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Germany's Successfully Developing Industry for Electric Power Assisted Cycles

A Multi-Theoretical Case Study

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Cover Page

Urban-Style Electric Power Assisted Cycle (picture provided by *Freygeist* 2016)

No other invention mixes business and pleasure as intimately as the bicycle.

(Adam Opel 1837-1895)

AFFIDAVIT

I hereby declare that this master thesis on "Germany's Successfully Developing Industry for Electric Power Assisted Cycles: A Multi-Theoretical Case Study" is solely my original work.

I have used only the sources and materials indicated and have not received any unauthorized assistance from others. All quotations from other works as well as paraphrases or summaries of other works have been identified as such and properly acknowledged in the thesis.

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_____ Aachen, 30. December 2016

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ABSTRACT

This thesis analyzes the development and influencing 'success-factors' of the German industry for electric power assisted cycles (EPACs). Earlier theoretical and case study research on industry development in economic geography highlight the importance of considering industrial peculiarities regarding structure, innovation, regulation, and institutions for empirical analysis. Against this background, this multi-theoretical case study is fruitfully guided by the empirical application of three theoretical frameworks: Michael Porter's approach of the *diamond*, emphasizing industrial interrelations; Benkt-Åke Lundvall's approach of *National Systems of Innovation*, focusing on learning, innovation, and R&D; and J. Roger Hollingsworth's and Robert Boyer's approach of *Social Systems of Production*, considering national idiosyncratic regulation and social constitutions. Through qualitative and quantitative verbal descriptions, the subsequent application of these frameworks, retraces the successful industry development and reflects upon the framework's suitability for industrial analysis. Each theoretical framework points to the existence of a particular set of different influencing 'success-factors' that have shaped the successful development. Regardless of the 'success-factors' coupled to a theoretical framework, all factors were closely intertwined and influenced the industrial formation during different development stages. These include: *distinct national structure of related and supporting industries*, *sophisticated customers*, *'green' mobility anchored in daily life, SME-structure and industry's size, trust in established enterprises*, *professionalization dynamics*, *informal horizontal and vertical knowledge accumulation, imitation and recombination practices, 'low' product complexity, (in-house) R&D in traditional industries*, *social values*, *industry associations*, *community and low hierarchy*, *product's quality* and *market dynamics*. These 'success-factors' appear to work on different spatial and organizational scales and can be aggregated to societal and functional types. Each 'success-factor' structures the industrial formation and has enabling, guiding, or facilitating functions.

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List of Acronyms

ADR	Accord européen relatif au transport international des marchandises Dangereuses par Route
App.	Appendix
BDA	Bundesvereinigung der Deutschen Arbeitgeberverbände
BIV	Bundesinnungsverband für das Deutsche Zweiradmechaniker-Handwerk
BMUB	Bundesministeriums für Umwelt, Naturschutz, Bau und Reaktorsicherheit
BMVBS	Bundesministerium für Verkehr, Bau und Stadtentwicklung
BMVI	Bundesministerium für Verkehr und digitale Infrastruktur
BMWI	Bundesministerium für Wirtschaft und Energie
CH	Switzerland
Ch.	Chapter/Sub-Chapter
CN	China
DE	Germany
DGB	Deutscher Gewerkschaftsbund
DGR	Dangerous Goods Regulation
DLR	Deutsches Zentrum für Luft- und Raumfahrt
DPMA	Deutsches Patent- und Markenamt
e.g.	exempli gratia
e-mobility	electro-mobility
EPAC	Electric Power Assisted Bicycle
etc.	et cetera
EU	European Union
EV	Electric Vehicle
FhG	Fraunhofer Gesellschaft
Fig.	Figure
ibid.	ibidem
ICAO TI	Technical Instructions for the Safe Transport of Dangerous Goods by Air
ifeu	Institut für Energie- und Umweltforschung Heidelberg
IN	India
ISIN	International Securities Identification Number
JP	Japan
km/h	kilometer per hour
LEV	Light Electric Vehicle
li-ion	Lithium-ion
MY	Malaysia
NACE	Nomenclature statistique des activités économiques dans la Communauté européenne
NiMH	Nickel–metal hydride
NSI	National System of Innovation
POC	proof of concept
RWTH	Rheinisch-Westfälische Technische Hochschule Aachen
R&D	Research & Development
SME	Small and Medium-sized Enterprise
SSP	Social System of Production
Tab.	Table
TW	Taiwan
U.S.	United States of America

