

ERASMUS UNIVERSITY ROTTERDAM

MASTER THESIS

Standardisation and Frugal Innovation

A case study analysis on the effect of standards and standardisation on frugal innovation in developing countries.

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Abstract

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Standards are an essential part of contemporary economies: they encourage trade, facilitate international consensus, safeguard health and the environment, and disseminate valuable information and knowledge. However, while the WTO encourages the national adoption of international standards in this regard, standards can be perceived as barriers to trade in the context of developing countries. This thesis studies the effect of standards and standardisation (the development of standards) on frugal innovations in developing countries. Frugal innovation is a relatively new discourse of innovation that arises within constraints, meeting the needs of people living under these same constraints. It aims for affordability, sustainability and quality, all at the same time. A case study of two frugal innovations in developing countries tests the hypothesis that better developed national standard capabilities within a country positively affect the diffusion of frugal innovation. Although the evidence cannot fully support this hypothesis, the analysis emphasises the importance of institutions such as standardisation for frugal innovations and for developing countries.

Acknowledgements

As part of my undergraduate studies I took part in a minor programme provided by the Centre for Frugal Innovation in Africa. The courses taught me all about frugal innovation and Sustainable Development Goals. Furthermore, the programme got me engaged in a medical frugal innovation project in Uganda. As a contribution to this project I visited Uganda for three months to investigate the local conditions on various levels: the goal was to find out if the right decisions were made for the innovation to fit within the local conditions. One of the bureaucratic issues that we come across early were national standards. We had the opportunity to meet with government officials from the Ministry of Health and from the national standards body. These officials informed us on the availability of standards and difficulties in applying them for new technologies. For some technologies there were simply no standards available yet, but standards were a key step for the import of new technologies. We took this information home with us, and new strategies had to be discussed. For example, one option was to import only separate materials and build the machine in the country, and another was to import a whole new technology but come across high transaction costs.

This real-life situation and my interest in frugal innovation motivated me to contact two members of the CFIA management team in January, two years after the minor programme took place. I was excited to try and contribute to the research of frugal innovation with my thesis. Prof.dr. Peter Knorringa (CFIA director) and Dr. André Leliveld (CFIA co-director) replied to my emails with enthusiasm and were able to make some time in their busy schedules to think it over. With the support of their insights and the knowledge I gained throughout this master programme I was able to design a research that contributes to the field of research on frugal innovation from an international public management and policy point of view. I am grateful for the time that Peter Knorringa and André Leliveld took to support me in this task.

Furthermore, in this acknowledgement I would like to specifically thank Dr. Pieter Tuytens for his supervision of my work. It was both fun and stressful at times. Both the academic personnel and students have been affected by the conditions of the pandemic. A whole year of working at home, with family and housemates right across the hall was a challenge. Dr. Tuytens was very involved with my efforts and I might have even caused him some concerns when he wasn't sure whether I was on the right track. I think it made both of us even more happy that at our last meeting it seemed everything had come together. Thank you for the inspiration and constructive criticisms!

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List of Abbreviations

AQSIQ	General Administration for Quality Supervision Inspection and Quarantine
BIS	Bureau of Indian Standards
BoP	Bottom of the Period
CAC	Codex Alimentarius Commission
CEN	European Committee for Standardization
CENELEC	European Committee for Electrotechnical Standardization
CFIA	Centre for Frugal Innovation in Africa
CIA	Central Intelligence Agency
CIQ	State Administration for Entry-Exit Inspection and Quarantine
COV	Co-Variational analysis
CPT	Causal Process Tracing
EMNC	Emerging Multinational Corporation
EU	European Union
FI	Frugal Innovation
GDP	Gross Domestic Product
GE	General Electric
GERD	Gross Domestic Expenditure on R&D
GNI	Gross National Income
GQII	Global Quality Infrastructure Index
HQ	Head Quarters
IEC	International Electrotechnical Commission
IMF	International Monetary Fund
INSS	Indian National Strategy for Standardisation
IPR	Intellectual Property Rights
ISO	International Organisation for Standardization
ITU	International Telecommunications Union
LGT	Local Growth Team
LPI	Logistics Performance Index
MNC	Multinational Corporation
NIST	National Institute of Standards and Technology
NSB	National Standards Body
OECD	Organisation for Economic Co-operation and Development
PTB	Physikalisch-Technische Bundesanstalt
QI	Quality Infrastructure
QTSB	State Quality and Technical Supervision Bureau
RI	Reverse Innovation
SAC	Standardisation Administration of China
SDGs	Sustainable Development Goals
SDO	Standards Development Organisation
SNAP	Standards National Action Plan
TBT	Technical Barriers to Trade
TC	Technical Committee
TRIPS	Agreement on Trade-Related Aspects of Intellectual Property Rights

UIS	UNESCO Institute for Statistics
UN	United Nations
UNCTAD	United Nations Conference on Trade and Development
UNESCO	United Nations Educational, Scientific and Cultural Organization
US	United States
USD	US Dollar
WDI	World Development Indicators
WGI	Worldwide Governance Indicators
WTO	World Trade Organization
X	Independent Variable
Y	Dependent Variable

Chapter 1

Introduction

The past year, the pandemic has changed a lot of things in our lives. When a crisis calls, we all have to be more inventive: policymakers, physicians, nurses, academics, engineers and entrepreneurs. The worldwide crisis has laid bare and underscored existing patterns of inequality and problems with policies and regulations. In an attempt to contribute to the situation, new innovations are arising rapidly around the globe. A Dutch government-broadcast television programme (Nieuwsuur) presented in January how engineers at the technical University of Twente have invented dozens of new products that can be of help during the pandemic in hospitals (Nieuwsuur, 2021). Academics such as Harris, Bhatti, Buckley, and Sharma (2020) refer to this form of innovation as *frugal innovation*: it is about doing more with less, for the many, under constraints in resources, finances and time.

At the same time the crisis has shown something else: that flexibility is possible in the most conservative contexts. Governments are rapidly forming new laws, policies and regulations to deal with the situation. As we speak, a waiver is being discussed among World Trade Organisation (WTO) members to grant an exception to the TRIPS Agreement regarding COVID-19 vaccines. This agreement protects intellectual property rights for innovations globally (WTO, n.d.(c)). After a request by South Africa and India, the waiver is being discussed for various COVID-19 vaccines, to "avoid barriers to the timely access of affordable medical products, including vaccines" (WTO, 2021).

Within WTO, other international organisations, and among national governments there exist countless of agreements and regulations, including TRIPS, that together shape international trade. One of the most important agreements made among WTO members is the Technical Barriers to Trade (TBT) Agreement. The WTO explains that, on the one hand, this ensures that regulations, standards and conformity assessment procedures that are set up by WTO members cannot form unnecessary or discriminatory barriers to trade. On the other hand, the agreement safeguards the members' autonomy to implement policies and measures regarding legitimate national issues (WTO, n.d.(d)). Such national issues are often concerned with the protection of health, safety and the environment. Furthermore, WTO states: "The TBT Agreement strongly encourages members to base their measures on international standards as a means to facilitate trade." (WTO, n.d.(d)).

These two elements: the spark for more innovations and the changes in business as usual for international trade, are interesting consequences of the crisis-situation that we are in. The conditions that many citizens are facing today in this crisis, present to the developed world what it can be like in developing countries all the time. Communities in low- and middle-income countries live under conditions of crisis permanently. It is interesting that the earlier introduced *frugal innovations* are most frequently seen in low- and middle-income countries as well. Harris, Bhatti, et al. (2020) argue that this can be explained by the described conditions in these contexts. They articulate this perfectly: "[D]oing more, with less, for the many, and being creative, innovative and resourceful in the face of institutional voids and resource constraints. This has been the reality of the experience of many low- and middle-income countries, even before the COVID-19 pandemic" (p.814). They further emphasise that frugal innovations are not inherently inferior in quality. Often these innovations are simpler, while offering exactly those functions that are necessary under the circumstances. However, these frugal innovations - from long before the pandemic - experience negative consequences that can be linked to the assumptions around their country-of-origin (Harris, Weisberger, Silver, and Macinko, 2015).

Theories of innovation state that the benefits from innovation in developed countries should eventually trickle down to developing countries. And many policies for innovation, trade, and other subjects are based on this assumption (Parthasarathy, 2020). Parthasarathy (2020) argues that the inequalities that are revealed by the COVID-19 crisis prove that this is not the case in reality.

Although the TBT Agreement is supposed prevent any unnecessary and discriminatory barriers to trade, it is debated whether elements of these agreements - such as standards - are effective in their goals. The United Nations Conference on Trade and Development (UNCTAD) argues that while standards are beneficial for both consumers and the planet, there is a downside to it as well (UNCTAD, 2018). Companies, producers and innovators from lower-income countries experience difficulties complying to these standards or keeping up with the required certifications. These are barriers that hold entrepreneurs back from exporting and accessing new markets. On the other hand, the function of these same standards is to improve health, well-being and sustainability, and diminish environmental impact. The ambiguous relation between standards, trade and innovation has been studied often by academics, and the effect of standards and standard-setting mechanisms on innovation remains indeterminate.

All that is described here is a form or part institutions, and it reveals their behaviour with and without the presence of a crisis. The pandemic shows once again that institutions matter: for international processes, for development and for the distribution of resources worldwide. In this research frugal innovation, standards, standardisation, national capabilities, and the interdependency of these concepts are studied.

1.1 Research objective and question

Between these concepts this study aims to contribute to a better understanding of role that standards and standardisation play for frugal innovations in developing countries. There are two motives that lead to this objective. First, the relation between standards, standardisation and innovation has been studied, but results are ambiguous. Since frugal innovation is part of a new discourse of innovation, its place within the ambiguous relation must be determined. In addition, frugal innovations are often found in developing countries. The literature presents reasons to assume that standardisation affects developing countries differently than developed countries. Therefore, in contrast to most existing research on standardisation, this study will focus on the effect in developing countries only.

This leads to the following research question:

How do standards and standardisation affect frugal innovations in developing countries?

Overall, this research aims to contribute to the field of research on frugal innovation. It is a new discourse within innovation and among other new discourses of innovation. The concept is often approached from a technical point of view, or regarding development. Therefore, this study will take on a new point of view: the effect of international and national governance.

1.2 Research approach

First several concepts will be explored: frugal innovation, quality infrastructure, national standard capabilities, standards and standardisation. The exploration leads to the hypothesis "Better developed national standard capabilities within a country positively affect the diffusion of frugal innovation.". To test the hypothesis a co-variational case study is employed. Two frugal innovations, one from China and one from India, are selected. For both these innovations the national standard capabilities of the country of origin will be determined as the independent variable, and the diffusion of the innovation will be determined as the dependent variable. The findings are compared and controlled for by the control variables. The findings show that there is not sufficient evidence to support the hypothesis, due to variation in the control variables. From the analysis it becomes apparent that a causal process tracing would contribute to the relation that is being studied. It is concluded from this study that

institutions matter for frugal innovation, something that policymakers, innovators and multinational corporation (MNC) managers should be aware of. Furthermore, international organisations should consider that traditional theories and principles do not necessarily apply to the context of developing countries. Future research should be able to study the relation and similar elements in more detail.

1.3 Theoretical relevance

There are three academic fields of research to which this thesis aims to contribute to: (1) frugal innovation, (2) standardisation and innovation in developing countries, and (3) the relation between standards, standardisation and innovation. First of all, this research is conducted in response to the increasing interest in the concept of frugal innovation. The area of literature concerned with frugal innovation is relatively new, therefore significant elements are still lacking. Empirical analysis is necessary to advance knowledge on institutional conditions that are appropriate for frugal innovation (Knorringa, Peša, Leliveld, and van Beers, 2016, p. 150). And, there are still insufficient explanations on the conditions under which frugal innovations arise, and conditions that benefit them (Soni and Krishnan, 2014). Theories that have been established to describe the behaviour, role and characteristics of innovation in general do not necessarily apply similarly to frugal innovation (Hossain, 2018; van Beers, Knorringa, and Leliveld, 2014).

Secondly, this thesis aims to contribute to the increasing academic interest in developing countries and their emerging markets. Over the last decades, the role of these markets within the global economy has increased in importance (Zeschky, Winterhalter, and Gassman, 2014). Academics argue that traditional theories do not necessarily apply to the emerging markets, as they do to developed countries (Hossain, 2018; van Beers et al., 2014). For example, both the mechanisms of standardisation and the capacity to diffuse innovations in traditional Schumpeterian economic theories are primarily based on industrialised economies (van Beers et al., 2014, p.18-19). The ongoing debate and the reality of developing countries dictate that a better understanding of the processes within these countries is necessary.

Third, the relation of standards, standardisation and innovation has been found to be ambiguous (Hawkins and Blind, 2017). However, since most research on this matter has been conducted with a focus on the developed world, it is now being questioned whether the relationship behaves similarly in developing countries. Zoo, de Vries, and Lee (2017) find a gap in the research on standardisation in developing countries.

All in all, studying standards and standardisation contributes to the research that is concerned with the role of institutions that either help or hinder frugal innovations. More specifically in developing countries, where it seems that traditional (economic) theories do not always hold. An answer to the research question is theoretically relevant because it can improve the understanding of the role of institutions, such as standardisation, for frugal innovations in developing countries. As a result, it contributes to the field of literature on frugal innovation in general and the relation between standards, standardisation and (frugal) innovation.

1.4 Societal relevance

Not only does this study contribute to the academic field of research, it is also socially relevant. First of all, benefits and disadvantages have been found for the effect that standards and standardisation have on innovation in general. A better understanding of the potential benefits and disadvantages for frugal innovations in developing countries and the conditions under which these occur is essential for institutional reforms in these countries. Often organisations such as the International Monetary Fund (IMF) encourage developing countries to install institutional reforms to boost economic growth and development (Pansera and Owen, 2018b). At the same time, these efforts are criticised for their

effectiveness (Reinsberg, Stubbs, Kentikelenis, and King, 2019). Therefore, an understanding of both the benefits and disadvantages is essential.

Furthermore, frugal innovation is a promising new discourse of innovation for not only the Global South, but increasingly the North as well. It potentially offers better and more sustainable solutions for reaching the United Nations' Sustainable Development Goals (SDGs) (CFIA, n.d. Leliveld and Knorringa, 2018; Science | Business, 2020). Zoo et al. (2017) argue similarly that innovation can be part of the solution for today's biggest problems. An increase in our understanding of the concept frugal innovation is key to maximise its potential and its effect in fighting poverty and other challenges in developing countries.

Lastly, this study can potentially contribute to the position of countries within the international system by visualising the reality of the standardisation institutions in developing countries. Currently developing countries, often latecomers to standardisation, are not in the lead on the international stage (Ernst, Lee, and Kwak, 2014). As a result, they are found to be more vulnerable to strategies, trade barriers and they experience higher efforts (e.g. financial efforts) to take part in standardisation. Creating a better understanding of the national standardisation systems is required in order to evaluate its role within the international system and to improve it.

1.5 Readers' guide

The introduction to this thesis is followed by the literature review in Chapter 2. In this chapter the debates from the literature are introduced: the role of innovation in development, economic growth, and developing countries, and most importantly the effect of standards and standardisation on innovation. Chapter 3, the theoretical framework, first describes all the essential concepts of this study. By combining this knowledge, the hypothesis that guides the resulting chapters of this thesis is formed. Chapter 4 introduces the approach that is applied in this study. Chapter 5 presents the findings for the two cases, and Chapter 6 analyses and discusses the findings and determines what can be concluded regarding the hypothesis. In Chapter 7 the study is summarised and concluded, and additionally recommendations are provided.

Chapter 2

Literature review

This chapter presents to the reader the two main debates that together sparked off the research goal and question. The first section introduces the concept of innovation for this study. Section 2.2 illustrates the political economic debate on innovation and economic growth and development, and illustrates criticism on the Western narrative. Third, the debate on the relation between standards, standardisation and innovation is introduced, guided by the question: ‘do standards enable or constrain innovation?’. These two debates are both part of another topic: a discussion on whether the theories and effects described behave similarly in the context of developing countries. This element will be introduced in all three sections as well.

2.1 Innovation

The concept of innovation is defined differently throughout the literature. Assessing the work of various scholars we find that “[i]nnovation is defined as an outcome in the form of new wealth from new combinations of factors of production, whether existing or new” (Hawkins and Blind, 2017, p.6). Moreover, the literature often refers to the work of Joseph Schumpeter who perceived innovation as a change in or introduction of new elements or functions such as: goods, services, methods of production, markets, sources of supply and/or organisational structures (Hawkins and Blind, 2017, p.6; McDaniel, 2000, p.278). Others focus more on approaches or tools in their definitions. Innovation involves experimentation and reformulation of strategy (Bhatti, Basu, Barron, and Ventresca, 2018, p. 39); tools, materials, processes and techniques are used to solve problems and the result creates value (Shane, 2008, p.xv). The concept can be defined from different points of view, contexts and principles.

Zanello, Fu, Mohnen, and Ventresca (2016) describe that innovation in developing countries can take on different forms than in developed countries. For example, in developed countries firms and governments tend to invest mostly in research and development (R&D) to increase knowledge. Developing countries include other, less costly knowledge-building activities such as “design and engineering activities, on-the-shop-floor attempts to improve productivity, investment in learning” (p.887). Another example is the low cost of labour, which provides firms with a comparative advantage relative to developed countries.

Within the world of innovation several new discourses have emerged recently, indicated by terminology such as *frugal*, *reverse*, *grassroots*, *inclusive*, *jugaad*, and so on (Brem and Wolfram, 2014; Pansera and Owen, 2018b; von Zedtwitz, Corsi, Sjøberg, and Frega, 2014). All of these are somehow related to innovation in low resource settings and emerging markets. These concepts will not all be explored in detail. Overall, they are found to be quite similar in general. The specific differences are mostly found in the purpose and motivation behind each concept (Zeschky, Winterhalter, and Gassmann, 2014). Frugal innovation, the main subject for this study, is a form of innovation that has been designed to meet the needs and demands of consumers in resource-constrained contexts. At the same time it is designed under these same constraints.

