products for anti-emissions and anti-environmental degradation (EMF, 2013; Garcés-Ayerbe et al., 2019; Tukker, 2015).

There is also a consensus that the circular economy could help reshape the dominant system of linear economy (Merli, Preziosi, & Acampora, 2018; Pearce & Turner, 1989). It is expected the ongoing shift to the circular economy is an opportunity worth billions of dollars derived from substantial net material input cost savings, abatement of price instability and supply uncertainties, growth multiplier due to sectoral shifts and possible employment benefits, reduced externalities, lasting benefits for a more resilient economy, new profit pool potential along the reverse value cycles, product remarketers and sales platforms, parts and component remanufacturing and product refurbishment (EMF, 2013). These opportunities would require innovative eco-product design capabilities (EMF, 2013) in this ongoing huge paradigm shift (Liao, Fei & Chen, 2007). In this foregoing narrative, the circular economy is a proactive strategy to protect resources and sustain the environment for environmental, economic and social objectives. Hence, the circular economy is a strategic and holistic driver for better firm competitiveness and sustainability (Kiron, Kruschwitz, Haanaes, & von Streng Velken, 2012; Kiron, Unruh, Kruschwitz, Reeves, Rubel, & Felde, 2017).

Since the circular economy importantly decouples economic growth from the consequences of resource depletion and environmental degradation (Crainer, 2013; Kalmykova et al., 2018; Moreau et al., 2017), it affects and benefits all global citizens of a borderless world and is therefore a universal agenda. This research attempts to provide evidence that circular economy's innovative eco-product design capabilities leveraged with customer involvement could effectuate the firms' SCA for a sustainable environment, economy and society (EMF, 2013; Kalmykova et al., 2018; Lieder & Rashid, 2016; Lüdeke-Freund, Gold, & Bocken, 2018; Rashid et al., 2013) to avoid the consequences of a linear economy.

1.2.5 Businesses with Circular Economy Practices

The circular economy is manifested in Malaysian and international businesses which are tabulated as follows (Table 1.2 – Table 1.5). Table 1.2 shows businesses which commonly support the circular economy in Malaysia are found among vehicle and parts, home electrical appliances, computers and supplies, batteries, metal parts fabrication, paper, musical instruments, warehousing, agriculture and poultry farming, building materials and energy. Whereas Table 1.3 shows businesses supporting the circular economy eco-product design capabilities. In addition, Malaysian companies support product development such as labelling (Table 1.4) e.g. Sirim eco-labels; idea generation (Cohen & Levinthal, 1990; Zahra & George, 2002) e.g. customer involvement; branding (Lim, 2019) e.g. SAYANG using only eco-friendly, natural fabrics like linen and cotton, tags and labels, which are made from recyclable materials and printed with only soy ink; KEDAI BIKIN offering woven bags and upcycled PVC; REAL.M producing garments that are sustainable and made only from natural fibres e.g. bamboo and cotton; packaging (Respack, 2019) e.g. plant-based packaging and biodegradable plastic packaging; and product design e.g. recycle, reuse, repairs, remanufacturing, refurbish, upgrade and multiple product lifecycles. Table 1.5 shows international companies offering products out of the circular economy.

Table 1.2 Businesses commonly supporting the circular economy with their activities in Malaysia

Nos.	Circular economy business	Recycle	Reuse	Repairs	Remanufacture	Refurbish	Upgrade	Multiple lifecycles
1	Vehicle parts	√	√	√	√	√	√	√
2	Electrical	√	√	√	√	√		√
3	Computers	√	√	√		√	√	√
4	Printer cartridges	√	√		√			√
5	Tyre rethreads	√	√	√	√			√
6	Rechargeable batteries	√	√					√
7	Car batteries	√	√	√	√		√	√
8	Paper	√						√
9	Piano	√	√	√		√		√
10	Fabrication – metal parts			√				√
11	Pallets	√	√	√				√
12	Cargo containers	√	√	√		√		√
13	Recyclers	√	√					√