VC	venture capital
vsf.	Verbund Service und Fahrrad g.e.V
VET	vocational education and training
WKN	Wertpapierkennnummer
WZ	Wirtschaftszweig
ZIV	Zweirad-Industrie-Verband

GLOSSARY

electric bicycle (e-bike)	An electric bicycle is subordinated to the **LEV**. The term electric bicycle is a collective and comprises all types of bicycles with an integrated motor for propulsion (overview App. A, Fig. 16). To be defined as an e-bike, the vehicle must retain the ability to be pedaled by the rider (Stewart 2014). E-bikes can be pedal-assisted bicycles, throttle- or switch-controlled bicycles or combinations of both (LEVA 2009, Rose 2012). This distinguishes e-bikes from electric scooters and motorcycles.
electric power assisted cycle (EPAC)	The electric power assisted cycle is an **electric bicycle**. It is referred to as **Pedelec** which only provides electric power if human power is used by pedaling. EPACs are classified into Pedelecs (assist up to 25 km/h) and **S-Pedelecs** (assist up to 45 km/h) (overview App. A, Fig. 16) (Weinert et al. 2008, Rose 2012).
electric vehicle (EV)	The term electric vehicle comprises all types of vehicles using one or more electric motors for propulsion (overview App. A, Fig. 16). In political practice the term only refers to electric cars, buses or trucks (The Federal Government 2010, König 2010).
light electric vehicle (LEV)	A LEV is subordinated to the **EV** (overview App. A, Fig. 16) and defined as "battery, fuel cell, or hybrid-powered 2-or-3-wheel vehicle generally weighing less than 100 kg" (LEVA 2009).
Pedelec	see **EPAC**
S-Pedelec	see **EPAC**

1 INTRODUCTION

"From virtually nothing a decade ago, electric bikes have become a $11 billion global industry," noted David Goodman (2010) in a New York Times article. This seems "even more remarkable" (Döring 2012:563), since electro-mobility (e-mobility) is not a new form of mobility. Electric vehicles (EVs) have existed for more than 150 years, with their importance tending to increase during phases of pressing environmental problems. In the twenty-first century, e-mobility has again aroused political interest in many countries and is regarded as a response to the public discussion on climate change and rising energy prices (Dittmann 1998, The Federal Government 2010, Bain & Company 2015). In 2010, political discussions in Germany resulted in the federal government's goal "to make Germany a leading market for electro-mobility in the long term, and by 2020 to get one million electric vehicles onto German roads" (The Federal Government 2010). Six years later however, in 2016, only 25,500 electric cars are registered in Germany and the goal is publicly regarded to have "miserably failed" (Bain & Company 2015). Yet the political programs and the development goal have not taken the developing industry for electric power assisted cycles (EPACs) into account.

In the year 2010, when the federal goal was declared, 150,000 electric bicycles (e-bikes) were sold in Germany. EPACs had a 95% share of those e-bikes sold and produced in Germany (CONEBI 2016). This trend has increased constantly. In 2007 – the first year of statistical data collection for EPACs – only 30,000 units were produced in Germany. In 2015, 310,000 units were produced and more than 500,000 were sold within the country. This results in a total of more than 1.5 million EPACs produced and 2.4 million EPACs sold in Germany until today (App. B). It is important to note that these EPACs sold cannot be considered substitutes to conventional bicycles, because the sales volumes of conventional bicycles have also increased since 2013 (ZIV 2016b).