2.2 Innovation, economic growth and development

Joseph Schumpeter also wrote that innovations can economically transform societies (Pansera and Owen, 2018b, p.25; van Beers et al., 2014). Scholars have researched the effects of innovation and found it leads to increased productivity and competition (Pansera and Owen, 2018b). In turn, these elements contribute in the long term to economic growth and as a result encourage the private and public sector to invest in innovation and related fields (Pansera and Owen, 2018b). Organisations such as the World Bank, IMF and Organisation for Economic Co-operation and Development (OECD) build on this transforming effect of innovation. They promote innovation and innovation policies, specifically to developing countries, because they believe that improving innovating environments and contexts will contribute to innovation and in turn contribute to economic growth (The World Bank, 2010). The World Bank (2010) further states that the dissemination of certain innovations and technologies contribute to economic and social development (p.46). Examples that illustrate this link are the diffusion of vaccines and innovations that provide access to clean water and sanitation. Furthermore, innovation in developing countries can encourage inclusion and be a tool for poverty reduction (Zanello et al., 2016, p.905). Additionally, some economists argue that economic growth can spill over from developed countries to less developed countries (Pansera and Owen, 2018b). All that these less developed countries need to do, is ‘catch up’.

At the same time, Pansera and Owen (2018b) critically explain that it is ‘Western imaginary’ that dictates that "the capacity to innovate is (...) a critical factor that explains why some countries are rich and ‘developed’ whereas others are backward, poor and in need of development." (p.xv) and that "[d]evelopment is a concept that is highly contested" (p.9). Terms such as the ‘underdeveloped’, or ‘others’, have deep roots and can be connected to colonialism. Similarly, ‘needs’ and ‘poverty’ are modern constructs based on social values. However, it is by these constructs that international organisations legitimise intervention, polices and regulations. Furthermore, political and cultural dimensions can be neglected in these contexts. Contemporary principles assume that technological innovation is a "universal fix" to reduce poverty (p.19).

These different views represent only the tip of the iceberg of debates surrounding the concept of development, development projects and innovation. Understanding the different views is essential when studying the context of what we (including myself), from the Global North, describe as ‘developing countries’.

2.3 Standardisation: enabling or constraining innovation?

Hawkins and Blind (2017) set out, in the Handbook of Innovation and Standards, that the academic world has not yet agreed on one definition or theory that defines the relationship between innovation and standardisation. The relationship is discussed in many different contexts, fields of research and for different purposes. Most studies are focused on technicalities, implementation or have been conducted from an engineering point of view. Only few have considered the relation in a sociological or political context. A review of the literature illustrates that the effect can be studied at different levels and points of view, and that these affect the conclusions that can be made.

Generally, the relation can be perceived as a two-way street: innovations affect standards and standards affect innovation (Blind, 2016; Cargill, 2017; Swann and Lambert, 2017). Moreover, the effect can be both enabling and constraining. One reason it is hard to define the relationship and its details is that innovation and innovation processes are affected by countless other factors which cannot all be eliminated (DIN, 2000). Most scholars acknowledge this controversy in their research but do tend to one side more than the other. On the one side it is primarily argued that standards and standardisation hinder innovation and their diffusion. A familiar example is that of the QWERTY keyboard (Allen and Sriram, 2000). Once the standard for keyboards was established it promoted the use of this keyboard and provided global compatibility. However, at the time, new keyboard layouts

were innovated that were proved to be more efficient. Due to the early standardisation, these newer and better keyboards never stood a chance. Secondly, several scholars have studied standards as a form of regulation and found that in some cases this can hinder innovation and change in specific sectors (Choi, Lee, and Sung, 2011; Gann, Wang, and Hawkings, 1998). Moreover, it is also found that (national) standards can act as non-tariff trade barriers for trade (Swann, 2000).

On the other side it is found that standards and standardisation can have enabling functions for innovation. First of all, the informative characteristics of standards provide knowledge and information on specific requirements and new technologies through agreements and norms (Blind, 2016). Second, standards and standardisation facilitate the diffusion of innovation (DIN, 2000). Standardisation can be perceived as defining shared knowledge norms, from which broad consensus facilitates widespread adoption of innovations (Zoo et al., 2017, p.335). Furthermore, standardisation can increase economies of scale and network externalities that contribute to diffusion as well (p.335). In that regard standards and standardisation can be seen as enablers of innovation (Swann, 2000).

Ortt and Egyedi (2014) give a potential explanation as for why these two different sides are not able to agree on the issue: they argue that the different effects apply for different types of standards or standardisation. More specifically they point out the timing: standards can already exist beforehand or arise only after an innovation is created. The informative element of standards, for example, is primarily found for de jure standards. The formality of these standards provides access to valuable information on "desirable characteristics" (DTI, 2005, p.59), which is often not the case for proprietary, de facto standards (DTI, 2005; Ortt and Egyedi, 2014).

Other scholars argue that the effect of standards and standardisation on innovation depends on the countries involved. Blind, Petersen, and Riillo (2017) find that in highly uncertain markets, standards have a positive influence on innovation, while in low uncertain markets standards hinder innovation. Guasch, Racine, Sanchez, and Diop (2007) point out that some studies have found that firms in developing countries are hindered in exporting their innovations by international or foreign standards. Other studies that only focus on Western countries find mixed evidence. This implies that country-specific contexts matter in the effect of standards and standardisation on innovation and its diffusion (p.40). In the next chapter, section 3.3, the relationship will be further explored with a distinction between developed and developing countries.

All in all, the following can be concluded from this literature review: the effect of innovation on economic growth in the developed world has been established; the relation between standardisation and innovation is ambiguous, it can both be enabling and constraining; innovation functions differently in developing countries than it does in developed countries; and lastly, it is questioned whether all of these effects are only 'Western imaginary' and thus only hold for developed countries. The effects and relations should be critically reviewed in the context of developing countries. This will be touched upon to some extent in each of the following chapters.

Chapter 3

Theoretical framework

This chapter will show the reader in more depth what the relationship between standards, standardisation and innovation is about. To deepen the understanding of all aspects of the relation, the different elements will be covered. The first section is primarily dedicated to the concept of frugal innovation (FI). Section 3.2 is dedicated to the concepts of standards and standardisation. The third section of this chapter further elaborates on the debate that was introduced in section 2.3: whether standards enable or constrain innovation. The debate will be evaluated in the context of developing countries in particular, as this can specifically relate to frugal innovations. The last section functions as a preface for the research design and analysis chapters. Section 3.4 completes the theoretical framework by introducing the hypothesis that will be tested in this research, the control variables, and the conceptual model for overview.

3.1 Frugal innovation

Following traditional theory and globalisation, new innovations originate from developed and industrialised countries (Ostraszewska and Tylec, 2015; von Zedtwitz et al., 2014). The innovations are invented and designed to meet the needs of people in these countries (Ostraszewska and Tylec, 2015; Trimble, 2012). These classifications make sense: wealthy consumers are able to spend money on new technologies and thus demand for innovation is created in wealthier countries (Trimble, 2012). Later innovations will reach markets of developing countries "when [the innovations] have become increasingly mature, out-of-date, and obsolete" (von Zedtwitz et al., 2014, p.12). Frugal and reverse innovation are two concepts within the context of innovations that contradict these views. In this section the reader will be informed on the first concept. The second subsection, 'Characteristics of frugal innovation', explores the origins of FI, the process and the diffusion.

Definition

A widely acknowledged definition for frugal innovation, as explained by Bhatti et al. (2018), is "means and ends to do more with less for many or more people" (p.181). This definition specifically encapsulates both the process and the outcome, and both the efficiency and the impact of the concept. Frugal innovation is defined by Hossain, Simula, and Halme (2016) as follows:

[A] resource scarce solution (i.e., product, service, process, or business model) that is designed and implemented despite financial, technological, material or other resource constraints, whereby the final outcome is significantly cheaper than competitive offerings (if available) and is good enough to meet the basic needs of customers who would otherwise remain un(der)served. (p.133)

This definition comprises the many elements that together form a frugal innovation. All in all, it is a concept of innovation that is motivated by resource constraints and aims for affordability, good performance, sustainability and usability (Hossain, 2017, p.200). Pisoni, Michelini, and Martignoni

(2018) and Soni and Krishnan (2014) illustrate that frugal innovation goes beyond innovation as a practice: it is also about mind-set and approach to process and outcome.

3.1.1 Characteristics of frugal innovation

As Zeschky, Winterhalter, and Gassmann (2014) illustrate with examples and figures, the concept of FI goes beyond the traditional view of innovation. Frugal innovation is not about altering products and services that we know and use, to make them suitable for developing contexts: this is known as 'cost' or 'good-enough' innovation and is mostly about optimising processes or changing elements to reduce costs. FI is about creating a new product or service of good quality that particularly meets the needs and demands of consumers in resource-constrained contexts. There are several ways through which this can come about. This subsection describes the origins of FI, the development process and a detailed discussion of the implementation and diffusion of FIs.

Origins of FI

The literature distinguishes three mechanisms from which frugal innovations arise: (1) grassroots-level, (2) domestic enterprises, domestic multi-national corporations (MNCs) and foreign MNCs with local offices, and (3) foreign MNCs without local offices (Hossain, 2017; Hossain, 2018; Pisoni et al., 2018; Soni and Krishnan, 2014). Soni and Krishnan (2014) state that there are shortcomings in the FI research on these levels separately: they argue that while the mechanisms are very different from each other, this is not distinguished as much. This paragraph will attempt to review the origins through the present literature.

The first mechanism to frugal innovations, at *grassroots-level*, originates from locals: individuals or groups who combine ingenuity with the needs of locals like themselves and around them (Hossain, 2017; Pisoni et al., 2018; Soni and Krishnan, 2014). The innovations are based on knowledge, experience and skills that are characteristic to the community, location and/or culture (Pisoni et al., 2018; Soni and Krishnan, 2014). The resulting products and services often solve problems that are characteristic to the area and they receive more trust and acceptance within the community (Pisoni et al., 2018). Frugal grassroots innovators are often not educated, inexperienced in innovation, and self-employed. As a result, the innovation is based on trial and error. The innovations are often realised without any support from firms or institutions and might have difficulties in accessing institutions or formal organisations, which obstructs their scaling up (Pisoni et al., 2018; Soni and Krishnan, 2014). Lastly, grassroots-level innovation has a positive effect on the empowerment and independence of locals (Niroumand, Shahin, Naghsh, and Peikari, 2021; Pansera and Owen, 2018a; Pisoni et al., 2018). An innovator's social network, engagement with the community, and involvement with the right actors and organisations can contribute strongly to the success of an innovation (Gupta, 2020; Hossain, 2016; Niroumand et al., 2021).

A second origin from which frugal innovations arise is the involvement of *domestic enterprises*, *domestic MNCs* (which Hossain (2018) refers to as emerging multinational corporations (EMNCs)) or *MNCs with local headquarters*. In contrast to the grassroots-level innovators, innovations by these companies are not intended to solve the innovator's own problems (Soni and Krishnan, 2014). These companies aim for BoP customers in the communities that they have close ties with, in other countries, or customers in places similar to those of their own (Hossain, 2017; Pisoni et al., 2018). They have the resources to perform R&D activities in these contexts and, like the grassroots innovator, the local knowledge, skills and experiences at their disposal (Hossain, 2017; Pisoni et al., 2018; Soni and Krishnan, 2014).

Third, we find that Western MNCs are more and more interested to enter developing countries and emerging markets (Hossain, 2017). The third level from which frugal innovations can arise is thus concerned with the *MNCs that have not established local offices*. Although these companies have all

the resources to achieve suitable outcomes (frugal innovations), Hossain (2018) states: "a key challenge to overcome is the highly fragmented nature of low-income markets and their low current value" (p.931). Specific actions and efforts are required for an MNC to be involved in frugal innovations in the context of developing countries: deep engagement with the local environment, new business models and strategies, overcoming institutional voids, and taking risks in unreliable markets (Hossain, 2018; Hossain, 2017; Soni and Krishnan, 2014; Pisoni et al., 2018). This can be done through the establishment of the earlier mentioned local headquarters, and furthermore by appointing local employees.

Process

In addition to the above mentioned enabling and constraining factors for different origins, there are general elements in the process that should be elaborated on. In his review paper The main driver for frugal innovation is the limitation of resources (Hossain, 2018). Financial constraints can be dealt with due to lower wages, reuse of materials, make use of local available resources, eliminating features, and reduced maintenance costs (p. 931). The resource-constrained contexts form a fruitful base to innovate FIs on the hand: FIs are affordable for the citizens in these markets; supply is more suitable to the context (e.g. Unilever offers soap powder sachets in smaller doses); and, business leads to new revenue streams, employment and value creation (Hossain, 2018, p.932-933). On the other hand, the constrained contexts imply weak infrastructure and other institutional limitations that hinder the innovation process as well: social exclusion or uneven distribution of resources (Pisoni et al., 2018, p.117). One of the biggest challenges in grassroots innovation, as described by Smith et al. (2014), represents the same enabling and constraining elements: 'locally-specific' versus 'widely-applicable' (p.120). Local engagement and suitability to the specific context are some of the most important factors for success in the first place. However, an innovation should be more widely applicable for diffusion opportunities.

Diffusion of FI

Although frugal innovations arise in many different countries across the globe, most are found in India, China and the US, respectively (Hossain, 2017). Both in Hossain et al. (2016) and Hossain (2020) the authors stress the scarcity of research into the diffusion of frugal innovation. Both papers refer to traditional theories of diffusion for the phenomenon of innovation in general. The existing theories are criticised and it is argued they are not suitable to explain diffusion of innovations that originate from developing countries. Some specific elements that affect the diffusion of innovation from developing countries are described by Zanello et al. (2016): the nature of the innovation, transportation channels, communication channels, strength of the institutional arrangements, and socio-economic contexts. Hossain et al. (2016) studied four cases of frugal innovation in an attempt to define the diffusion for frugal innovations. They found that factors affecting the diffusion of FIs can be: the need for the FI; the functional and technological qualities; the marketing channels and logistics; and lastly, the capabilities of the innovator, firm or MNC (p. 136). Consequently, the authors distinguish four levels of diffusion: (1) local, (2) proximity, (3) distance, and (4) global. *Local diffusion* is diffusion of the FI within the country of origin. A characteristic of FIs that diffuse only locally can be the use of "cheap, local, simple and/or used materials" (Hossain et al., 2016, p.136). *Proximity diffusion* is diffusion of the FI to other countries that share geographical region and are characterised by similar social and economic conditions. Often countries with similar conditions are also neighbours, but evidently, similar socio-economic conditions exist further away as well. Diffusion to similar conditioned countries but in another region or on another continent is what is termed *distant diffusion*. Whenever a next step is taken: diffusion to countries with different socio-economic conditions, the FI can potentially be received by any other country. This is *global diffusion* of FIs. Globally diffused FIs are reverse innovations as well. Reverse innovation (RI) is another new discourse within the field of innovation. It can be defined by the opposing order of introduction and consumer group to traditional innovation.

The concepts of RI and FI do overlap but they are not the same, as Hossain (2017) explains: "reverse innovation (...) goes a step further. It encompasses some set of customers in rich countries. Developing capability of frugal innovation is a prerequisite for reverse innovation." (p.199). Elements that speed up the diffusion or ignore one of the steps are the fast exchange of knowledge through the internet, the global connection of social media and the involvement of Western MNCs (Hossain et al., 2016, p.136-137).

3.2 Standards and standardisation

Standards are an essential part of contemporary economies. This section contributes to the readers' understanding of the concepts 'standards' and 'standardisation'. The first subsection introduces standards: a definition and characteristics. What follows is a subsection that does the same for standardisation. Lastly, the third subsection is dedicated to the governance of standards and standardisation: the way it is arranged on the international and the national levels.

3.2.1 Standards

The International Organization for Standardization (ISO) provides a general definition for a standard:

a document, established by consensus and approved by a recognized body, that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context. (ISO, n.d.(b))

This definition takes into account the mechanisms of standards-setting and it encompasses many characteristics. In reality there are different forms of standards. Each form can be characterised by their own mechanisms for development and rules for compliance. There are three ways in which standards can be distinguished. First of all, standards can be distinguished based on their origin. *De jure* standards are relatively formal, either because of the underlying economic pressure or because they are formalised and enforced by governmental agencies or industry committees (Langenberg, 2006; Lea and Hall, 2004). In contrast, *de facto* standards arise and exist informally within the industry (Lea and Hall, 2004). Secondly, standards are either proprietary or open. *Proprietary*, or sponsored, standards are property of a business or organisation that can grant or sell licenses for the standards (Ernst et al., 2014; Stango, 2004). These standards depend on the demand of both the consumer and the producer and the price is set by the owner: owners might subsidise the standard first to improve its popularity (Stango, 2004; Steinfield, Wigand, Markus, and Minton, 2006). Oppositely, *open*, or unsponsored, standards are free to use for anyone who is interested and their creation depends solely on the consumers' demands (Stango, 2004; Steinfield et al., 2006). In practice *de jure* standards are never proprietary while *de facto* standards often are (Ernst et al., 2014; Stango, 2004). Third, standards can be either voluntary or mandatory. Mandatory standards are enforced by governments (Breitenberg, 2009).

3.2.2 Standardisation

Standardisation is defined by the Oxford English Dictionary as "the process of making things of the same type all have the same basic features" (Cambridge Dictionary, n.d.), in other words: the action of setting the standards. To understand the underlying processes and interests, the playing field must be described more extensively.

Generally, one can distinguish three standard setting mechanisms. First of all, the majority of standards originate from the market itself (David and Greenstein, 1990; Lea and Hall, 2004; Mattli and Büthe, 2003; Steinfield et al., 2006). This either happens naturally through competition for

consumer preferences and demand, or by informal industry bodies in which industry actors are represented. The industry bodies and actors together "provide the technical and institutional framework *within* which competition might then take place" (Lea and Hall, 2004, p.70). Standards which are set by the industry are de facto standards and can both be open or proprietary (Lea and Hall, 2004; Stango, 2004; Steinfield et al., 2006). Secondly, non-governmental international and national standards bodies assemble both private and public actors to develop widely acknowledged standards (David and Greenstein, 1990; Lea and Hall, 2004; Steinfield et al., 2006). The standards are de facto standards and can, again, be both open and proprietary. Lastly, we distinguish governmental standard setting. These are often (but not always) mandatory standards decided on by regulators at different levels and thus involve bureaucracy and politics (David and Greenstein, 1990; Lea and Hall, 2004). As a result, these standards can be both de facto and de jure, depending on the legislative basis, and are mostly open (David and Greenstein, 1990).