Table 1.2
Continued

Nos.	Circular economy business	Recycle	Reuse	Repairs	Remanufacture	Refurbish	Upgrade	Multiple lifecycles
14	Manufacturers' warranties	√	√	√	√	√		√
15	Solid waste management	√	√					√
16	Used clothings	√	√	√				√
17	Poultry manure		√					√
18	Oil palm biomass	√	√					√
19	Rubber wood	√			√		√	√
20	Recycled concrete aggregates 9% emissions	√	√					√
21	Construction waste	√	√					√
22	Hydro-electric power supplier						Transformation of energy forms	Renewable resource
23	Solar energy						Transformation of energy forms	Renewable resource

Note: A compilation of businesses engaging in circular economy activities.

It is timely to take note that the innovative eco-product design capabilities are precisely located at the upper end of the supply chain but implemented in the post-design product lifecycle. The following Table 1.3 contains common manufacturing sectors which support the design activities.

Table 1.3 Businesses supporting the circular economy eco-product design capabilities

Nos	Business sector	Products-examples	Pro-environment	Pro-economy	Pro-social	Multiple lifecycles
1	Electrical	Refrigerators, washing machines, air-conditioners	√	√	√	√
2	Electronics	Home theatres, notebooks, mobile phones	√	√	√	√
3	Packaging	Aluminum cans, paper bags, reusable plastic bags	√	√	√	√
4	Cars	Honda City (Turbo), Toyota Innova, BMW X1, Mercedes Benz 450H	√	√	√	√
5	Computers	Desktops and notebooks	√	√	√	√
6	Music	Pianos, guitars, drum sets	√	√	√	√
7	Battery	Car batteries, AAA and AA dry cell rechargeable batteries, notebook batteries	√	√	√	√
8	Tyre manufacturers	Tyres	√	√	√	√
9	Garden equipment	Lawn mowers, strimmers	√	√	√	√
10	Paper manufacturers	Books	√	√	√	√
11	Two wheelers	Motorcycles, bicycles	√	√	√	√
12	Garments	Clothings	√	√	√	√
13	Eco-designed buildings	Homes, offices	√	√	√	√
14	Industrial machinery and equipment	Conveyor system	√	√		√
15	Furniture	Antique furniture	√	√		√
16	Hydro-electric power supplier	Energy	√	√	√	Renewable resource

Table 1.3
Continued

Nos	Business sector	Products-examples	Pro-environment	Pro-economy	Pro-social	Multiple lifecycles
17	Solar energy	Energy	√	√	√	Renewable resource
18	Scavenging economy	Recyclables	√	√	√	√

Note: A compilation of businesses with eco-product design capabilities

In Malaysia, examples of products contributing to the circular economy in terms of lower resource usage such as water, use of renewable materials such as timber, paper products and oil palm cultivation, lower emissions such as lower carbon footprints and energy saving devices of light emitting diodes, fans and inverter refrigerators could use appropriate labels. These green labels are tabulated as follows (Table 1.4).

Table 1.4 Green Labels in Malaysia

No.	MyHIJAU Mark Category	Certification /Labelling Scheme	Logo	Standard Compliance	Certification Body
1	Green Label Certification (ISO 14024 Type I Eco-labels)	SIRIM Eco Labelling Scheme	SIRIM ECO-LABEL	ISO 14024:1999 Environmental labels and declarations -- Type I environmental labelling -- Principles and procedures	SIRIM QAS International Sdn. Bhd.