This positive development has given rise to diverse observations: Within a dissertation on bicycle value chains it is noted that "a new product, named EPAC, is gaining positions […] and all the technology is made in Germany" (Gabrieletto 2014:46ff.). Print and online magazines observe that "the 'Made in Germany' [EPACs] are in high demand on the country's export markets. Some 4.6% more e-bikes were sold abroad by German companies" (Van Schaik 2015), that the Indian EPAC "Specialist *A2B* relocates production facilities toward Germany" (Rund ums Rad 2013)[1], and also that "Germany is the leading e-bike market in Europe" (Reidl 2014). Such statements highlight the successful development of the EPAC industry in Germany. This industrial setting is briefly outlined in the following section to facilitate a background understanding of the product's design and production.

EPAC INDUSTRY: THE SETTING

EPACs mainly differ from conventional bicycles in two ways: In addition to the bicycle frame and mechanical components, they include a battery and its charging indicator, as well as an electric motor, including an electronic control system, and a sensor to detect the motion of the cranks. The motors can be located in one of three places: The front wheel hub, the bottom bracket, or the rear wheel hub (App. A, Fig. 17). Accordingly, EPACs are classified as light electric vehicles (LEVs) (App. A, Fig. 16). Due to a regulatory framework established in 1994, however, EPACs are treated

[1] Direct quotations from German language references or interview statements were translated by the author.

as legally equivalent to conventional bicycles in Germany. Both means of transportation mechanically resemble each other in their mode of locomotion and optical appearance. Additionally, both products are represented by the same industry associations. A legally binding definition assigning EPACs to, or detaching them from the closely related industry for conventional bicycles, however, does not exist.

The EPAC industry comprises EPAC production, component production, equipment production, and specialist dealers, as well as industry advocacy groups (Statista 2015c). In 2015, the whole German cycling sector, including industry, trade, associations, tourism, and infrastructure, provided 278,000 jobs and produced €16 billion in revenue (ZIV et al. 2015). 2,600 people were employed in bicycle and EPAC producing companies, "mainly" small and medium-sized enterprises (SMEs) (ibid.). An additional 4,000 employees produced bicycle and EPAC parts and accessories (CONEBI 2016). Production itself involves three types of activities: The vehicle's design, its assembly, and the production of its parts (Kotha 1995). The typical production process of a German EPAC involves several steps. Initially, EPAC producers customize frame constructions to the engine's suspensions and the battery devices. They select bicycle components such as cranks, tires, wheels, or gears. Motor and battery producers supply the required electronic devices. Those main parts of an EPAC were initially developed independently in Germany and other European countries during the 19th century (GRS 2013, Dittmann 1998). The matured technologies were independently produced for diverse purposes and increasingly organized through global supply chains (Gabrieletto 2014, Tzeng et al. 2002, GRS 2013). Thus, today, the standardized components are commonly produced and processed by subcontracting between brand-name companies at cost-advantageous locations (Contractor et al. 2010, Gabrieletto 2014, Chen et al. 2009), respectively "five, six well-known Asian contract-manufacturers" (I 2.11). In theory, however, German companies in plant engineering and construction would be able to domestically produce all these components as well (Schlick et al. 2011). The production of the designed frames and a few specific components, as well as the assembly of all produced components is performed either by the producer in Germany or by sub-contractors in Asia (Burdack 2015). An outsourced organization requires a lead time of about 15 months for the product to be designed, manufactured, and shipped. A domestic production requires half that time (I 2.2, I 2.17). An EPAC's manufacturing cycle begins in September, when new prototypes are presented at the largest European trade fair, the Eurobike in Friedrichshafen. There, specialized dealers order the commodity for the following season. Due to the EPACs similarities to conventional bicycles, EPACs established within the same traditional distribution channels. Today, 69% of all bicycles and EPACs are sold by specialized dealers, 13% over the Internet and 18% by discounters (Burdack 2015, ZIV 2016a). Production begins based on the pre-orders of these distributors, and delivery is around February of the following year (I 2.2, I 2.4).

At first glance, the global industry for electric bicycles is dominated by Chinese firms. About 85% of all electric bicycles produced in the world are sold in China (Stewart 2014), and more than 80% of worldwide e-bike imports originate in China (ibid.). The annual production of Chinese factories in 2011, for example, comprised about 33 million units. However, it is important to distinguish that very few of the vehicles produced for the Chinese market are EPACs (Neupert 2011). The main governmental goal in China is to replace fuel-powered mopeds and small motorcycles instead of automobiles (Goodman 2010), so electric bicycle production often implies cheap and low-quality e-scooters, throttle-controlled e-mopeds, and other LEVs.