3.2.3 Governance

Standardisation takes places on all levels: local, national, regional and international. This subsection describes the organisation of the system based on the extensive reports of Kellermann (2019a) and Kellermann (2019b). First the international standardisation is discussed. Secondly the concept of 'quality infrastructure (QI)' is introduced. The concept encompasses the organisation of the national system and includes standardisation as one of its fundamental pillars.

International standardisation

The WTO has established, as part of the TBT Agreement, principles for good standardisation practice (Kellermann, 2019b, p.47). Furthermore, the organisation promotes the use of standards and the national adoption of international standards, as it is essential for trade without barriers. International standardisation is organised by several international standards development organisations (SDOs) such as: ISO, the Codex Alimentarius Commission (CAC), the International Electrotechnical Commission (IEC) and the International Telecommunications Union (ITU). Within these organisations there are different levels of membership: national standards bodies (NSBs) represent their countries. Higher levels enjoy more rights in voting and participation. Some latecomer or developing countries are part of these organisations by a lower level of membership (ISO, n.d.(a)).

Among smaller groups of countries, regional organisations have been set up (Kellermann, 2019b). Some of those are also recognised by the international organisations mentioned above.

Quality infrastructure (QI) and standardisation

Before introducing standard setting on the national level, a more broad national concept should be introduced. In the literature there are several different terms used to describe the same concept. While Guasch et al. (2007) refer to it as 'National Quality System', here it will be referred to as 'quality infrastructure (QI)' similar to Kellermann (2019b). It is defined by Kellermann (2019b) as follows:

The system comprising the organizations (public and private) together with the policies, relevant legal and regulatory framework, and practices needed to support and enhance the quality, safety, and environmental soundness of goods, services, and processes. (...) It relies on metrology, standardization, accreditation, and conformity assessment. (p.41)

Figure A.1 (Appendix A) visualises the relations and interactions between the three pillars: standards, metrology and accreditation. Kellermann (2019b) argues that a well-developed QI contributes to competitiveness, access to new markets, productivity, innovation, environmental protections, and the safeguarding of human health and safety (p.ix). The standards-'pillar' in a country takes on the form of the NSB. Although the national system can be different for every country, generally the NSB

is on top of the hierarchy in the organisation of national standard setting. In some countries the NSB is one single body, in others it is a combination of entities. An NSB represents the country in regional and international organisations, it determines strategy and direction, and it facilitates the development, publication, evaluation, purchasing and information services of national standards. Important entities under an NSB are technical committees (TCs). A TC is established to develop standards for one specific subject (Kellermann, 2019a, p.26-27). Committee membership should be open to any stakeholder. The TC should consist of a balanced representation of all interested parties, and within a TC there can be subcommittees and working groups. TCs often function as ‘mirror committee’ for regional and international committees. A mirror committee has similar functions as the TC in regional or international organisations where the country takes part in. Moreover, the mirror committee decides what the country’s stance is on subject that are debated in the international TC. An NSB should provide training for TC members in general and the chairpersons, secretaries and information personnel in particular (p.34). This ensures quality in the development of standards. In addition to the NSB there are often other SDOs to be found within the country such as ministries and industry SDOs (p.37). These should be recognised by the NSB so that the NSB can ensure good standardisation practices in these SDOs. Lastly and NSB is responsible for the provision of information and sales of standards (Kellermann, 2019b). These services used to take place offline, only hard copies of standards were available. Nowadays, most information services are provided online, and more and more countries are selling their standards through the Internet as well. However, in many lower-income countries, hard copies are and should still be available for small entrepreneurs who cannot access the Internet (p.51).

3.3 Standards, standardisation and innovation

Section 2.3 introduced the debate that is discussed in various literature on the role of standards and standardisation in innovation. Now that these concepts have been elaborated on in the previous sections, this section will discuss the relation in more depth. The earlier introduced work by Blind (2016) refers to Swann (2000) who categorised standards into four categories with each its own enabling and constraining effect on innovation. This classification serves as a basis for other scholar’s research as well (Blind, 2016; Zoo et al., 2017). Zoo et al. (2017) argue that the effects take on different forms in developing countries. In the first subsection the different types of standards and their effects, according to the classification, are discussed along with a comparison to the context of developing countries. Table A.1 (Appendix A) provides an overview of the elements for both contexts. Afterwards the importance of QI for the catching up of developing countries is discussed.

3.3.1 Standards and their effects

The first category consists of standards is concerned with *variety reduction* (Blind, 2016). Generally, limited variety optimises the production process because production costs decrease. In turn, production can be scaled up resulting in economies of scale and further diffusion of innovation. In the context of developing countries this also means that production can be modernised and be upgraded in order to catch up with the rest. Furthermore, it encourages inclusiveness to the needs of consumers, and will therefore diffuse easier to similar areas and countries (Swann, 2000; Zoo et al., 2017, p.337). However, local needs can also become overlooked by variety reduction. And, when variety reducing standards are introduced too early within a market, they might hold back the development of certain innovation and result in situations similar to the QWERTY keyboard as introduced in section 2.3. Furthermore, the market concentration increases which reduces competition and incentives for innovation (Blind, 2016, p.426; Swann, 2000).

Second is the category of *minimum quality and safety standards*. These standards safeguard health and safety, and guarantee minimum quality for consumers. They furthermore provide a way for innovators to prove the quality and safety of their product, which is especially important for new technologies that are associated with higher risks and for innovations from developing countries (Zoo et al., 2017).

As a result, they increase trust, reduce transaction costs and information asymmetry, and the standards can protect third parties or prevent negative externalities (Blind, 2016; Swann, 2000). Moreover, in developing countries the compliance increases productivity and efficiency and thus facilitates more innovation, which improves quality (Zoo et al., 2017). However, the costs for compliance, either by purchasing licenses or by implementing requirements can form barriers to trade, which decreases competition and thus the incentives for innovation (Blind, 2016; Zoo et al., 2017). Moreover, in developing countries, the international and national minimum standards create two parallel systems. The result is that the innovations comply with different standards for different customers, and thus there is no "spillover effect to the domestic population" (Zoo et al., 2017, p.338).

Third is the category of standards concerned with *compatibility and interface*, which facilitate that different products from different producers are compatible and interoperable (Blind, 2016; Zoo et al., 2017). This reduces switching costs, induces positive network externalities, increases dissemination of innovations and infrastructure can arise from it. In turn this leads to more innovation and increase value, but it can also lock in inferior designs or create monopolies (Blind, 2016; Swann, 2000; Zoo et al., 2017). Since infrastructure might be absent or non-interoperable in developing countries, the positive effect can be even bigger. Moreover, in these countries the standard can promote local innovations and increase their impact. However, at the same time this can lead to government monopoly, or "political capture" (Zoo et al., 2017, p.339-340).

The fourth and last category is concerned with information and measurement. These standards overlap with the three others in their functioning and are only described by their positive effects (Blind, 2016; Swann, 2000; Zoo et al., 2017). Standards diffuse knowledge and best practices, they decrease transaction costs, diminish information asymmetry and increase trust.

3.3.2 QI and developing countries

The World Bank describes that National Quality Systems contribute to international competition, facilitate the diffusion of standards, and facilitate the coordination of the development and adoption of standards within the economy (Guasch et al., 2007, p.10). Secondly, a QI that is both efficient and effective is essential for the innovation of new products (Kellermann, 2019b, p.xi). At the same time however, it is emphasised that: "[d]eveloping countries are generally characterized by weak standardization culture" (Aldaz-Carroll, 2006, p. 7), while the role of standards for economic growth has increased because of globalisation (Choi, Hyun, Hong, and Kang, 2014, p.969). Choung, Hameed, and Ji (2012) state that standardisation "remains a playing field of governments and firms from developed nations" (p.771). Standards are expected to contribute to 'catching up' economically, but countries need the institutional capacity to realise this catch up. This is why various developing countries, emerging markets, or 'latecomers' are evaluating their systems for standardisation and planning for strategic improvements or reforms (Aldaz-Carroll, 2006; Choi, Hyun, et al., 2014). Some of these countries are concerned with the impact of their domestic standard capabilities on trade, technical barriers and recognition of conformity assessments results (Choi, Hyun, et al., 2014, p.969-970). The upgrading of the standardisation system in developing countries contributes to demand, export quality, reduction of transaction costs, higher integration with developed countries and greater market access, which in turn all contribute to the diffusion of innovation. It is thus an essential step in the economic 'catch-up' of developing countries.

3.4 Hypothesis, control variables and the conceptual model

Ending the theoretical framework chapter, the hypothesis and control variables can now be defined. Together these will form the basis on which the research design is created. First the hypothesis is introduced, secondly the choice for control variables is elaborated on, and the chapter ends with a visual of the conceptual model.

3.4.1 Hypothesis

Sections 3.2.3 and section 3.3.2 described the role of national standard capabilities, as part of a country's QI, in national and firm-individual performance on the market. The national standard capabilities are therefore essential in any process that is related to standards. Additionally, section 3.3.1 assessed the debate on the role of standards and standardisation in innovation and illustrates the uncertainty about this relation in the context of developing countries: based on the available research we can assume this relation differs from the context of developed countries while being of great importance for economic growth and the diffusion of innovations.

In relation to this distinction, we find a new discourse within the phenomenon of innovation: frugal innovation, as described in the first section. The subsections elaborate on the specifics and show that similarly, traditional theories do not necessarily apply to the concept of FI, which often takes place in developing countries. Therefore, this research will attempt to contribute to these two gaps by looking into the role of standards and standardisation in frugal innovations. More specifically: in the context of developing countries, by assessing national standard capabilities. The conceptualisation and operationalisation of these aspects will be elaborated on in the next chapter. Altogether, it leads to the following hypothesis:

Hypothesis 1 *Better developed national standard capabilities within a country positively affect the diffusion of frugal innovation.*

3.4.2 Control variables

As has been outlined in the previous chapters, there are various elements that affect frugal innovation at different moments and in different ways. Therefore control variables are distinguished as part of this study, which are introduced here and worked out in more detail in the next chapter.

In section 3.1.1 various influential factors for the diffusion of frugal innovation are pointed out based on the academic paper by Zanello et al. (2016). First of all, taking into account both information and transport channels the (*digital*) *infrastructure* of the country should be determined. Through (digital) information channels the potential consumers can be reached. Higher quality information channels can reach more people, more easily. Transport channels include traditional infrastructure modes: roads, airports and harbours. Not only distance but even more importantly a higher quality and efficiency of a country's transport channels positively affect the diffusion of an innovation.

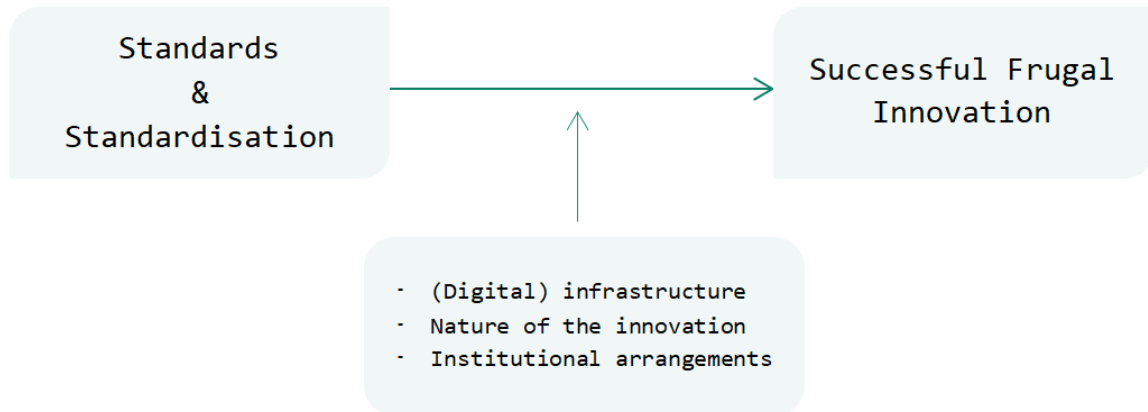
Secondly, the *nature of the innovation* is said to be of great importance for the diffusion of the technology. There are several elements that define the nature of the innovation: adaptability, compatibility, utility and complexity. In lower-income countries low-tech innovations tend to diffuse faster than high-tech innovations since it can more easily be adopted in different environments with different resources. Furthermore, the characteristics of an innovation should suit the consumers' needs in order for it to be adopted. Local knowledge, expertise and insights can increase the adaptability, compatibility and utility of the innovation in these countries' contexts and therefore increase the diffusion rate.

And third, the *institutional arrangements* of a country affect import and export and therefore diffusion of innovation. There are several elements that are characteristic of a country's institutional arrangements. Low political stability and law enforcement in a country discourages foreign investors to invest, and therefore decrease the chances for diffusion of innovations (p.889). Moreover, democratic governments have a more positive effect than non-democratic governments do. The economic openness of a country represents the levels of import and export, in a more open economy, more export takes place which enables the diffusion of innovations. Lastly, a more developed innovation system within a country encourages the development of innovation and the diffusion of it. Financial support by the government can be part of a well-functioning innovation system.

3.4.3 Conceptual model

By joining together the described concepts, relations and the hypothesis a conceptual model can be drawn up.

FIGURE 3.1: Conceptual model



Chapter 4

Research design

This chapter will provide the reader with an elaborate overview of the research design. What choices have been made and which options are avoided, how will the chosen method be worked out and what can be concluded? The reader will first find an explanatory report of the choices that are made for this thesis and how these will be executed. The second section elaborates on the case selection. The last section is concerned with the implications of the methods for results and conclusions.

4.1 Research approach

This research performs a qualitative empirical case study that is X-centred and applies a co-variational (COV) analysis. An X-centred approach "aims to investigate whether a specific factor makes a difference" (Blatter and Haverland (2012), p.24). This can be accomplished by comparing cases that are similar on almost all levels, except for the independent (X) variable. The independent variable has to diverge between the cases. The values for X and Y (the dependent variable) for all cases are compared and the variations are measured. The idea behind this type of research is to simulate an experiment to be able to determine the effects of a specific factor (p.37). To approach experiment-like characteristics, all other conditions have to be controlled for. This is why the cases must be most similar, to be comparable. As a result of these requirements, the selection of cases is essential in a COV study. In qualitative research with only few cases, the cases should be purposefully selected. Lastly, it must be acknowledged that a COV approach "assumes that the causal effect of 'independent variables' have an autonomous causal power" (Blatter and Haverland, 2012, p.41), that is independent of other possible independent variables.

Another approach that would have perfectly suited this research is causal process tracing (CPT), and even a combined approach of the two is possible in theory. However, a research takes place within an established time-frame and with limited resources. The COV approach is better equipped to be performed within the availability of data and cases, and the time-frame of a master's thesis, than the CPT would. Moreover, co-variational analysis compares similar cases in order to analyse the effect of the independent variable on the dependent variable. This perfectly describes the aim of this research. Applying CPT to this study was seriously considered, but eventually it was impossible under the circumstances.

The approach that is performed is a form of cross-case analysis: "an analysis that involves an examination of more than one case" (Babbie, 2016, p.383). A cross-case analysis attempts to discover patterns by analysing these cases. More specifically, the proposed research design is an example of a variable-oriented analysis: "an analysis that (...) explains a particular variable" (Babbie, 2016, p.383). As Babbie (2016) further explains, a variable-oriented analysis attempts to "achieve a partial, overall explanation using relatively few variables" (p.383), with no pretence that this explanation will predict the outcome of every other individual case. This section further presents to the reader what steps are made in the design to define the approach. First the independent variable is introduced in detail by conceptualisation, operationalisation and measurement. The second part does the same for the dependent variable. Both variables and their according choices are visualised in tables and supported

by an explanation of the data collection. After the comprehensive overview of the variables, the control variables and lastly the selection of cases is introduced.

4.1.1 Independent variable

To execute any analysis we must define the X and Y concepts more precisely. The process of defining what we mean is conceptualisation (Babbie, 2016, p.128). Furthermore, a nominal definition of the concept distinguishes the interpretation of the concept for its use in this study (p.131-132). In addition to the conceptualisation, this research requires an operationalisation of the two variables. Operationalisation enables the analysis and measurement of the concepts. It specifies what indicator represents the concept and how it will be measured. This section illustrates the conceptualisation, operationalisation, measurement and data collection for the independent variable. It includes a visualisation of these steps.

Concept

The independent variable in this study is 'standards and standardisation'. This variable is independent because its effect on the dependent variable will be analysed (Babbie, 2016). As illustrated in the previous chapter, 'standards and standardisation' encompass various elements and factors. The independent variable includes all of these possible configurations: both the documents that are standards and the activity of standard setting by national and international private and public organisations. What is meant with the variable 'standards and standardisation' in this study in particular is: the international and national systems, including all bodies, actions and rules, that together perform standardisation and all that is required to develop, implement and comply with standards.

This research is especially interested in the national and international public actions and institutions and their effect on frugal innovations. In Chapter 3 it is described what the role of a national quality infrastructure means for innovation. Standardisation is one of the fundamental elements of quality infrastructure, and the national capabilities for standardisation are essential in that. As a result, the independent variable is specified as 'national standards capabilities': the capabilities within a country for standardisation and the quality of the standards system.