Table 1.4
Continued

No.	MyHIJAU Mark Category	Certification /Labelling Scheme	Logo	Standard Compliance	Certification Body
2	Green Label Certification (ISO 14025 Type III Eco-labels)	SIRIM Product Carbon Footprint Certification Scheme		ISO 14025:2006 Environmental labels and declarations -- Type III environmental declarations -- Principles and procedures	SIRIM Berhad
3	Green Label Certification (Other Type I-like Voluntary Sustainable Scheme; VSS)	Energy Efficiency Rating & Labelling Scheme		1. Domestic Fan 2. Television 3. Refrigerator 4. Air Conditioning	Suruhanjaya Tenaga
4	Green Label Certification (Other Type I -like Voluntary Sustainable Scheme; VSS)	Water Efficient Product Labelling Scheme		1. Water Taps and Mixers 2. Water Closet 3. Urinal Equipment 4. Shower Head 5. Washing Machine	Suruhanjaya Perkhidmatan Air Negara
5	Green Label Certification (Other Type I -like Voluntary Sustainable Scheme; VSS)	Malaysian Timber Certification Scheme		PEFC ST 2002:2013 Chain of Custody of Forest Based Products Programme for the Endorsement of Forest Certification (PEFC) schemes	Malaysian Timber Certification Council

Table 1.4
Continued

No.	MyHIJAU Mark Category	Certification /Labelling Scheme	Logo	Standard Compliance	Certification Body
6	Green Label Certification (Other Type I -like Voluntary Sustainable Scheme; VSS)	Malaysia Palm Oil Certification Scheme		MS 2530:2013 Malaysian Sustainable Palm Oil	Malaysian Palm Oil Board

Note: A compilation of green labels in Malaysia

Similarly, conformance to eco-friendly and safe products in the international business are labelled for example with Waste Electrical and Electronic Equipment Directive (WEEE) or Restriction of Hazardous Substances Directive (RoHS) compliances especially so for electronic products or semi-conductors. Firms producing fully circular products could have them certified to the circular economy instead. Some examples of these companies are tabulated as follows (Table 1.5).

Table 1.5 International Firms Producing Circular Economy Products

	Companies	Circular economy products
1	Timberland	From tires to shoes
2	Johnson Controls	Recycled batteries
3	Aquazone	Turning wastewater into fertilizer
4	Vigga	Shared wardrobe
5	Raw for the Oceans	Upcycling ocean trash into clothing
6	Suroboyo Bus Line	Turning plastic into currency
7	Winnow	Smart meters that analyse our trash and then identify ways to reduce waste
8	DyeCoo	Process of dyeing cloth that uses no water at all, and no chemicals other than the dyes themselves. Partnerships with major brands like Nike and IKEA

Table 1.5
Continued

	Companies	Circular economy products
9	Close the Loop	Turns old printer cartridges and soft plastics into materials for roads
10	Enerkem	Turn the carbon into a gas that can be used to make biofuels like methanol and ethanol
11	Schneider Electric	Uses recycled content and recyclable materials in its products, prolongs product lifespan through leasing and pay-per-use, and has introduced take-back schemes into its supply chain
12	Cambrian Innovation	Treats industrial wastewater and even producing biogas that can be used to generate clean energy
13	Lehigh Technologies	Turns old tyres and other rubber waste into a wide variety of applications from tyres to plastics, asphalt and construction
14	HYLA Mobile	Repurposes and reuses old smartphones and tablets Stopping 6,500 tons of e-waste ending up in landfill
15	AB InBev	Drinks are sold in returnable glass bottles

Source: The World Economic Forum and the Forum of Young Global Leaders, in collaboration with Accenture Strategy, recognized the best of them at The Circulars

In relation to Table 1.2 through 1.5, the businesses in Malaysia showed they practised the CE in pre-designing for pro-environment, pro-business to benefit the firms, and pro-society for a holistic sustainable development. These are operationalized with CE activities such as recycling, reuse, repairs, remanufacture, refurbish and upgrade for multiple lifecycles. Further, the government and certification bodies encourage eco-design for eco-labels, reduction of the carbon footprint, energy and water efficiency, sustainable timber and palm oil. In the international arena, some international companies have already embarked on the shift to the CE by producing products where their materials are recyclable. These augur well for the global environment especially for climate action, the economy balanced with sustainable consumption and production (SDG12), and social equity for humankind. In balancing these three dimensions, they helped Malaysia and the borderless world to achieve

Vision 2030 of the Paris Agreement to cap temperature increase at 2°C and Vision 2050 for zero waste.