A second look at the global market reveals that Germany, while operating on a smaller scale than China, is no minor player and seems to offer an exceedingly innovative, competitive, or otherwise

advantageous environment for the successful development of an EPAC industry (App. B). It is thus at the core of this thesis' research..

RESEARCH QUESTION, OBJECTIVES, AND CONTRIBUTIONS

From a theoretical viewpoint in economic geography, one could summarize this industry development in form of the *geographic paradox of globalization*. Initially localized capabilities such as the knowledge or context specific practices for the production of bicycles, batteries or electric motors dispersed globally over time (Maskell and Malmberg 1999). Even though the technologies were initially discovered and developed in European contexts, much development of motor or battery technologies takes place in Asia today. Yet, simultaneously to the continuous dispersion, capabilities that had already diffused re-localized for a different reason – the EPAC (Storper 1997). This means that the industrial organization of the EPAC must be regarded as "a two-way street between localization and diffusion, not [as] a one-way highway to dispersion" (Storper 1997:192). Accordingly, "the counterintuitive fact that […] industries sometimes continue to prosper in high-cost environments while common sense as well as economic theory would have us believe the opposite" (Malmberg 1997:579), also holds for the EPAC industry evolving in Germany. Malmberg is convinced that "trying to explain and understand these and related phenomena, is […] certainly worth exploration" (1997:579).

Research at the edge of specific industries such as the EPAC's or of industry development in general is no new issue and was already investigated by Adam Smith (1776). Close study of the existing research on industry development (Ch. 2) reveals the influence of national framing conditions and industrial structures, institutional and regulatory aspects, as well as transfer-mechanisms of technical knowledge on the formation of industries. Even though core-questions are often similar, industry studies result in a variety of explanations for successful industry development. There is no one-size-fits-all theory providing all-encompassing answers to the questions raised regarding successful industry development. Instead, a variety of theoretical approaches have evolved over time, each focusing on single aspects of industry development and providing only partial explanations. Also Storper and Harrison (1991:407) realize that "we remain limited in our ability to forward in understanding the causes of industrial success." Similarly, EPAC-experts have tried to explain Germany's success in this industry during exploratory talks, but only presented selective statements such as:

> It's because [the German conventional bicycle companies] hold a strong market position (I 1.1),
>
> it's all about image. You cannot assume that Made-in-Germany products fulfill higher technical standards than, for example, Taiwan does. But the name serves its purpose (I 1.2),

or as Siegfried Neuberger, head of the German bicycle industry association (*ZIV*), put it: "[It] is because [the German EPAC industry] is able to produce close to the market" (ZDF heute Journal 18.5.2015).

Such statements neither provide comprehensive explanations for the conditions, determinants, or mechanisms that have enabled the German EPAC industry to develop successfully, nor do they examine the aspects regarded as important for research from a theoretical viewpoint. Research on the EPAC industry's development providing alternative answers does not yet exist. Thus, the research question for this thesis is:

HOW DID THE GERMAN EPAC INDUSTRY DEVELOP AGAINST ITS STRUCTURAL-ORGANIZATIONAL, INNOVATIVE, AND INSTITUTIONAL-REGULATORY BACKGROUND, AND IN WHAT WAY DID IDENTIFIABLE 'SUCCESS-FACTORS' FOSTER THIS DEVELOPMENT?