Operationalisation

There exist several tools that attempt to measure quality infrastructure as a whole or specific elements of it such as the national standards system. Three of those methods are pointed out and one is selected for operationalising the independent variable of this study: (1) GQII program, (2) the Rapid and Comprehensive Diagnostic tools, and (3) the maturity table. First of all, the *Global Quality Infrastructure Index (GQII) Program* forms an index that evaluates the state of a nation's QI. The program was created over the past years based on the increased interest in QI, and published in March of this year (Harmes-Liedtke and Matteo, 2021; Harmes-Liedtke and Matteo, 2019). The designers emphasise the potential of the index for the future and they aim to establish a database to enhance knowledge concerning QI. Due to the short existence of the index, there is no data available for cases in the past and it can therefore not be applied. The second method includes two diagnostic tools, set up by the World Bank, in cooperation with the German National Metrology Institute (PTB). The *Rapid and Comprehensive Diagnostic Tools* are two extensive tools to determine the quality infrastructure of a country, including an evaluation of the standardisation system (Kellermann, 2019b). The tools are designed for experts to apply by analysis on location for two to six weeks, "provided that he or she has the full support of knowledgeable local persons" (Kellermann, 2019b). Unfortunately, this research is not equipped to perform such methods. Therefore, these tools are not applied in this study. However, the tools provide us with a third option. As part of the Rapid and Comprehensive tools, a table is provided that consists of factors which reflect the maturity of a country's national standards body as part of the national standardisation system (Kellermann, 2019a). In contrast to the first two methods, this

table is perfectly applicable to this research. It provides eight indicators to measure the independent variable. The eight factors together - as will be described below - take into account the diversity of elements within a national system of standardisation. Therefore, the measure represents our concept. And lastly, the tool can realistically be applied within the scope of a master's thesis.

The independent variable of this study is operationalised by the measurement of the maturity level of a country's national standards body. The measurement will be executed in accordance with the categories and factors as depicted by Kellermann (2019a), and illustrated in the table of Figure 4.1.

FIGURE 4.1: Maturity levels of a country's national standards body, by factor

FACTOR	RUDIMENTARY (LITTLE QI IN PLACE)	BASIC (LOW- TO MIDDLE-INCOME COUNTRY APPROACH)	ADVANCED (ECONOMYWIDE APPROACH, SECTORAL APPROACH)	MATURE (INNOVATIVE, CUTTING-EDGE TECHNOLOGY)
International liaison and membership	None	Correspondent member of ISO Involved in affiliate country program of IEC	Member of ISO Associate member of IEC Member of CAC	Member of ISO and IEC Member of CAC and ITU
National technical committees (TCs)	None	A few TCs for nationally important products and services	A number of TCs for nationally important products and services	A large number of TCs relevant for the country's needs
Mirror committees for international or regional standardization	None	None	A small number for strategically important products and services	A number determined by the strategic importance of the national industry
Participation in international TCs	None	None	A few based on strategically important products or services for the country	A number based on the strategic influence the country wishes to have in international standardization
Standards development organizations (SDOs)	None	None	One or two SDOs, as relevant	Number of SDOs, as relevant
Standards information service	Rudimentary, at government department level	Rudimentary	Fully electronic access to national standards	Fully electronic access and sales for standards
Human resources	No training	Training on the job	Training on the job Training courses for TC chairpersons and secretariats	Training on the job Training courses for TC chairpersons and secretariats
Demand orientation	None	Demand surveys, mostly through projects	Demand surveys Stakeholder participation and consultative mechanism	Strong instruments and constructs to ensure demand orientation

Note: CAC = Codex Alimentarius Commission; IEC = International Electrotechnical Commission; ISO = International Organization for Standardization; ITU = International Telecommunication Union.

Note. From "Comprehensive Diagnostic Tool Annex to the QI Toolkit", by M. Kellermann, 2019, *The World Bank and Physikalisch-Technische Bundesanstalt (PTB)*, p.14.

Measurement

To measure the maturity level of a country's NSB, eight factors are assessed as is shown in the table in Figure 4.1. For each of the factors there are four levels of maturity. First of all, the *rudimentary* level includes countries that have just established an NSB. It describes the most primitive form of quality infrastructure: almost none of the factors are in place (Kellermann, 2019a; Kellermann, 2019b). The *basic* level of maturity can be found in low- and middle-income countries. Some elements are in place and some are still missing. All factors can still be improved (Kellermann, 2019a; Kellermann, 2019b). Third, the *advanced* level of maturity can be found in countries that take into account sectoral needs and apply an economy wide approach. Most factors have been implemented, but there is still room for improvement (Kellermann, 2019a; Kellermann, 2019b). Lastly, the *mature* level of maturity can be found in free market countries and high-income economies (Kellermann, 2019a; Kellermann, 2019b).

The factors that will be assessed according to the categories of maturity from Kellermann (2019a) are explained as follows:

1. *International liaison and membership*

This concerns the membership of the main international organisations. These organisations are ISO, CAC, IEC and ITU. This factor will be assessed according to the categories as distinguished in the table by Kellerman (Figure 4.1).

2. *National technical committees (TCs)*

This factor assesses the number of technical committees that are present in a country. In countries with a rudimentary standardisation system there are no technical committees at all. A basic system will have established a few TCs that are concerned with only the few most essential groups of products and services in that country. In an advanced system this will be extended to other important groups of products and services in the country, and in a mature system there is a TC for almost every group of product and services.

3. *Mirror committees for international or regional standardisation*

This factor assesses the number of mirror committees that are present in a country. Mirror committees are only found in advanced or mature NSBs, since it relates to participation in international TCs. Rudimentary and basic NSBs do not take part in the international TCs - as can be seen in the fourth factor - and therefore do not establish mirror committees. In an advanced system there will be a limited amount of mirror committees. The small number that is established is concerned only with the groups of products and services that are most essential for the economy of the country. In a mature system the number of mirror committees will be bigger. The total amount is determined based on the strategic importance of the sectors of products and services for the country.

4. *Participation in international TCs*

NSBs can take part in international TCs in different roles, depending on their form of membership. Participation and control in these committees yields a country with influence on the international stage. This factor assesses frequency of involvement in international technical committees. Similar to the factor that measures mirror committees, the NSBs at the rudimentary and basic level do not participate in these international TCs. For the biggest part this can be explained by their membership in the international organisations in the first place. In an advanced system one can find, similar to the mirror committees, only participation in the few TCs that are concerned with essential elements of the country's economy.

5. *Standards development organizations (SDOs)*

The factor determines the presence of (recognised) SDOs within the country and will be assessed according to the categories as distinguished in the table by Kellerman (Figure 4.1).

6. *Standards information service*

This factor determines where the information service is provided, and if the standards and sale of standards are accessible online. It will be assessed according to the categories as distinguished in the table by Kellerman (Figure 4.1).

7. *Human resources*

Training can support standards officers, chairs and secretariats to execute their jobs well. This factor determines whether there is training provided at all, and to what extent. It will be assessed according to the categories as distinguished in the table by Kellerman (Figure 4.1).

8. *Demand orientation*

Kellermann (2019a)'s report states: "Standards must facilitate trade, prevent unnecessary trade

barriers, not distort the market, respond to regulatory and market demands, and take technological development into account." (p.29). It is therefore essential for the NSB to orientate on the demand. This factor determines how and to what extent a demand orientation takes place: surveys, on project basis or regularly, participation of stakeholders, consultative mechanisms, and other instruments. It will be assessed according to the categories as distinguished in the table by Kellerman (Figure 4.1).

TABLE 4.1: Overview of the independent variable

Standards and standardisation	
Conceptualisation	The international and national systems, including all bodies, actions and rules, that together perform standardisation and all that is required to develop, implement and comply with standards.
Nominal definition	National standards capabilities (NSC).
Operationalisation	Maturity
Measurement	<i>Indicators</i>
	<ol style="list-style-type: none"> 1. International liaison and membership 2. National technical committees (TCs) 3. Mirror committees 4. Participation in international TCs 5. SDOs 6. Information services 7. Human resources 8. Demand orientation

The factors are evaluated for the countries of origin of the selected cases at one point in time. This will be the year that the innovation was brought onto the domestic market. If significant reforms have taken place close in time to the evaluated year, this will be taken into account. By evaluating each of these factors for the selected countries, the cases can be compared. Yin (1994) argues that the analysis of case study evidence is the aspect that is least developed among academics (p.102). In order to analyse the data, the case study will include a detailed description of the cases. In addition the evidence will be shown, so that these finding combined can finally be presented in tables.

For the independent variable specifically, we see that Kellermann (2019a) and Kellermann (2019b) do not describe how the factors can be aggregated to an overall classification of maturity. Furthermore, the eight factors are all ordinal variables. Ordinal variables are categorical variables: while the 'scores' can be ranked, the distance between the scores is unknown. Therefore, two ordinal variables with a different score cannot be compared in the same way two numbers can. As a result, the findings for the eight maturity factors for each case will be visualised in a table to compare the cases, without an analytical aggregation of the data (Yin, 1994). The visualisation will reflect the general orientation for each case and show for which and how many factors one case might score better than another.

A summary of this section is presented in Table 4.1.

4.1.2 Dependent variable

This section illustrates, similar to section 4.1.1, how the dependent variable of this research is conceptualised, operationalised and measured. It concludes with a report of the data collection and a visualisation of the steps that are made in this section.

Concept

The dependent variable of this study is 'frugal innovation'. The definition and details that are presented in section 3.1 will be used in this study. In this research we are attempting to explain how the success of frugal innovation is affected by the independent variable. Although success can be perceived as a normative concept, it can be defined in its context. In the context of FI, a frugal innovation can be successful - among other things - if it is perceived by the public as frugal, sustainable and affordable; if it meets the needs of consumers; is of quality; is sold to many consumers; has diffused to many countries; or has generated profits.

This research's focus will be on the diffusion of the frugal innovation, as a characteristic of success. Similar to Hossain et al. (2016) this study uses Rogers (2003)' definition for diffusion of innovation: "[d]iffusion is the process in which an innovation is communicated through certain channels over time among the members of a social system" (p.5).

Operationalisation

The diffusion of frugal innovation is operationalised by determining the level of diffusion of the innovation, inspired by Hossain et al. (2016). As described in Section 3.1.1, four levels of diffusion are distinguished by the literature. Three elements have to be determined in order to be able to apply the levels: (1) whether the innovation has been brought onto the market of an another country at all, (2) if yes, whether the country is socio-economically similar or of higher income, and (3) whether the country can be found geographically in the same or a distant region. The categories and their characteristics are shown in Table B.1 (Appendix B). It should be understood that often distant diffusion includes proximity diffusion and that in turn global diffusion includes both distant and proximity diffusion. However, this is not always the case.

Measurement and data collection

To determine the level of diffusion, three elements must be measured. First of all, the location of sales will be determined by collecting data from the company's websites, annual reports, news outlets and (academic) analyses. Secondly, if the innovation has been brought to markets outside of its own, the country has to be classified as either close or distant. First, the socio-economic conditions of the countries need to be compared to the domestic conditions. To measure this, the World Bank income classifications will be employed. Countries are classified into four different forms of economies based on income (GNI per capita): low-income economies, lower-middle-income economies, upper-middle-income economies, and high-income economies. (World Bank Group, 2021). Secondly, it is determined whether the market is found in a neighbouring country to the domestic country. The US Central Intelligence Agency (CIA), provides a list of all countries along with their neighbours (CIA, n.d.). A country is considered to be a neighbouring country if the two countries share a piece of border. If said country is a neighbour, with similar socio-economic conditions, it is characterised as proximity diffusion. Then, if the country is not a neighbour, the World Bank regions will apply (World Bank Group, 2021). The World Bank has classified all countries by region and by income. In total, there are 7 regions: East-Asia and Pacific, Europe and Central Asia, Latin America & the Caribbean, Middle East and North Africa, North America, South Asia, and Sub-Saharan Africa. By aggregating the findings from these three elements the case can be assigned to a level of diffusion.

All in all, there are either one or three questions to be answered:

1. Has the frugal innovation been exported?
2. If yes, are the socio-economic conditions of the exporting country similar to or better than the home country?

3. Has it been exported to a neighbouring country, a country in the same region or a country in another region - as classified by the World Bank?

The questions are applied to the furthest form of diffusion that can be found for the frugal innovation in increasing order: local, proximity, distant and global.

Similar to section 4.1.1, the steps from this section (4.1.2) are summarised in Table 4.2.

TABLE 4.2: Overview of the dependent variable

Frugal innovation (FI)		
Conceptualisation	Success of FI	
Nominal definition	Diffusion of the FI	
Operationalisation	Level of diffusion	
Measurement	<i>Elements</i>	<i>Database</i>
	1. Countries of export	
	2. Geographical region	WB regions
	3. Socio-economic conditions	WB income groups

4.1.3 Data collection

The data for this study as a whole will be collected from two types of sources: (online) documentation and archival records. These sources are stable, exact, have a broad coverage and are unobtrusive (Yin, 1994, p.80). At the same time it must be taken into account that documentation and archival records can be hard to find, are not accessible or deliberately blocked/left out, and there one must be aware of selectivity bias and reporting bias (Yin, 1994, p.80). Documentation is not only valuable for its content; its distribution can reflect on the organisation and communication. To make sure the measurements do not unjustly rely on the content the source must be reviewed: conditions such as the identity of the writer, the purpose it was written for and the way it is communicated have to be considered before interpretation (Yin, 1994). The data from documentation and archival records can be both qualitative and quantitative. Which form of data is required depends on the indicator that is measured. Another essential issue to consider is the reliability of data. With online sources there is a higher risk of unreliability. Reliability is carefully considered for all of the sources that are used in this study. Websites generally present authors, dates and sources, which give an indication to the credibility (Kent State University, 2020). Moreover, certain domains such as '.gov' ensure credibility, in this case for government websites. Lastly, more subtle elements such as the writing style and layout indicate reliability to some extent. More information on the data collection can be found in Table B.2 (Appendix B).

4.1.4 Control variables

Another fundamental element of the COV approach is taking into account control variables (Blatter and Haverland, 2012). These are variables that represent other aspects that might affect the dependent variable. 'Controlling' for these variables contributes to the evaluation of the causal effect that is studied. The earlier selected control variables are measured as follows (technical details are presented in Table B.3 (Appendix B)):

- *(Digital) infrastructure.* Infrastructure and digital infrastructure encompass many different elements. The quality of infrastructure of the case's countries will be assessed by evaluating the LPI score for 'infrastructure' in the year closest to the establishment of the FI.
- *Nature of the innovation.* The nature of the innovation can be defined by several indicators: advancement, utility, adaptability, compatibility, and so on (Zanello et al., 2016). For this study

the concept will be operationalised by measuring (1) the advancement of the innovation, and (2) the local engagement of the innovator.

1. Advancement. The advancement of the frugal innovation will be assessed according to a classification of either low-tech, indeterminate or high-tech, based on the table in Figure B.1 (Appendix B) from Carroll, Poll, and Robertson (2000).
 2. Local engagement. As introduced in Chapter 3, the local engagement or embeddedness of the innovator is essential for the FI in all its forms. A product is adaptable and compatible if it suits the needs of the consumer (Zanello et al., 2016). The elements of local engagement, as described, contribute to the adaptability and compatibility of the FI. Therefore, the local engagement will be assessed. We define three categories based on the three different mechanisms described in section 3.1.1 and the notion that MNCs can tap into local knowledge and experience by establishing offices in the country and employing local employees and managers (Appendix B, Table B.3).
- *Institutional arrangements*. Apart from the institutional standards system itself that is evaluated in this study, there are other institutional arrangements to consider. The variable 'institutional arrangements' is operationalised by four indicators:
 1. Public R&D investment. The 'public R&D investment' will be assessed by the gross domestic expenditure on R&D (GERD) as a percentage of the gross domestic product.
 2. Political stability. The 'political stability' of the case's countries will be assessed by the Worldwide Governance Indicators (WGI) values for 'Political Stability and Absence of Violence/Terrorism'.
 3. Law enforcement. The 'law enforcement' in the case's countries will be assessed by the WGI values for 'Rule of Law'.
 4. Economic openness. As Keman (n.d.) describes, economics openness is defined as "the degree to which nondomestic transactions (imports and exports) take place and affect the size and growth of a national economy" (introduction). The 'economic openness' of the case's countries will be assessed by the World Development Indicators (WDI) values for 'Trade (% of GDP)'.

4.2 Case selection

This section elaborates on one of the most critical aspect of the COV approach: the selection of cases. It starts with supporting theory, and secondly the choices will be explained. Lastly the two cases are introduced briefly.

4.2.1 Purposive sampling in COV

This research attempts to contribute to the upcoming research on frugal innovations by obtaining insights on the effect of standardisation on the phenomenon of FI in developing countries. Therefore, cases should be selected that increase this understanding (Onwuegbuzie and Leech, 2007). However, extensive examples of FI are scarce. For this research two cases can be relevant if they 'facilitate comparison' (p.240), which is the purpose of co-variational analysis. The two cases facilitate comparison if the independent variables score differently. Therefore, the cases will be selected from two different countries. Additionally, not only the control variables should score similarly, but also the basic characteristics of the cases should correspond to facilitate comparison. Either an MNC should be involved in both cases or they should both be grassroots innovations, in order to avoid the influence of this difference on diffusion. Moreover, the time of launch should have taken place around the same time in history to avoid temporal developments of influence. Lastly, the two countries should have similar

basic conditions to avoid a too big discrepancy in starting point. For example, contrasting basic economic conditions for the two cases can lead to diverging scores for multiple of the control variables such as R&D investment or economic openness, and these in turn can be argued to have influenced the diffusion patterns. The World Bank argues to compare, among other things, the gross national income (GNI) per capita (in US dollars) and populations as country characteristics (The World Bank, n.d.(a)).

4.2.2 Selection of the cases

The two frugal innovations are selected from two different countries with each a different standardisation system. The selected cases will have their origin in a developing country, corresponding to the research objective. What ‘developing’ or ‘developed’ means in this context is not clear-cut. The literature contained and referred to in this research such as Zoo et al. (2017) do not define these terms precisely. In this research, a developing country is categorised by the World Bank income categories of ‘low-income economies’ (L) and ‘lower-middle-income economies’ (LM) (World Bank Group, 2021). The independent and control variables will be measured for these cases in the launching year of the innovation. The dependent variable will be determined over the years following the launch.

In his paper *Mapping the frugal innovation phenomenon* Hossain (2017) provides an appendix that presents a list of frugal innovations and their appearance in the literature. Since the availability and accessibility of information on the cases is of great importance, the cases are selected from the top of this list. Expecting that a high frequency of appearance in literature contributes to the availability of data. The first 10 cases with the highest frequency of appearance are:

1. Tata Nano, India;
2. GE’s ECG machine, India;
3. GE’s Ultrasound machine, China;
4. Aravind Eye Care, India;
5. Tata Swach, India;
6. Aakash, India;
7. M-Pesa, Kenya;
8. ChotuKool, India;
9. Husk Power Systems, India;
10. MittiCool, India (p.205-206).