1.3 Problem Statement

The connection between the linear economy and its consequences was explained and illustrated above. The circular economy as an antidote has been suggested by various countries, world bodies and the United Nations. The problem statement derived from the aforementioned introduction and the background of the study is described as follows.

Noting the global problem of resource depletion, emissions, environmental degradation (Crainer, 2013; EMF, 2013; Korhonen et al., 2018a; Korhonen et al., 2018b; Lieder & Rashid, 2016) and climate change (Diffenbaugh, et al., 2017; McDonough & Braungart, 2013; Shakun et al., 2012; Stern & Rydge, 2012; WBCSD, 2010) arising from the linear economy (EMF, 2013; Frosch & Gallopoulos, 1989; Jacobs, 2018) and because it is a borderless world, local actions with circular economy capabilities must be accelerated in this uphill task of sustainable development. Ignoring the local resource depletion (Vincent, 1997), rise in temperature and mean sea level (Begum, 2017; Tang, 2019) and emissions, global warming in climate change (Chung & Timbuong, 2019; UNDP, 2016) would perilously affect husbandry, water resources for basic livelihood and business, biodiversity and forestry, coastal residences and industries, marine areas, energy supplies and transport and public health (Al-Amin, Rasiah, & Chenayah, 2015; Begum, 2017). These directly and adversely affect the environment, economy and society. The aforementioned problem statement is further expanded into two sub-problems – the theoretical problem and the practical problem to clarify and strengthen the justification for this research.

1.3.1 Theoretical Problem

The following expresses selected theoretical problems encountered in circular economy research.

a) The paucity of empirical research in the sustainability performance of the circular economy.

b) The spread of the circular economy is hampered because the circular economy field is currently filled with divergent approaches which are mostly theoretical suggestions.

c) The absence of the study of innovative eco-product design capabilities to produce products fit for the sustainability performance in the circular economy, and customer involvement moderator to leverage such capabilities.

d) The absence of an empirical support with evidence for the business case to help shift a company from a linear to a circular approach.

e) The research using solid theoretical foundations is rather scanty.

Therefore, this research has attempted to fill the empirical theory-based absence of pro-circular economy research in sustainability performance. This will be done in a scientific way.

1.3.2 Practical Problem

The following items are practical problems encountered in the linear economy.

a) The depletion of resources causing price spirals and volatility.

b) The emissions of CO_2 in a linear economy severely causing climate change such as rising local and global temperature, and flooding.

c) The unsustainable landfills because land is a non-renewable resource and is scarce and landfills are not perfectly secure.

d) Population growth and increase in production and consumption aggravate resource depletion, emission and volatile prices.

e) Economic progress at the expense of the environment and society.

These point to a dire need for an empirical research in the circular economy for a more persuasive shift to sustainability performance. This is in search for the scientific evidence to replace the linear flow which is unsustainable development in environment, economic and social (Korhonen et al., 2018a).

1.4 Research Objectives

The overall objective of the research is to find supporting evidence to accelerate the transition from the linear to the circular economy which is restorative and regenerative through the exploitation of resources for firms' SCA and consequently for sustainability performance. This research will extend the advocacy of circular economy (UNFCCC, 2020a, b; WBCSD, 2010), conceptual work (EC, 2015; EMF, 2013) of several scholarly work (Alix & Vallespir, 2010; Bocken et al., 2016; Braungart & McDonough, 2002; Crainer, 2013; De los Rios & Charnley, 2017; Garcés-Ayerbe et al., 2019; Kirchherr et al., 2017; Korhonen et al., 2018a; Lüdeke-Freund et al., 2018; Mayyas, Qattawia, Omara, & Shana, 2012; Moreno, los Rios, Rowe, & Charnley, 2016), circular economy survey of EU (2015), statistical descriptive studies (Kirchherr, Piscicelli, & Bour, 2018) and environmental studies (Lai et al., 2013; Zhu & Sarkis 2004; Zsidisin & Hendrick, 1998) to a circular economy empirical investigation. The research objectives are to:

a) Determine whether firms' innovative eco-product design capabilities positively influence their SCA.

b) Determine whether firms' SCA positively influences their sustainability performance.