Similar questions have been investigated by a wide variety of single theoretical approaches. This study, on the contrary, applies three scientifically established frameworks (Ch. 3). They are used to provide theoretical languages for a supplementary description of Germany's industrial EPAC development, which also allows the extraction of influencing 'success-factors'. Each framework uses a different approach to investigate industry specifics within the national environment in which the EPAC industry is embedded. The choice of frameworks is derived from the research question's thematic aspects in combination with theoretical elaborations on the topic of industry development and earlier industry studies. Michael Porter's *diamond* emphasizes industrial structures and their interrelations within a national setting and serves as an analytical starting point. The *national system of innovation (NSI)* supports the investigation of the developing EPAC industry within a national innovation-environment. It addresses national processes and institutions of technological advancement, learning, and knowledge generation, which can be related to the development of a specific industry. The *social systems of production* (*SSP*) complements the two preceding approaches by emphasizing national idiosyncratic social institutions and mechanisms for economic coordination. The *SSP* thereby extends the EPAC's industrial portrayal by offering insights into the institutional and regulatory backgrounds. Inherently, these approaches are not industry specific, but depending on industrial settings, different individual forms of coordination and regulation are reflected. In conjunction with each other, the three frameworks provide an approach to consider each of the theoretically important aspects for industrial investigation. They also build a comprehensive basis to explore the potentially influencing 'success-factors'.

This study is important and original for different reasons and can be equally interesting for social scientists, industrial actors, and policymakers, because:

(1) It facilitates a better understanding of the EPAC industry's surprisingly successful development in Germany by carefully analyzing the industrial formation and its 'success-factors'. Even though this thesis explicitly does not attempt to provide any empirical recommendations for further action, it draws attention to a successfully growing but politically underrepresented part of the German e-mobility sector.

(2) This thesis injects long-lasting discussions about the reasons for industrial growth with new insights and offers an unconventional multi-theoretical approach to the backgrounds of development. It identifies concrete success-determining factors based on the industry's portrayals in order to further understand the backgrounds of successful industry development.

(3) In the form of a case study research design[2], this thesis addresses important research gaps in the study of national industry development in general and the EPAC industry in particular (Ch. 2). The study confronts the need for qualitative research with the operationalization, collection, and analysis of qualitative data from primary and secondary sources. The application of complementing frameworks to the collected data results in verbal descriptions that avoid the typically selective and narrow explanations of other studies, responding to the call for rigorous and comprehensive

[2] Case studies are "acknowledged as useful in the identification of important variables" (Wilson et al. 2014:306) and as a research strategy to focus on understanding the dynamics of a specific national or industrial setting (Eisenhardt 1989).

investigations. These descriptions meet the demand for more history-eliding and dynamic analyses by explicitly tracing the temporal development of the industry within the context of the theoretical facets mentioned in the research question.

(4) The research findings extend the range of previous scientific and case study contributions, which are critically contrasted regarding underlying explanations of successful industry development.

(5) Finally, this thesis contributes to the theoretical discussion and reflection on the applicability of the three applied frameworks. Frameworks can provide only a theoretical language for description, rather than detailed theoretical assumptions or explanatory causalities (Ostrom 2005), therefore this thesis explicitly does not provide specific hypothesis testing. However, the value of the frameworks applied in this empirical context is discussed, as well as the particular contributions and limitations of mutual supplementation. This in turn stimulates scientific discussions about the approaches' advantages and disadvantages in describing the national success of industries.

To serve its purpose, the thesis is structured as outlined in the following section.

STRUCTURE

As part of economic and industrial geography, Chapter 2 provides a background understanding of the most fundamental research on national industry development. Since case study research is the procedure most frequently applied to investigate the theoretical topic (Storper and Harrison 1991), the Chapter then reviews previous case studies of successful industry development within nations and of e-mobility. This theoretical and empirical review leads to the identification of current gaps in research and to the choice of frameworks, which is justified in Chapter 3. This Chapter explains why the *diamond*, the *NSI*, and the *SSP* are particularly useful in addressing the identified research gaps and generating a comprehensive description of the industry's development. Based on a theoretical explanation of each framework in Chapter 3, Chapter 4 presents a methodical approach, containing desk research and expert interviews, suitable for collecting, processing, and analyzing the required qualitative and quantitative data. Data is operationalized according to the frameworks' requirements and analyzed following Mayring's (2000) idea of a qualitative content analysis. After a brief history of industrial formations in Germany and the EPAC's invention, the case-study research design is empirically applied in Chapter 5. Successively, each framework is applied and used as a basis for identifying particular 'success-factors' influencing different phases of industry development. The results are interpreted on an meta industry level in Chapter 6. Within the concluding Chapter 7, all findings are finally summarized, related to their empirical and theoretical contributions, as well as to further research potential.