Of these cases, India and China are the most similar. First of all, they are neighbouring countries and are both considered to be emerging markets (IMF, 2015). China and India have similar values of GNI per capita and relatively similar populations. Therefore, the two cases for this research are:

1. GE’s Ultrasound machine, China;
2. Tata Nano, India.

The two cases are both involved with an MNC. While there are many similarities between the cases, it seems China and India take on a different role in the contemporary standardisation discourse. As a result, it is expected that the two score differently for the independent variable.

4.2.3 Case 1: GE Healthcare LOGIQ Book XP, China

In 2007 General Electric (GE) Healthcare launched a frugal, portable, PC-based ultrasound machine *LOGIQ Book XP* from their offices in China (Immelt, Govindarajan, and Trimble, 2009). General Electric Company is an MNC from the US with several subdivisions, from which one is GE Healthcare. Today (2021) GE Healthcare operates in 130 countries around the world (ge.com). From 1979 GE had entered the Chinese market with their healthcare subdivision. GE decided to enter markets outside of the US, EU and Japan to defend itself to upcoming competition in these other regions. After years or trials, research and development, GE launched the frugal LOGIQ Book XP in 2007: for a price of 15.000 US Dollars (USD). It was built from scratch with local experience and expertise. The portable machine cost only 15% of the initial price. Without many of the conventional high-end characteristics it was offering exactly those qualities to rural clinics that was necessary: compatibility and adjustability in its software, increased functionality, and portability so that the machine can be brought to the people instead of the people to the machine. The innovation turned out to be a global success and ended up being part of a new discussion: whether GE might be disrupting itself.

4.2.4 Case 2: Tata Motors Tata Nano, India

In 2008 Tata Motors unveiled to the world, from New Delhi, India, the Tata Nano: a small, affordable and efficient city car. It was introduced as: ‘the people’s car’, and brought by news outlets such as The New York Times as ‘the world’s cheapest car’ (Chang, 2008). Tata Motors is an Indian automobile manufacturing MNC and part of the Indian multinational Tata Group. The existence of the company (Tata Motors) dates back to 1945, when it was founded to manufacture locomotives and other engineering products (Tata Motors, n.d.). Tata Motors operates in 125 countries across all continents. The Tata Nano was launched by the company in an effort to bring an item of luxury to people who could normally not afford it: a big (new) group of consumers (Shafiqulla, 2014) - earlier introduced as BoP consumers. Conventional transport among this consumer group was an inspiration for the design: some would travel with their whole family of four on one scooter. The Tata Nano could replace these risky forms of transport. While the car is really small, there is room to sit for four people, it has a maximum speed of 105 km, and it is fuel efficient. The car was brought onto the market for a price within the range of 2000 - 2500 USD. Although the initial reception was unprecedented with media attention and high demand, Tata Nano and Tata Motors faced several setbacks and controversies in the years following.

4.3 Doing social research: implications

By performing social research, as this research can be regarded, we try to understand the world around us. But by performing social research, we have to be critical. This section evaluates critically the research design. First the internal validity will be reviewed and afterwards external validity, or generalisability, is touched upon.

4.3.1 Internal validity

Before the case study can be performed and the according conclusions can be settled, we must evaluate the validity of the proposed design. The internal validity of an approach is concerned with accuracy of the conclusions that will be drawn from the results (Babbie, 2016). The internal validity can be affected if there is reason to assume that another concept might have caused the measured effect. Several choices have been made in the design to safeguard the internal validity of this research. First of all, the case selection is aimed at the most similarity that is possible for the control variables and basic conditions. If the results support the attempt and additionally show the expected variance of the independent variable, the internal validity is ensured. Whether this applies must be evaluated after the

case study is executed. Although exact cut off is provided for some of the variables, the outcomes can still be reviewed. For each variable, a variance in the scores will be discussed and its possible effect evaluated. Secondly, it must be noted that for one of the cases the outcome was clear before executing the case study. As presented by Hossain et al. (2016), the GE Ultrasound machine has become a reverse innovation, and is therefore classified by Hossain as globally diffused. To avoid a bias, this case was only selected after reviewing the above-mentioned list of cases with according frequencies. Independent of its outcome, the case is relevant for this study and for comparison. Furthermore, the outcome of the other case is still unclear.

All in all, it can be concluded that all conditions have been established for the best chance at ensuring internal validity. It will depend on specific outcomes and explanations of their potential variance whether the internal validity holds.

4.3.2 External validity

External validity is concerned with the generalisability of the conclusions that are drawn from the results (Babbie, 2016). It is therefore also known as generalisability. Inherent to a small-N case study such as COV is the probabilistic nature of the hypothesis (Blatter and Haverland, 2012, p.93). The causality that is investigated allows for exceptions. At most the research shows whether X made a difference in the researched cases, and sometimes conclusions can be made regarding the generalisability of this effect among similar cases. Only cases that experience similar values for the independent and control variables are candidates for generalisation (Blatter and Haverland, 2012). The generalisability of the potential conclusions will be evaluated in the discussion of the findings.

Chapter 5

Findings

5.1 Case 1: China - GE Healthcare LOGIQ Book XP

5.1.1 Introduction to the case

GE Healthcare entered the Chinese market in 1979. One of their products, at that time, was ultrasound equipment. After its entrance in China, GE Healthcare tried to sell ultrasound machines that were initially developed in the US and Japan. But during the first years in China they found that "ultrasound machines were typically found in sophisticated imaging centres in hospitals" (Immelt et al., 2009, p.62), and thus the product often didn't reach the new consumers of the emerging market. At the end of the 1990s, after disappointing results, the company realised how different the Chinese market was from the ones they were used to before (Hossain et al., 2016; Immelt et al., 2009). As a result, the company changed its strategy to a more suitable one. Both the products and the organisation in China were going to be built from scratch, in local growth teams (LGTs). The LGTs meant the participation of local managers and experts, and involvement of locals and their knowledge in all other parts of the value chain. Furthermore, a frugal approach was applied by studying the local needs more specifically. GE Healthcare realised that in China the price, portability and ease of use were more important (in first instance) than high functionality (Clark, Lee, Madishetty, and Daim, 2017, p.239). Around 2002 an ultrasound machine in the US, EU and Japanese markets would cost 100.000 USD, or more (Immelt et al., 2009). The first version of the GE Healthcare China ultrasound (LOGIQ Book) was launched in 2002 for a price of 30.000 to 40.000 USD. Although this was already a lot cheaper than conventional models, it still wasn't received in the way that the company had hoped it would. After applying the new strategy and installing the local growth teams the frugal LOGIQ Book XP was launched in 2007. This one complied with all the local needs, and sales took off in China (Immelt et al., 2009, p.61). It was portable, simple, and durable: local hardware was used to reduce costs, more advanced software was used to ensure global compatibility, high-end features were left out, and an efficient battery was implemented (Clark et al., 2017). In the years following the success grew even bigger: the machine was sold in the US as well where it did not replace conventional machines but instead found its way into US ambulances for emergencies. In these same years the company was able to improve the functionalities and qualities even more. Thus, a frugal innovation had become a reverse innovation.

5.1.2 National standard capabilities

Reliable and complete primary information on the Chinese standardisation system is hard to find, confusing, and subject to change. There are different bodies for every element of the standardisation system. Although the Standardisation Administration of China (SAC) is on top of the hierarchy, many responsibilities are delegated to the other bodies. The result is a tangled web of Chinese government websites. Moreover, the English and Chinese versions of the websites are often very different, and it is a challenge to find older information or versions for analysis of previous situations. A research note by Zhao and Graham (2006) thoroughly explains standardisation in China. This paper, as secondary information, supplements the primary information perfectly and is therefore used to describe the Chinese standardisation system. In Table C.1 (Appendix C) some basic information and facts on the

People's Republic of China are presented. The first part below describes the institutions, organisation and national standardisation, along with a focus on the current reform strategy. Lastly, the findings for the maturity factors are presented.

The Chinese standardisation system

Standardisation in China is a state-driven business, contrasting the mixed models of the EU and the US. As described above, the Chinese standardisation system consists of many different (governmental) bodies. The system under review (2007) is based on the Standardisation Law from 1989, supplemented by the Regulations for the Implementation of the Standardisation Law from 1990. WTO membership inevitably comes with conditions and agreements. As a result, China was required to establish an NSB from 2001 (Zhao and Graham, 2006). It established two institutions: the State Administration for Entry-Exit Inspection and Quarantine (CIQ) and the State Quality and Technical Supervision Bureau (QTSB). Together these two form the General Administration for Quality Supervision Inspection and Quarantine (AQSIQ). Under AQSIQ the Chinese national standards body was established: the SAC. The SAC is the body responsible for drafting and revising state laws, and for formulating and implementing relevant policies (p.70). Moreover, the SAC represents China on the international stage: in global and regional international standards organisations. Within the SAC there are technical committees, one committee is concerned with one field of interest.

Since the opening up, there had been plans to evaluate the standardisation system. In 2015 an Action Plan was announced, and finally in 2018 the standardisation law and regulations were reformed (ANSI, 2015).

Findings: maturity level

TABLE 5.1: Findings: maturity level for case 1

Maturity level: China, 2007				
	Rudimentary	Basic	Advanced	Mature
International liaison and membership				X
National TCs				X
Mirror committees				X
International TCs				X
SDOs				X
Information service				X
Human resources			X	X
Demand orientation			X	X

Note. This table represents a simple visualisation of the classification of maturity for China in 2007. An overview of sources for the data can be found in Appendix D, Table

D.1

China is a full member of ISO since 1978, of IEC since 1957, of CAC since 1984 and of ITU since 1920. Zhao and Graham (2006) describe that in 2005 there were already 264 TCs and 386 subcommittees. Data from the 2007 government website supports this: there are 290 technical committees and even more subcommittees. The bigger part of the TCs is concerned with national important subjects: all aspects of manufacturing or fuel and mining. But the TCs also cover other needs of the country such as work quota, geographical regions, insurances, cosmetics, tourism and animal health. Zhao and Graham (2006) and Gerst (2015) both illustrate that the national committees function as mirror committees on many different subjects. This is reflected by the national TC websites as well: national

technical committees undertake international standardisation in their international counterparts. Participation in international committees is similar to the national committees. Most of the international TCs China is participating in, somehow relate to national strategically important subjects. But at the same time they take part in TCs for cinematography, noise, tobacco, footwear, graphical symbols, social research, financial services and health informatics. The Chinese system scores high in maturity for the presence of SDOs: part of the system is based on these organisations. Trade standards are created by three different SDOs in the industry and local standards by local bureaus, all recognised by the NSB (Zhao and Graham, 2006). Furthermore, China provides its services online. Both the information on standards and the sale of standards is organised digitally. This characterises a mature system. Within the web of bodies that make up the national standards system there are several bodies responsible for training. The Department of Policies and Regulations, Staff Service Center, is responsible for public servant training and the CAS for quality management. There are several forms of training in place that together score ‘advanced’ to ‘mature’. Lastly, at the time of review, China was busy establishing a structure that is more responsive to market demand. Moreover, as mentioned above, many of the Chinese standards originate from the industries. Therefore, the country scores ‘advanced’ to ‘mature’ for this factor.

5.1.3 Diffusion

Section 5.1.1 reports that the GE Healthcare LOGIQ Book XP was first brought onto the market in China and later exported to the US. While there is no record to be found for all exporting countries, some articles state that the portable pc-based ultrasound machine was sold in other emerging markets and has reached developed states other than the US as well. Archived GE Healthcare websites show the availability of the LOGIQ Book XP in India, Brazil (enhanced version) and the UK (enhanced version) (GE Healthcare, 2008; GE Healthcare, 2013; GE Healthcare, 2014). However, more specifics are not necessarily required to determine the level of diffusion, since the questions from section 4.1.2 can be answered as follows:

1. *Has the frugal innovation been exported?*
Yes, the frugal innovation (LOGIQ Book XP) has been exported to at least the US.
2. *If yes, are the socio-economic conditions of the exporting country similar to or different from the home country?*
In 2007 China was classified as a lower-middle-income country (The World Bank, n.d.(b)). The US was classified as a high-income country in 2007.
3. *Has it been exported to a neighbouring country, a country in the same region or a country in another region - as classified by the World Bank?*
China has been categorised by the World Bank in the region of East Asia and Pacific (World Bank Group, 2021). The US is not a neighbouring country of China. It is not a part of the region East Asia and Pacific; it is part of North America as classified by the World Bank.

With these findings it can be concluded that the LOGIQ Book XP has diffused to a distant geographical region to a country with different socio-economic conditions: a higher income country. The GE Healthcare ultrasound machine is thus found at the *global* level of diffusion.

5.2 Case 2: India - Tata Motors Tata Nano

5.2.1 Introduction to the case

As shortly introduced in the previous chapter, the Tata Nano was welcomed as ‘the People’s Car’. The unprecedented amount of media attention for this tiny car by a big MNC might be explained by its frugal approach. This innovation ticks all of the frugal boxes as introduced in Chapter 3. First of

all, it is a product designed within financial constraints: the innovation of the car was aimed at lower and middle-income consumers: 'meeting the needs of otherwise unserved citizens'. A price of 2500 USD for the Tata Nano is around 50% of other small city cars such as the Maruti 800 (Clark et al., 2017). Secondly, Tata Motors was able to bring a small and simple car onto the market while still complying with safety requirements and meeting all the local needs: 'doing better with less'. With the aim to reduce costs significantly, the company inevitably had to innovate on other levels as well: all materials and ingredients had to be evaluated with a frugal mind-set. Lastly, the car was designed without 'extra' characteristics one might find in other cars such as high maximum speeds, radio and air conditioning (Singh and Srivastava, 2013).

After the promising reception the company faced several setbacks. First of all, the demand of the car was too big in relation to the supply right after the launch (Chang, 2008, p.82). The second problem that arose was concerned with safety: there were fire and smoke incidents due to electrical circuit failure in 2010. The third issue was a mismatch of marketing. All issues were resolved in the years after.

In 2011 the Tata Nano was sold for the first time on the international market in Sri Lanka, after which it was launched in Nepal and Bangladesh (Aschmoneit and Janevska, 2013; Baggonkar, 2018; Hossain et al., 2016; Times, 2014). Although the company had aimed to sell in African countries as well, this was not achieved. Furthermore, from the start Tata Motors had also aimed for the US and EU markets. While the car was considered safe in India, it did initially not meet European emission and safety standards, as was reflected by crash tests in 2009 in the UK (Schedel, 2009). In 2015 a more advanced version was launched the Tator GenX Nano, but no version of the Nano ever made it onto the streets of the EU or the US (Hossain et al., 2016; Tata Motors, 2015).

5.2.2 National standard capabilities

The Indian standardisation system

India follows a standard model, hierarchy and process for standardisation in their country. It is similar to many other systems in the world such as the EU and the US (Saqib, 2003). The Indian system of 2008 was based on the Bureau of Indian Standards Act from 1986. This act established the Bureau of Indian Standards (BIS) as the national standardisation body. The BIS falls under the authority of the Ministry of Consumer Affairs, Food & Public Distribution and is responsible for the establishment, publication and promotion of 'the Indian Standard' (Government of India, 1986). Moreover, the body represents India on the international stage. Standards are developed based on requests from consumers or organisations. Outside of the BIS there are other government departments involved in the standardisation on specific subjects.

In 2016 the BIS act of 1986 was replaced by the BIS act of 2016. From that time the Ministry became more active in planning a standardisation strategy for India and the BIS. In 2018 the Indian National Strategy for Standardisation (INSS) was released and in 2019 the Standards National Action Plan (SNAP) was developed by the BIS (Directorate of Standardisation, 2021).

Findings: maturity level

India has been a full member of ISO since 1947, of IEC since 1929, of CAC since 1984, and of ITU since 1920. As described above, the BIS includes 14 technical divisions with an aggregated total of 313 TCs. Although this is a high number, the subjects of standardisation are mainly concerned with domestic important issues. It seems the committees are highly specialised in these nationally important subjects, but don't cover some other needs. For international TCs and mirror committees the Indian system can be considered as mature. The BIS Manual for Standards Formulation states that India has a mirror committee for every international committee it takes part in. In ISO, for example, India is either participating or observing member in 594 TCs. These are concerned with a broad array of subjects. For the factors of SDOs, information services, human resources and demand orientation

TABLE 5.2: Findings: maturity level for case 2

Maturity level: India, 2008				
	Rudimentary	Basic	Advanced	Mature
International liaison and membership				X
National TCs			X	X
Mirror committees				X
International TCs				X
SDOs		X	X	
Information service			X	
Human resources		X		
Demand orientation		X		

Note. This table represents a simple visualisation of the classification of maturity for India in 2008. An overview of sources for the data can be found in Appendix D, Table D.2

India seems less mature. Although a few SDOs exist, they are not recognised by the BIS, in the INSS and SNAP this is mentioned as a point of improvement. While a standards catalogue and all information is provided online, the standards still have to be purchased at the office, offline. The BIS has established a training centre (NIST), however, it seems that the trainings that are offered are aimed at people from outside of BIS and the technical committees. Lastly, although the development of standards is done on request basis and ad hoc consultations take place, there are no consultative mechanisms or demand surveys established.

5.2.3 Diffusion

Section 5.2.1 introduced the Tata Nano and it was found that the export of the Tata Nano was limited to Sri Lanka, Nepal and Bangladesh. Therefore, the three questions (section 4.1.2) can be answered as follows:

1. *Has the frugal innovation been exported?*
Yes, the frugal innovation (Tata Nano) has been exported to Sri Lanka, Nepal and Bangladesh.
2. *If yes, are the socio-economic conditions of the exporting country similar to or different from the home country?*
In 2008 India was classified as a lower-middle-income country (The World Bank, n.d.(b)). All of the other three countries - Sri Lanka, Nepal and Bangladesh - were considered to be either a low-income or lower-middle-income country.
3. *Has it been exported to a neighbouring country, a country in the same region or a country in another region - as classified by the World Bank?*
India has been categorised by the World Bank in the region of South Asia (World Bank Group, 2021).
 - Sri Lanka is not a neighbouring country of India. It is also part of the region South Asia, as classified by the World Bank.
 - Nepal is a neighbouring country of India (CIA, n.d.).
 - Bangladesh is also a neighbouring country of India.

With these findings it can be concluded that the Tata Nano has diffused within a close geographical region to countries with similar or lower incomes, thus similar socio-economic conditions. The Tata Nano is thus found at the *proximity* level of diffusion.

5.3 Control variables

The scores for the control variables were gathered as described in the previous section. Table C.3 in Appendix C shows the values for China in 2007 along with the values for India in 2008.

Chapter 6

Analysis and discussion

6.1 Analysis

This section interprets the findings by first comparing the outcomes of the two cases for the independent and the dependent variables and then evaluating the control variables.

First of all, Table 5.1 and Table 5.2 have shown that the two countries have diverging scores for the independent variable. The standardisation systems of China and India show different levels of maturity among five of the eight factors. While China scores 'mature' for almost all of the factors, India's scores are divided over 'basic', 'advanced' and 'mature'. The differences are found among the factors that regard domestic issues: national TCs, SDOs within the country, human resources and demand orientation. Although the data cannot be aggregated to one classification of maturity for each country, we conclude from the data that there is a difference in maturity between the standardisation systems of China and India. China scores higher in maturity than India does.

Furthermore, the two cases have scored differently for the dependent variable as well. The GE Healthcare LOGIQ Book XP from China has diffused more than the frugal innovation from India - the Tata Group Tata Nano.

Third, the control variables in Table ?? can be evaluated. The first control variable is quality of infrastructure. The difference between the LPI scores (within a range of 1-5) for the two countries is small. The LPI score is an aggregation of many elements and both countries score is around 3, therefore the two can be perceived as similar. Secondly, the cases also score similar for the two factors that represent the nature of the innovation. Both innovations are neither high- or low-tech innovations and the two companies enjoy similar levels of local engagement. While Tata Group originates from India, and GE Healthcare solely relies on its China headquarters. But both companies can access local knowledge, expertise and resources. One can argue that Tata Group's potential roots into the Indian system might make a difference: influence in the system could work out in their favour. However, this possibility is against the direction of the studied relationship, therefore this can be ignored. Furthermore, it could be argued that diffusion comes easier for an MNC that originates from the US. However, both MNCs have long established ties all over the world and the case analyses suggest that both have put in similar efforts for diffusion. Third, the institutional arrangements of both China and India are measured. This is done by four indicators. The difference of R&D spending in percentage of GDP of the Chinese and Indian governments is small. The highest record of public R&D spending in 2007 and 2008 was 4,4% of the GDP in Israel and the lowest record is that of Gambia: 0,01%. We can therefore interpret the 1,37% and 0,86% of China and India, respectively, as similar. Equal conclusions can be made for the scores of 'economic openness'. The highest record in 2007 and 2008 was 86,8% for the Virgin Islands (US) and the lowest was 0,18% for Myanmar. Therefore, the values of 62,19% and 53,37% of China and India, respectively, can be interpreted as similar. The scores for 'law enforcement' do diverge for the two countries. Last are the values for 'political stability'. Within a range of approximately -2,5 and 2,5 the China and India score 0,50 and -1,1 respectively. There is thus a variation in the control variable for political stability as well.

6.2 Discussion

This section evaluates the meaning of the interpreted findings first. Subsequently the consequences, limitations and other arguments are discussed.

The case study has attempted to examine the effect of national standard capabilities on the diffusion of frugal innovations. Table 6.1 briefly displays the scores for all of the variables in this study. As Blatter and Haverland (2012) explain, a correct inspection of the table can tell whether the cases support the relation under research, disconfirm it, or whether it is inconclusive. In case a control variable has diverging scores in opposite direction of the proposed relation, the outcomes can still support the relation with additional theoretical reasoning.

TABLE 6.1: Evidence from the case study

Variable	Indicator	Case 1 (China)	Case 2 (India)
Control variable	<i>(Digital) infrastructure</i>	Similar	
Control variable	<i>Advancement</i>	Similar	
	<i>Local engagement</i>	Similar	
Control variable	<i>R&D investment</i>	Similar	
	<i>Political stability</i>	Higher	Lower
	<i>Law enforcement</i>	Lower	Higher
	<i>Economic openness</i>	Similar	
Independent variable	<i>Maturity</i>	More mature	Less
Dependent variable	<i>Diffusion level</i>	Global	Proximity

Note. The table summarises the scores for all the variables in this study. Adapted from "Designing Case Studies", by J. Blatter and M. Haverland, 2012

By first inspection of the table, one can deduce that the scores for the independent and dependent variable support the hypothesised relationship. China's national standard capabilities score higher in maturity and at the same time, the frugal innovation that originated from China (GE LOGIQ Book XP) has diffused further than the Tata Nano from India did. However, the table also shows the variance for two indicators of the control variable 'institutional arrangements' as interpreted by section 6.1 of this chapter. The variance for law enforcement behaves in opposite direction of the hypothesised relationship. Therefore, this control variable does not cause any problems for the evidence. The variance for political stability, however, makes the evidence for the hypothesised relationship inconclusive. The variance for this indicator behaves in a similar direction as the hypothesised relation does. Rules for empirical research dictate that the result from the two cases is therefore statistically indeterminate (Blatter and Haverland, 2012). Although the independent and dependent variable point in the direction of the hypothesised relation, we must conclude that there is not enough evidence from these two cases to support the hypothesis "*Better developed national standard capabilities within a country positively affect the diffusion of frugal innovation.*" because of the variance in political stability.

The relationship and all its variables must be researched in more detail to be able to determine whether the political stability has had a contribution to the diffusion of the frugal innovations. Inherent with the choice for the COV approach is the limitation of studying these variables in more detail. As introduced shortly in Chapter 4, this could be done by causal process tracing.

While the COV case study cannot support the hypothesis, there are some elements that contribute to its plausibility and that could be taken into account during a CPT approach. First of all there is no reason to believe that the political stability by itself caused the proved variance in diffusion of the cases. Although the choice of indicators for institutional arrangements was based on the arguments made by Zanello et al. (2016), the authors do not indicate how the different institutional arrangements interact. The CPT approach could illustrate the course of events for the cases and distinguish the

underlying mechanisms, such as these institutional arrangements, in more detail. Moreover, the CPT approach allows more details of the cases to be considered. For example, while on paper the two national standard systems show small variance in their scores for maturity, based on the data there are reasons to believe that the variance is greater. The Bureau of Indian Standards has established in their rules and regulations the involvement of stakeholders. However, further inspection reveals that although positions have been created for these stakeholders, many are vacant. All in all, the CPT approach would allow for a study of the effect of specific standardisation elements in the process of innovation and diffusion. It could reveal what elements are influential, and which are not.

Although no conclusions regarding the hypothesis can be made from this case study, there are other implications. First of all, the case study shows the complex nature of the national standardisation system. This insight, on the one hand, contributes to the suitability of one of the World Bank's tools to study this relationship (the Rapid or Comprehensive Tool). However, these tools include more than just the standardisation system. On the other hand, we therefore see the need for a more extensive tool to evaluate a country's national standardisation system separately. Secondly, what strikes from the findings on the maturity level of China and India's national systems is the difference in scores on the international and national levels. While both countries show high scores for the international factors, there is a difference for the national elements. Apparently, a country can have different priorities for their domestic system and the international representation. This has not been distinguished in the literature that is discussed in the earlier chapters of this study. Lastly, we find that those control variables that conflict with the evidence are the ones concerned with institutional arrangements. The standardisation system that is under research in this study is also a form of institutional arrangements, as is the QI as a whole. The results once more underline the importance of institutions for innovation and its diffusion, as has been mentioned throughout this study. Separating institutional elements that are inevitably intertwined is a complex business.

Chapter 7

Conclusion

7.1 Conclusion

This thesis has aimed to contribute to research on frugal innovation. The objective was furthermore to try and position frugal innovations in developing countries, within the ambiguous relationship between innovations and standardisation. In this attempt the concepts of frugal innovation, standardisation, standards and quality infrastructure, along with many of their characteristics were introduced. Through exploration of the concepts and their intertwined interdependence it was hypothesised that a better developed national standardisation system positively affects the diffusion of frugal innovation. To test the hypothesis, a case study was set up. Two frugal innovations from developing countries were studied: the GE ultrasound machine from China and the Tata Nano city car from India. For both countries the national standardisation system was explored in order to determine the level of maturity. China's standardisation system was considered to be more mature, and thus better developed than the Indian system. Furthermore, while GE's ultrasound has diffused globally, the Tata Nano has only been exported on proximity level. Although these outcomes of the independent and dependent variables point in the right direction for supporting the hypothesis, the control variables could not confirm it. Due to variations in the control variables, more specifically the institutional arrangements, it was not possible to prove the hypothesis. What has become clear from this research, however, is that institutions matter. Not only is the quality infrastructure an important feature of a country with far reaching consequences, the interdependence of several forms of institutions is once again revealed. The case study has shown that institutions are involved in every step of the innovation process. Although literature provides theories and information on institutions for the context of developed countries with traditional innovation streams, it is necessary to explore this relation specifically for frugal innovation in the context of developing countries. For developing countries there are issues that the developed world might not take into account: there are higher transaction costs in various steps of the innovation process and for accessing markets, and the origin of an innovation comes with certain bias.

The conditions of the research approach, as selected upfront, were internally valid. The case selection and control variables together ensured high internal validity for this study. Unfortunately, the outcomes did not fully represent this. Not all control variables scored similar values. A limitation of this study is therefore the choice of control variables. Although these specific outcomes cannot be avoided, their meaning could be explored further. This limitation could be overcome by application of the causal process tracing method. By further exploring the whole process and specifically the role that institutional arrangements play in this process, the internal validity would be higher. Another limitation of this study is that the independent variable could not be aggregated to one level of maturity. This was not possible because the applied maturity table did not apply such a mechanism. The table is only a simplified version of more extensive tools. There are two ways to overcome this issue. First of all, an interval scale could be designed that suits the content of the table. Interval scales allow for aggregation of the data. Secondly, in a study of bigger scope the Rapid or Comprehensive tools could be applied. Within the time-frame of this study and under the conditions of the pandemic, it was not possible to use these tools. Furthermore, in line with the two previous limitations, there is a more general shortcoming. As mentioned in the introductory chapter, it is difficult, sometimes even

impossible, to eliminate other elements of influence on (frugal) innovation. A more in-depth approach to the cases, such as CPT, could have controlled for the role of elements such as marketing, the links with the US in the GE case or the ties that Tata Group might have with the Indian government. The cases were selected based on their similarities and both cases show similar efforts for exportation of their product. However, it is inevitable that other elements are important for innovation and diffusion, and these should be considered in more in-depth studies.

This thesis presents a small-N case study. Inherent to this method is the limited generalisability, or external validity. The discussed implications in Chapter 6 and above apply to cases similar to those under research here: frugal innovations established by an (E)MNC in developing countries show on average at least advanced maturity in their standardisation capabilities. The generalisability could be increased by performing larger-N studies. The GQII Program, as introduced in Chapter 4, could be applied for larger-N studies on this subject to increase the external validity.

Although it was not possible to prove the hypothesised relation in this study, it does not imply that it cannot ever be proven. This study has first of all introduced a combination of concepts that is fairly new: the combination of frugal innovation and standardisation. It has revealed the uncertainty of the interdependence of some of these concepts. The frugal innovation discourse requires scholars to evaluate traditional links and study new ways. In addition to the work of scholars that have already looked into these new ways, this study introduces the institutional point of view. The work of Zoo et al. (2017) presented the differences of standardisation in developed and developing countries. The work of Hossain et al. (2016) proposed new ways to study diffusion for frugal innovations. In addition to these works, this study has proposed to join these elements together and explore their dependence.

7.2 Recommendations

This study can be socially relevant for policymakers and standard setters. It shows that institutions play an important role for frugal innovations: standardisation and other national institutional arrangements are a complex set of institutional elements that affect innovation processes. Various actors should take this into account. First of all, national and international policymakers should be aware of the structures if they intend to embrace the concept of FI and to promote it. Embracing FI can potentially improve global sustainability, durability and contribute to the UN SDGs. Secondly, they should take into account these structures and as a result investigate more broadly the impact of their institutions and frameworks on developing countries' socio-economic well-being. This can be specifically of importance for organisations such as the WTO and IMF. The WTO aims to lower trade barriers, this case study analysis could be taken into account to evaluate this. The IMF requires developing countries to install institutional reforms as a condition for their support. Some of the concepts that are introduced in this study could be helpful in determining these conditions. Furthermore, awareness of these institutional structures can help managers of MNCs to design suitable strategies and invest in local engagement. Lastly, as introduced in the acknowledgements, this research can be helpful for the Centre of Frugal Innovation in Africa (CFIA). This study is an attempt to research the role of governance and institutions in frugal innovation. It can contribute to the understanding of this role and possibly spark off new research.

7.3 Future research

As a result of this study, interesting areas of study are revealed for possible future research. First of all, the same relation could be studied in more detail by applying causal process tracing. This would provide more insights into different parts of the process. It could be applied to other cases as well to provide insights on diffusion of grassroots-level innovation and within-country diffusion. Secondly, the role that MNCs play in frugal innovation can be investigated more. From this study, and some others, it can be deduced that MNCs and all their characteristics are of great importance for the

results of their innovation strategies in developing countries. Third, the relation in this research can be studied from a legal perspective. Studying and evaluating the role of international trade law, trade barriers and regulatory capture in developing countries in general and specifically for frugal innovation can be of great interest. Lastly, since every country and NSB is involved with different policies and regulations, specific forms of innovation policies and environments could be studied to understand what policy conditions can enable frugal innovation. For example, the success of frugal innovations in countries with almost no standardisation system in place would contribute to the literature on FI and of standardisation.

Bibliography

- Aldaz-Carroll, E. (2006). *Regional approaches to better standards system* [Policy Research Working Paper 3948]. World Bank.
- Allen, R., & Sriram, R. (2000). The Role of Standards in Innovation. *Technological Forecasting and Social Change*, 64(2-3), 171–181. [https://doi.org/10.1016/S0040-1625\(99\)00104-3](https://doi.org/10.1016/S0040-1625(99)00104-3)
- ANSI. (2015). *China's State Council announces plan for standardization reform*. Retrieved June 6, 2021, from <https://ansi.org/news/standards-news/all-news/2015/04/chinas-state-council-announces-plan-for-standardization-reform-27>
- Arvis, J.-F., Ojala, L., Wiederer, C., Shepherd, B., Raj, A., Dairabayeva, K., & Kiiski, T. (2018). *Connecting to compete 2018, trade logistics in the global economy*. Washington, DC. <https://openknowledge.worldbank.org/bitstream/handle/10986/29971/LPI2018.pdf>
- Aschmoneit, M., & Janevska, D. (2013). *Closing the gap between frugal and reverse innovation: Lessons learned from the case of tata nano* (Master's thesis). Linköping University. <https://www.diva-portal.org/smash/get/diva2:648098/FULLTEXT01.pdf>
- Babbie, E. (2016). *The practice of social research*. Cengage Learning.
- Baggonkar, S. (2018). Tata nano exports come to naught. is this the beginning of the end of the mini car? *Moneycontrol*. <https://www.moneycontrol.com/news/technology/auto/tata-nano-exports-come-to-naught-is-this-the-beginning-of-the-end-of-the-mini-car-2587175.html>
- Bhatti, Y., Basu, R. R., Barron, D., & Ventresca, M. J. (2018). *Frugal innovation: Models, means, methods*. Cambridge University Press.
- BIS. (2007). *Manual for standards formulation*. Retrieved June 1, 2021, from <https://web.archive.org/web/20070508031923/http://bis.org.in/qazwsx/TD/manual.pdf>
- BIS. (2008a). *BIS on-line Catalogue (Sept 2006)*. Retrieved June 1, 2021, from <https://web.archive.org/web/20080519092910/http://www.bis.org.in/bis/start.htm>
- BIS. (2008b). *National Institute of Training for Standardization NITS*. Retrieved June 1, 2021, from <https://web.archive.org/web/20080516214639/http://www.bis.org.in/trg/train.htm>
- BIS. (2008c). *Programme of Work of Technical Departments*. Retrieved June 1, 2021, from <http://web.archive.org/web/20080425180536/http://www.bis.org.in/sf/pow/powork.htm>
- BIS. (2009). *Sales Offices*. Retrieved June 1, 2021, from <https://web.archive.org/web/20090207195858/http://www.bis.org.in/dir/sales.htm>
- BIS. (2021). *Overview of NITS*. Retrieved June 1, 2021, from <https://bis.gov.in/index.php/training-2/overview-of-nits/>
- Blatter, J., & Haverland, M. (2012). *Designing case studies*. Palgrave Macmillan.
- Blind, K. (2016). The Impact of Standardization and Standards on Innovation. In J. Edler, P. Cunningham, A. Gök, & P. Shapira (Eds.), *Handbook of Innovation Policy Impact* (pp. 423–449). Edward Elgar Publishing.
- Blind, K., Petersen, S., & Riillo, C. (2017). The impact of standards and regulation on innovation in uncertain markets. *Research Policy*, 46(1), 249–264. <https://doi.org/10.1016/j.respol.2016.11.003>
- Breitenberg, M. (2009). *The ABC's of Standards Activities* [NISTIR 7614]. National Institute of Standards and Technology.
- Brem, A., & Wolfram, P. (2014). Research and development from the bottom up - introduction of terminologies for new product development in emerging markets. *Journal of Innovation and Entrepreneurship*, 3(9). <https://doi.org/10.1186/2192-5372-3-9>

- Cambridge Dictionary. (n.d.). Standardization. *Online Cambridge Dictionary*. Retrieved March 13, 2021, from <https://dictionary.cambridge.org/dictionary/english/standardization?q=standardisation>
- Cargill, C. (2017). Standardization, innovation and reality: Matching theory and practice. In R. Hawkins, K. Blind, & R. Page (Eds.), *Handbook of Innovation and Standards* (pp. 412–426). Edward Elgar Publishing.
- Carroll, P., Poll, E., & Robertson, P. (2000). Classification of industries by level of technology: An appraisal and some implications. *Prometheus*, 18(4), 417–436. [10.1080/08109020020008523](https://doi.org/10.1080/08109020020008523)
- CAS. (2004a). (13) [translated]. Retrieved June 1, 2021, from https://web.archive.org/web/20040312183059mp_/http://www.china-cas.org/zhijian/index-02.htm
- CAS. (2004b). *National Standard Catalogue Query* [translated]. Retrieved June 1, 2021, from <https://web.archive.org/web/20041010043104/http://www.china-cas.org/zhishi/index.php3>
- CFIA. (n.d.). *Education Program Frugal Innovation for Sustainable Global Development*. Retrieved February 28, 2021, from <https://www.cfia.nl/education/minor-fi4sgd>
- CFSTC. (2013). *About CFSTC: Introduction*. Retrieved June 1, 2021, from <https://www.cfstc.org/en/2932534/2968795/index.html>
- Chang, R. (2008). Tata nano: The world's cheapest car. *The New York Times*. <https://wheels.blogs.nytimes.com/2008/01/10/tata-nano-the-worlds-cheapest-car/>
- Choi, D., Hyun, O.-S., Hong, J.-I., & Kang, B.-G. (2014). Standards as catalyst for national innovation and performance - a capability assessment framework for latecomer countries. *Total Quality Management & Business Excellence*, 25(9-10), 969–985. <https://doi.org/10.1080/14783363.2014.893082>
- Choi, D., Lee, H., & Sung, T.-K. (2011). Research profiling for 'standardization and innovation'. *Scientometrics*, 88, 259–278. <https://doi-org.ezproxy.leidenuniv.nl/10.1007/s11192-011-0344-7>
- Choung, J.-Y., Hameed, T., & Ji, I. (2012). Catch-up in ict standards: Policy, implementation and standard-setting in south korea. *Technological Forecasting and Social Change*, 79(4), 771–788. <https://doi.org/10.1016/j.techfore.2011.10.007>
- CIA. (n.d.). *Field Listing - Land boundaries* [dataset]. Retrieved June 5, 2021, from <https://www.cia.gov/the-world-factbook/field/land-boundaries/>
- Clark, M., Lee, Y., Madishetty, S., & Daim, T. (2017). Technology management: Case of cost, frugal and reverse innovations. In T. Daim, J. Kim, & K. Phan (Eds.), *Research and development management. science, technology and innovation studies* (pp. 227–246). Springer.
- David, P., & Greenstein, S. (1990). The economics of compatibility standards, an introduction to recent research. *Economics of Innovation and New Technology*, 1(1-2), 3–41. <https://doi.org/10.1080/10438599000000002>
- DIN. (2000). *Economic benefits of standardization: Summary of results*. DIN German Institute of Standardisation. Berlin. <https://vdocument.in/economic-benefits-standardization.html>
- Directorate of Standardisation. (2019). *National Policy*. Retrieved June 1, 2021, from <https://ddpdos.gov.in/standards/national-policy>
- Directorate of Standardisation. (2021). *National Policy*. Retrieved June 8, 2021, from <https://ddpdos.gov.in/standards/national-policy>
- DTI. (2005). *The empirical economics of standards* [Economics paper no.12]. UK Department of Trade and Industry (DTI). <https://webarchive.nationalarchives.gov.uk/20121205151320/http://www.bis.gov.uk/files/file9655.pdf>
- Ernst, D., Lee, H., & Kwak, J. (2014). Standards, innovation, and latecomer economic development: Conceptual issues and policy challenges. *Telecommunication Policy*, 38(10), 853–862.
- Gann, D., Wang, Y., & Hawkins, R. (1998). Do regulations encourage innovation? - the case of energy efficiency in housing. *Building Research & Information*, 26(5), 280–296. [DOI:%2010.1080/096132198369760](https://doi.org/10.1080/096132198369760)

- GE Healthcare. (2008). *LOGIQ Book XP*. Retrieved June 8, 2021, from <http://web.archive.org/web/20081007151325/http://www.gehealthcare.com/euen/ultrasound/products/general-imaging/logiqbook-xp/index.html>
- GE Healthcare. (2013). *LOGIQ Book XP Enhanced*. Retrieved June 8, 2021, from http://web.archive.org/web/20130604154256/http://www3.gehealthcare.co.uk/en-GB/Products/Categories/Ultrasound/LOGIQ/LOGIQ_Book_XP_Enhanced
- GE Healthcare. (2014). *LOGIQ Book XP Enhanced*. Retrieved June 8, 2021, from http://web.archive.org/web/20140127092130/http://www3.gehealthcare.com.br/pt-BR/Products/Categories/Ultrassom/LOGIQ/LOGIQ_Book_XP_Enhanced
- Gerst, M. (2015). Ipr in standardization. *IP Key report*. https://ipkey.eu/sites/default/files/legacy-ipkey-docs/gerst_report_ipr-in-standards.pdf
- Government of India. (1986). *The Bureau of Indian Standards Act, 1986*. Retrieved June 8, 2021, from <http://web.archive.org/web/20080821122453/http://www.bis.org.in/bs/bisact.htm>
- Government of India. (n.d.). *Profile*. Retrieved June 7, 2021, from <https://www.india.gov.in/india-glance/profile>
- Guasch, J., Racine, J., Sanchez, I., & Diop, M. (2007). *Quality systems and standards for a competitive edge*. The World Bank. <https://openknowledge.worldbank.org/bitstream/handle/10986/6768/405160Quality0101OFFICIAL0USE0ONLY1.pdf?sequence=1>
- Gupta, S. (2020). Understanding the feasibility and value of grassroots innovation. *Journal of the Academy of Marketing Science*, 48(5), 941–965. <http://dx.doi.org/10.1007/s11747-019-00639-9>
- Harmes-Liedtke, U., & Matteo, J. D. (2019). *Project: Global Quality Infrastructure Index (GQII)*. Retrieved May 27, 2021, from <https://www.researchgate.net/project/Global-Quality-Infrastructure-Index-GQII>
- Harmes-Liedtke, U., & Matteo, J. D. (2021). *Global quality infrastructure index report 2020*. Mesopartner and Analytical. Buenos Aires, Argentina, Bad Homburg, Germany. https://gqii.files.wordpress.com/2021/04/2021_03-gqii-report_low.pdf
- Harris, M., Bhatti, Y., Buckley, J., & Sharma, D. (2020). Fast and frugal innovation in response to the covid-19 pandemic. *Nature Medicine*, 26, 814–817. <https://doi.org/10.1038/s41591-020-0889-1>
- Harris, M., Weisberger, E., Silver, D., & Macinko, J. (2015). ‘They hear “Africa” and they think that there can’t be any good services’ – perceived context in cross-national learning: A qualitative study of the barriers to Reverse Innovation. *Globalization and Health*, 11(45). <https://doi.org/10.1186/s12992-015-0130-z>
- Hawkins, R., & Blind, K. (2017). Introduction: Unravelling the relationship between standards and innovation. In R. Hawkins, K. Blind, & R. Page (Eds.), *Handbook of Innovation and Standards* (pp. 1–20). Edward Elgar Publishing.
- Hossain, M. (2016). Grassroots innovation: A systematic review of two decades of research. *Journal of Cleaner Production*, 137, 973–981. <https://doi.org/10.1016/j.jclepro.2016.07.140>
- Hossain, M. (2017). Mapping the frugal innovation phenomenon. *Technology in Society*, 51, 199–208. <https://doi.org/10.1016/j.techsoc.2017.09.006>
- Hossain, M. (2018). Frugal innovation: A review and research agenda. *Journal of Cleaner Production*, 182, 925–936. <https://doi.org/10.1016/j.jclepro.2018.02.091>
- Hossain, M. (2020). Frugal innovation: Conception, development, diffusion, and outcome. *Journal of Cleaner Production*, 262, 1–10. <https://doi.org/10.1016/j.jclepro.2020.121456>
- Hossain, M., Simula, H., & Halme, M. (2016). Can frugal go global? diffusion patterns of frugal innovations. *Technology in Society*, 46, 132–139. <https://doi.org/10.1016/j.techsoc.2016.04.005>
- IMF. (2015). World economic outlook: Adjusting to lower commodity prices. *International Monetary Fund*.

- Immelt, J., Govindarajan, V., & Trimble, C. (2009). How ge is disrupting itself. *Harvard Business Review*, 87(10), 56–65.
- ISO. (2008). *Participation in TCs*. Retrieved June 1, 2021, from https://web.archive.org/web/20081121051549/http://www.iso.org/iso/about/iso_members/iso_member_participation_tc.htm?member_id=1635
- ISO. (n.d.[a]). *Members*. Retrieved June 12, 2021, from <https://www.iso.org/members.html>
- ISO. (n.d.[b]). *Standards in our world*. Retrieved May 19, 2021, from https://www.iso.org/sites/ConsumersStandards/1_standards.html#top
- Kellermann, M. (2019a). *Comprehensive diagnostic tool annex to the qi toolkit*. Washington, DC.
- Kellermann, M. (2019b). Ensuring quality to gain access to global markets: A reform toolkit. *The World Bank and Physikalisch-Technische Bundesanstalt (PTB)*.
- Keman, H. (n.d.). Economic openness. *Encyclopaedia Britannic, Inc*. Retrieved June 1, 2021, from <https://www.britannica.com/topic/economic-openness>
- Kent State University. (2020). *Identifying credible websites*. Retrieved June 9, 2021, from <https://libguides.stark.kent.edu/websites>
- Knorringa, P., Peša, I., Leliveld, A., & van Beers, C. (2016). Frugal Innovation and Development: Aides or Adversaries? *The European Journal of Development Research*, 28, 143–153. <https://doi.org/10.1057/ejdr.2016.3>
- Langenberg, T. (2006). *Standardization and expectations*. Springer. <https://doi.org/10.1007/3-540-28113-4>
- Lea, G., & Hall, P. (2004). Standards and intellectual property rights: An economic and legal perspective. *Information Economics and Policy*, 16(1), 67–89. <https://doi.org/10.1016/j.infoecopol.2003.09.005>
- Leliveld, A., & Knorringa, P. (2018). Frugal Innovation and Development Research. *The European Journal of Development Research*, 30, 1–16. <https://doi.org/10.1057/s41287-017-0121-4>
- Mattli, W., & Büthe, T. (2003). Setting International Standards: Technological Rationality or Primacy of Power? *World Politics*, 56(1), 1–42. [doi:10.1353/wp.2004.0006](https://doi.org/10.1353/wp.2004.0006)
- McDaniel, B. A. (2000). A survey on entrepreneurship and innovation. *The Social Science Journal*, 37(2), 277–283. [https://doi.org/10.1016/S0362-3319\(00\)00060-4](https://doi.org/10.1016/S0362-3319(00)00060-4)
- Ministry of Commerce PRC. (n.d.). *Mission*. Retrieved June 6, 2021, from <http://english.mofcom.gov.cn/column/mission.shtml>
- Nieuwsuur. (2021). *Corona leidt wereldwijd tot vele uitvindingen*. Retrieved June 10, 2021, from <https://nos.nl/nieuwsuur/video/2364125-corona-leidt-wereldwijd-tot-vele-uitvindingen>
- Niroumand, M., Shahin, A., Naghsh, A., & Peikari, H. (2021). Frugal innovation enablers, critical success factors and barriers: A systemic review. *Creativity and innovation management*, 1–20. <https://doi.org/10.1111/caim.12436>
- Onwuegbuzie, A., & Leech, N. (2007). Sampling designs in qualitative research: Making the sampling process more public. *The Qualitative Report*, 12(2), 238–254.
- Ortt, J., & Egyedi, T. (2014). The effect of pre-existing standards and regulations on the development and diffusion of radically new innovations. *International Journal of IT standards and Standardization Research*, 12(1), 17–37. [10.4018/ijitsr.2014010102](https://doi.org/10.4018/ijitsr.2014010102)
- Ostraszewska, Z., & Tylec, A. (2015). Reverse innovation - how it works. *International journal of Business and Management*, 3(1), 57–74.
- Pansera, M., & Owen, R. (2018a). Framing inclusive innovation within the discourse of development: Insights from case studies in india. *Research Policy*, 47(1), 23–34. <https://doi.org/10.1016/j.respol.2017.09.007>
- Pansera, M., & Owen, R. (2018b). *Innovation and development: The politics at the bottom of the pyramid*. Wiley-ISTE. [10.1002/9781119453604](https://doi.org/10.1002/9781119453604)
- Parthasarathy, S. (2020). Innovation policy, structural inequality, and covid-19. *Democratic Theory*, 7(2), 104–109. <https://www.berghahnjournals.com/view/journals/democratic-theory/7/2/dt070213.xml>

- Pisoni, A., Michelini, L., & Martignoni, G. (2018). Frugal approach to innovation: State of the art and future perspectives. *Journal of Cleaner Production*, 171, 107–126. <https://doi.org/10.1016/j.jclepro.2017.09.248>
- Reinsberg, B., Stubbs, T., Kentikelenis, A., & King, L. (2019). The world system and the hollowing out of state capacity: How structural adjustment programs affect bureaucratic quality in developing countries. *American Journal of Sociology*, 124(4), 1222–1257. <https://doi.org/10.1086/701703>
- Rogers, E. (2003). *Diffusion of innovations*. Free Press.
- Roser, M. (2013). Democracy. *Our World in Data*. <https://ourworldindata.org/democracy>
- SAC. (2007a). *China Association for Standardization (CAS)*. Retrieved June 1, 2021, from <https://web.archive.org/web/20071026133310/http://www.sac.gov.cn/templet/english/ShowArticle.jsp?id=2791>
- SAC. (2007b). *Chinese Technical Committees of Standardization*. Retrieved June 1, 2021, from <http://web.archive.org/web/20071120132634/http://www.sac.gov.cn/templet/english/displayTechnicalCommitteeList.do>
- SAC. (2007c). *General Office Dept. of Policies and Regulations, Staff Service Center*. Retrieved June 1, 2021, from <http://web.archive.org/web/20071111020802/http://www.sac.gov.cn/templet/english/bm.jsp?id=3193>
- Saqib, M. (2003). Technical barriers to trade and the role of indian standard-setting insitutions. In A. Mattoo & R. Stern (Eds.), *India and the wto* (pp. 269–298). The World Bank.
- Schedel, R. (2009). Crash test for tata nano. *ATZ Worldwide*, 111, 36–38. <https://doi.org/10.1007/BF03225097><https://doi.org/10.1007/BF03225097>
- Science | Business. (2020). *Erasmus University Rotterdam: Why Europe Needs Frugal Innovation*. Retrieved February 28, 2021, from <https://sciencebusiness.net/network-updates/erasmus-university-rotterdam-why-europe-needs-frugal-innovation>
- Shafiulla, B. (2014). Tata nano to tata no-no. *IUP Journal of Marketing Management*, 13(1).
- Shane, S. (2008). *The handbook of technology and innovation management*. John Wiley & Sons.
- Singh, S., & Srivastava, P. (2013). The turnaround of the tata nano: Reinventing the wheel. *Vision*, 16(1), 45–52. [10.1177/097226291201600105](https://doi.org/10.1177/097226291201600105)
- Smith, A., Fressoli, M., & Thomas, H. (2014). Grassroots innovation movements: Challenges and contributions. *Journal of Cleaner Production*, 63, 114–124. <https://doi.org/10.1016/j.jclepro.2012.12.025>
- Soni, P., & Krishnan, R. (2014). Frugal innovation: Aligning theory, practice, and public policy. *Journal of Indian Business Research*, 6(1), 29–47. [10.1108/JIBR-03-2013-0025](https://doi.org/10.1108/JIBR-03-2013-0025)
- SPC. (2006). *Introduction to Standard Press* [translated]. Retrieved June 1, 2021, from <http://web.archive.org/web/20061215144035/http://www.spc.net.cn/about/about.asp>
- Stango, V. (2004). The Economics of Standards Wars. *Review of Network Standards*, 3(1), 1–19.
- Steinfeld, C., Wigand, R., Markus, M., & Minton, G. (2006). Promoting e-business through vertical IS standards: Lessons from the US home mortgage industry. In S. Greenstein & V. Stango (Eds.), *Standards and public policy* (pp. 160–207). Cambridge University Press.
- Swann, G. (2000). *The economics of standardization: Final report for standards and technical regulations directorate department of trade and industry*. UK Department of Trade and Industry (DTI). <https://webarchive.nationalarchives.gov.uk/20121104024433/http://www.bis.gov.uk/assets/biscore/corporate/migrateddd/publications/f/file11312.pdf>
- Swann, G., & Lambert, R. (2017). Standards and innovation: A brief survey of empirical evidence and transmission mechanisms. In R. Hawkins, K. Blind, & R. Page (Eds.), *Handbook of Innovation and Standards* (pp. 21–37). Edward Elgar Publishing.
- Tata Motors. (2015). *Press releases: Tata Motors launches the GenX Nano range, its new compact hatch*. Retrieved June 7, 2021, from <https://www.tatamotors.com/press/tata-motors-launches-the-genx-nano-range-its-new-compact-hatch/>

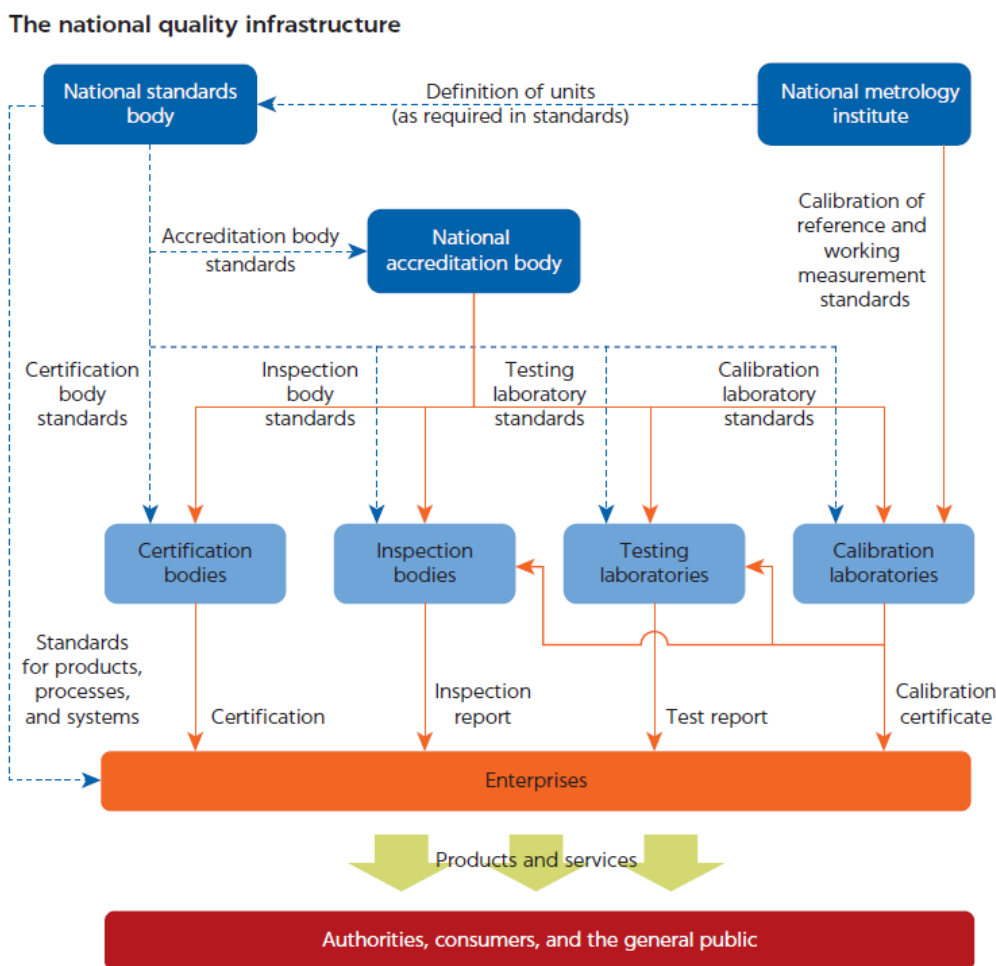
- Tata Motors. (n.d.). *About us: Company Profile*. Retrieved June 7, 2021, from <https://www.tatamotors.com/about-us/company-profile/>
- The World Bank. (2010). *Innovation policy: A guide for developing countries*. The World Bank.
- The World Bank. (2021a). *World Development Indicators* [dataset]. Retrieved June 1, 2021, from <https://databank.worldbank.org/source/world-development-indicators>
- The World Bank. (2021b). *Worldwide Governance Indicators* [dataset]. Retrieved June 1, 2021, from <https://databank.worldbank.org/source/worldwide-governance-indicators>
- The World Bank. (n.d.[a]). *Economic Characteristics*. Retrieved June 4, 2021, from <https://www.doingbusiness.org/en/data/exploreconomies/economycharacteristics>
- The World Bank. (n.d.[b]). *OGHIST* [dataset]. Retrieved June 4, 2021, from <https://datahelpdesk.worldbank.org/knowledgebase/articles/378834-how-does-the-world-bank-classify-countries>
- The World Bank. (n.d.[c]). *The World Bank In China*. Retrieved June 6, 2021, from <https://www.worldbank.org/en/country/china/overview#1>
- The World Bank. (n.d.[d]). *The World Bank In India*. Retrieved June 7, 2021, from <https://www.worldbank.org/en/country/india/overview>
- Times, T. E. (2014). Tata motors launches nano car in bangladesh market. *The Economic Times*. Retrieved June 7, 2021, from <https://economictimes.indiatimes.com/tata-motors-launches-nano-car-in-bangladesh-market/articleshow/40584859.cms>
- Trimble, C. (2012). Reverse innovation and the emerging-market growth imperative. *Ivey Business Journal*, 76(2), 19–21.
- UNCTAD. (2018). *Standards keep people and planet healthy but cost small firms*. Retrieved June 10, 2021, from <https://unctad.org/news/standards-keep-people-and-planet-healthy-cost-small-firms>
- van Beers, C., Knorringa, P., & Leliveld, A. (2014). *Understanding Frugal Innovation in Africa: Schumpeter revisited*. <https://www.cfia.nl/news/understanding-frugal-innovation-in-africa-schumpeter-revisited>
- von Zedtwitz, M., Corsi, S., Sjøberg, P., & Frega, R. (2014). A typology of reverse innovation. *Journal of Product Innovation Management*, 32(1), 12–28. [10.1111/jpim.12181](https://doi.org/10.1111/jpim.12181)
- World Bank Group. (2021). *World Bank Country and Lending Groups*. Retrieved May 30, 2021, from <https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups>
- WTO. (2021). *Members discuss TRIPS waiver, LDC transition period and green tech role for small business*. Retrieved June 10, 2021, from https://www.wto.org/english/news_e/news21_e/trip_11mar21_e.htm
- WTO. (n.d.[a]). *China and the WTO*. Retrieved June 6, 2021, from https://www.wto.org/english/thewto_e/countries_e/china_e.htm
- WTO. (n.d.[b]). *India and the WTO*. Retrieved June 7, 2021, from https://www.wto.org/english/thewto_e/countries_e/india_e.htm
- WTO. (n.d.[c]). *Intellectual property and the public interest*. Retrieved June 10, 2021, from https://www.wto.org/english/tratop_e/trips_e/trips_and_public_interest_e.htm
- WTO. (n.d.[d]). *Technical barriers to trade*. Retrieved June 10, 2021, from https://www.wto.org/english/tratop_e/tbt_e/tbt_e.htm
- YEYANET. (2007). *National Hydraulic and Pneumatic Standardization Technical Committee (SAC/TC3)* [translated]. Retrieved June 1, 2021, from <http://web.archive.org/web/20070127235804/http://www.yeyanet.com/qgybw.asp>
- Yin, R. (1994). *Case study research: Design and methods*. SAGE Publications.
- Zanello, G., Fu, X., Mohnen, P., & Ventresca, M. (2016). The creation and diffusion of innovation in developing countries: A systemic literature review. *Journal of Economics Surveys*, 30(5), 884–912. <https://doi.org/10.1111/joes.12126>

- Zeschky, M., Winterhalter, S., & Gassman, O. (2014). *What is frugal innovation? Conceptualisation and empirical evidence*. <https://www.alexandria.unisg.ch/232145/1/StephanWinterhalter.pdf>
- Zeschky, M., Winterhalter, S., & Gassmann, O. (2014). From cost to frugal and reverse innovation: Mapping the field and implications for global competitiveness. *Research-Technology Management*, 57(4), 20–27. [10.5437/08956308X5704235](https://doi.org/10.5437/08956308X5704235)
- Zhao, C., & Graham, J. (2006). The prc's evolving standards system: Institutions and strategy. *Asia Policy*, 2, 63–87. [10.1353/asp.2006.0000](https://doi.org/10.1353/asp.2006.0000)
- Zoo, H., de Vries, H., & Lee, H. (2017). Interplay of innovation and standardization: Exploring the relevance in developing countries. *Technological Forecasting and Social Change*, 118, 334–348. <http://dx.doi.org/10.1016/j.techfore.2017.02.033>

Appendix A

Figures and tables for theoretical framework

FIGURE A.1: Visual of the fundamental elements in a national quality infrastructure



Note. The national standards body is one of the three pillar that are part of the national quality infrastructure. From "Ensuring Quality to Gain Access to Global Markets: A Reform Toolkit", by M. Kellerman, 2019, *The World Bank and Physikalisch-Technische Bundesanstalt (PTB)*.

TABLE A.1: The effect of standards on innovation

	Pros	Cons
Variety reduction	Economies of scale Diffusion of innovation	Reducing choice Increased market concentration Premature selection of technologies
↳ <i>Developing country context</i>	Upgrading Catching up Inclusive innovation	Reducing choice → negligence of local needs
Minimum quality and safety	Information symmetry Trust Reduced transaction costs Control/decrease of negative externalities	(Too) High costs for compliance to be able to enter the market
↳ <i>Developing country context</i>	Compliance can lead to more innovation, increased productivity, increased quality and thus capacity, reduced transaction costs, and access to international markets	Constraining possible spill-over effects Costs for compliance might be too high to enter the market Restricted competition
Compatibility and interface	Positive network externalities Reduced switching costs Reduced transaction costs Dissemination Increased value	Monopolies Lock-in to (old) technologies in cases of strong network externalities
↳ <i>Developing country context</i>	Even more benefits from positive network externalities Possibly technical independence Promotion of local innovation	Monopoly by government (political capture)
Information and measurement	Providing codified knowledge Reduced transaction costs Information symmetry Trust Dissemination	

Note. The positive (pros) and negative (cons) effect that different types of standards have on innovation in general and in the context of developing countries, according to Blind (2016), Swann (2000) and Zoo et al. (2017). Adapted from "The impact of standardisation and standards on innovation", in J. Edler, P. Cunningham, A. Gök & P. Shapira, *Handbook of Innovation Policy Impact* (p. 423-449), by K. Blind, 2016.

Appendix B

Figures and tables for research design

TABLE B.1: Characteristics of the levels of diffusion

	Outside domestic market [yes/no]	Socio-economic conditions [similar/higher income]	Geographical region [close/distant]
<i>Local</i>	no	n.a.	n.a.
<i>Proximity</i>	yes	similar	close
<i>Distant</i>	yes	similar	distant
<i>Global</i>	yes	higher income	distant

TABLE B.2: Sources for data collection

Sources	
i.	Official websites of governments, departments and organisations
ii.	Documents from these websites, such as: <ul style="list-style-type: none"> Legislation Regulations Annual reports Press releases Info graphics Manuals
iii.	The Internet archive (https://archive.org/) will be used to access older versions of websites
iv.	News outlets
v.	Academic papers that have analysed the national standardisation systems
vi.	Wikipedia will be used to find useful sources (often it uses older website URLs as sources, which can otherwise not be found)
vii.	Databases as indicated for certain variables.

FIGURE B.1: Classification of industries by level of technology

	High-tech	Indeterminate	Low-tech
Radio, TV and communication equipment	⊗		
Office and computing machinery	⊗		
Pharmaceutical products		□	
Professional goods		□	
Motor vehicles		□	
Chemicals		□	
Electrical machinery		□	
Non-electrical machinery		□	
Other transport equipment		□	
Petroleum products		□	
Rubber and plastic products		□	
Non-metallic mineral products		□	
Food, beverages and tobacco		□	
Iron and steel		□	
Non-ferrous metals		□	
Other manufacturing n.e.c.		□	
Metal products			□
Paper and paper products			□
Textiles, apparel and leather			□
Wood products and furniture			□

Source: Tables 1, 2 and 3.

Legend: ⊗ means 'it satisfies all the three one-dimensional criteria for "high-tech" industry'. □ means: 'it does not meet at least one of the three criteria'. □ means: 'it satisfies all the three one-dimensional criteria for "low-tech" industry'.

Note. From "Classification of Industries by Level of Technology: An Appraisal and some Implications", by P. Carroll and E. Poll and P.L. Robertson, 2000, *Prometheus*, 18(4), p.425.

TABLE B.3: Sources and information for control variables

Indicator	Source	Details
Infrastructure quality	World Bank LPI https://lpi.worldbank.org/	This index assesses all of a country's activities encompassed by logistics, including infrastructure quality (Arvis et al., 2018). The value for the indicator ranges between 1 (very low) and 5 (very high), based on answers to questions with the same range.
Advancement	Carroll et al. (2000) Table in Figure B.1	This table presents a classification of products and services into three categories of low-tech, indeterminate and high-tech by testing other classifications that are all based on different criteria, including the OECD classification based on R&D intensity.
Local engagement	Section 3.1.1	<i>Grassroots-level</i> : the innovator is part of the local community; this is the highest possible local engagement. Or <i>EMNCs and MNCs with local headquarters</i> : the innovator can easily tap into local knowledge, expertise and experience because of close ties with the community. Or <i>MNC without local headquarters</i> : the innovator is not engaged with the local community, and cannot easily be informed on local knowledge, expertise and experience.
Public R&D investment	UNESCO UIS http://data.uis.unesco.org/	The Institute for Statistics (UIS) value for 'GERD as a percentage of GDP' will be used. GERD = gross domestic expenditure on R&D.
Political stability	World Bank WGI The World Bank, 2021b	The World Bank Worldwide Governance Indicators (WGI) assess a country's governance based on six indicators. One of those indicators is 'Political Stability and Absence of Violence/Terrorism'. It measures "perceptions of the likelihood of political instability and/or politically-motivated violence, including terrorism" (metadata). It is an aggregated estimate within the range of a normal distribution between approximately, -2, 5 and 2, 5.
Law enforcement	World Bank WGI The World Bank, 2021b	Another WGI indicator is 'Rule of Law', which: "captures perceptions of the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence" (The World Bank, 2021b, metadata). It is an aggregated estimate within the range of a normal distribution between approximately, -2, 5 and 2, 5.
Economic Openness	World Bank WDI The World Bank, 2021a	The World Development Indicators (WDI) assess economic openness by the indicator 'Trade (% of GDP)': "the sum of exports and imports of goods and services measured as a share of gross domestic products" (The World Bank, 2021a, metadata).

Appendix C

Supporting data for findings

TABLE C.1: Basic information on the People's Republic of China

People's Republic of China
<p>The official name for China is the People's Republic of China. It is one of the largest countries in the world and is populated by around 1,4 milliard people ($1,4 * 10^9$) (The World Bank, 2021a). The political regime of China is regarded as an autocracy (Roser, 2013). The country has a unitary political system and the party in power is the Chinese Communist Party, led by president Xi Jinping since 2012. From 1978 China has started to open up its economy to the world (The World Bank, n.d.(c)). In 2001 the country became an official member of the WTO. Since the opening up a lot has changed: the GDP has grown significantly, poverty has been reduced and many living conditions have been improved for the citizens (The World Bank, n.d.(c)). From 1999 the country was classified by the World Bank as a low-middle-income country instead of a low-income country and from 2010 it is recognised as an upper-middle-income country (The World Bank, n.d.(b)). The biggest trade sectors of China include manufacturing, fuels and mining products, and agriculture (WTO, n.d.(a)). The Ministry of Commerce of the People's Republic of China is responsible for trade and for standardisation (Ministry of Commerce PRC, n.d.).</p>

TABLE C.2: Basic information on the Republic of India

Republic of India
<p>The official name for India is the Republic of India. It is, like China, one of the biggest countries in the world, and populated by around 1,4 milliard people ($1,4 * 10^9$) (The World Bank, 2021a). India is classified as a secular democratic republic: a democracy with a parliamentary system (Government of India, n.d. Roser, 2013). It is emphasised by the World Bank that India has done a remarkable job of reducing poverty over the last 20 years (The World Bank, n.d.(d)). Moreover, the economy has been growing at high rates. In 2007 the country was first classified as a lower-middle-income country instead of a low-income country, but unlike China it has not been upgraded to an upper-middle-income country yet (The World Bank, n.d.(b)). India has been a WTO member from the founding day in 1995. Like China, India's main sectors include manufacturing, fuels and mining products, and agriculture (WTO, n.d.(b)). Other big sectors in India specifically are pharmaceuticals, textiles and automotive. The Ministry of Commerce and Industry of the Government of India is responsible for trade and the Ministry of Consumer Affairs, Food & Public Distribution is responsible for standardisation.</p>

TABLE C.3: Findings: control variables

Control variables			
Variable	Indicator	Case 1 (China)	Case 2 (India)
(Digital) infrastructure	Quality	2007 LPI: 3,20	2007 LPI: 2,90
Nature of the innovation	1. Advancement	<i>Electrical machinery</i> = Indeterminate	<i>Motor vehicles</i> = Indeterminate
	2. Local engagement	MNC with local HQs	EMNC
Institutional arrangements	1. Public R&D investment	1,37369% of GDP	0,85876% of GDP
	2. Political stability	-0,49882	-1,10751
	3. Law enforcement	-0,54221	0,086039
	4. Economic openness	62,19336 % of GDP	53,36822% of GDP

Note. This table presents the values for the control variables for both in China (2007) and India (2008). A full overview including sources can be found in Annex

Appendix D

Findings log-book

TABLE D.1: Maturity information China

Maturity level - China - 2007	
<i>Factor</i>	<i>Sources/data</i>
International liaison and membership	https://www.iso.org/ , https://www.itu.int/ , https://www.iec.ch/ http://www.fao.org/fao-who-codexalimentarius/
National TC	Zhao and Graham (2006), p.73; CFSTC (2013); and SAC (2007b). Shows 290 TCs.
Mirror committees	Gerst (2015), p.22; Zhao and Graham (2006), p.74; and an example YEYANET (2007).
Participation in part international TCs	There are already 603 in ISO (ISO, 2008). These are for the biggest manufacturing & fuels/mining, but e.g. also: social security, tourism, health information, tobacco and financial services.
SDOs	The whole system is based on the different established SDOs (Zhao and Graham, 2006)
Information service	Standards are sold online (SPC, 2006). Catalogue from 2004 already: CAS (2004b)
Human resources	SAC (2007a); Zhao and Graham (2006), p.71; CAS (2004a), article 13; and training of public servants (SAC, 2007c).
Demand orientation	China is establishing a market demand system (Zhao and Graham, 2006) and many standards come from industry SDOs.

TABLE D.2: Maturity information India

Maturity level - India - 2008	
<i>Factor</i>	<i>Sources/data</i>
International liaison and membership	https://www.iso.org/ , https://www.itu.int/ , https://www.iec.ch/ http://www.fao.org/fao-who-codexalimentarius/
National TC	14 departments (BIS (2008c)), with per department: PGD: 29, CED: 35, CHD: 20, ETD: 41, FAD: 25, LITD: 22, MED: 26, MSD: 8, MTD: 28, PCD: 11, TED: 16, TXD: 20, WRD:17, MHD:15. In total 313 TCs
Mirror committees	BIS (2007), p.2, article 4.7.6.3.
Participation in international TCs	There are already 267 in ISO (ISO, 2008).
SDOs	There are some, but not officially recognised by BIS (Directorate of Standardisation, 2019). INSS and SNAP included this in the plan for the coming years.
Information service	Standards are sold offline (BIS, 2009). There is an online standards catalogue (BIS, 2008a).
Human resources	Many trainings are offered to people outside BIS: from the industry, consumers and internationals, and to some scientists in BIS (BIS, 2008b; BIS, 2021).
Demand orientation	There is a mailing list for 'public consultation' near the end of the development process, and ad hoc consultations (BIS, 2007).