2 LITERATURE REVIEW: RESEARCH ON NATIONAL INDUSTRY DEVELOPMENT AND EPACS

This Chapter briefly reviews socio-scientific research on the topic of national industry development in an effort to clarify why the research question particularly investigates the EPAC industry's structural-organizational, innovative, and institutional-regulatory backgrounds. Additionally, it provides context for this thesis within the current body of research and identifies research gaps that are important to consider when researching this scientific field.

Economists have been researching national industry development since Adam Smith (1776) first explored why some social groups, economic institutions, and nations advance and prosper over two hundred years ago. Since the 1890s, it has been of great interest in the social sciences to identify why specific countries succeeded better in industrial production than others (Williams 1896). Later investigations also focused on why some nations have become the home base for internationally successful competitors of an industry (Porter 1990) or why some national industries are more successful than others (Murmann 2003). Such research is conducted in industrial geography, which is a sub-discipline of economic geography.

Its central ideas have been popular since the 1970s (Brücher 1982) and are closely related to industrial organization research in economics. Despite the omnipresence of its research, the sub-discipline of economic geography seems outdated, because it is hardly represented as such in today's textbooks and publications. Uniform definitions of terms, theoretical relations, aims, thematic priorities, or research procedures, however, do not exist (Maier and Beck 2000, Pangborn 2012. For example, Porter (1990) defines an industry as a group of naturally selected firms that produce products which are close substitutes in the marketplace. Van de Ven and Garud (1989), in turn, conceive of an industry as a social system consisting of instrumental, resource procurement, and institutional sub-systems. Traditional industrial organization research describes an industry based on the interrelation of supply, demand, and production costs (Bester 2012). Accordingly, the current body of research is diverse and does not offer all-embracing approaches (Murmann 2003) for answering the question raised in this thesis.

Nevertheless, the following review of theoretical and empirical research suggests the relevance of investigating structural-organizational, innovative, and institutional-regulatory backgrounds of national industry development.

THEORETICAL RESEARCH ON NATIONAL INDUSTRY DEVELOPMENT

Research on industry development, also referred to by terms such as 'industrial leadership' (e.g. Mowery and Nelson 1999), 'competitive advantage' (e.g. Porter 1990), or 'industrial competitiveness' (e.g. Maskell and Malmberg 1999), focuses on the interrelations of humans, space, and industry (Brücher 1982, Piore and Sable 1984, Maier and Beck 2000) and emphasizes contexts and compositions of change (Watts 1987). As the locations of industry development cannot be understood in isolation from the wider socioeconomic and technological context, "the overall processes of transformation of capitalist production systems, institutions, and markets" (Malmberg 1994:532) and their regulatory functions are considered when researching industry development (Amin and Thrift 1994, Schamp 2000, Malmberg 1997). Accordingly, the state as a spatial creative and regulatory force, as well as social and ecological aspects, are increasingly researched in connection with industry development (Gibbs and Healy 1997, Maier and Beck 2000, Schamp 2000). Understanding processes of innovation during an industry's development is important because it identifies the driving forces of technological and organizational change in contemporary societies (Rigby and Webber 1997, Hayter and Patchell 2011). The nation as a spatial entity for research on industry development is regarded as particularly important, because it "remains of decisive importance in the governance and regulation of economy and society, in innovation and technology transfer, in environmental policy, and in education, training and the labor market" (Hudson 1998:16). It is considered important for institutions in mediating economic change and production conditions (Gertler 1992, Cumbers 2000, Dicken 2007, O'Neill 2004, Martin 1999).

As indicated, concrete theoretical approaches to research specific characteristics of industry development or to investigate a particular industry have been developed, enhanced, or borrowed throughout economics and economic geography. According to aim, scale, and scope of the research, theoretical approaches focus on different analytical entities. Elaborations span from traditional theories such as Weber's (1909) least cost theory, Vernon's product life-cycles (1979) or Porter's (1990) *diamond*, to more recent approaches such as spatial and sectoral varieties (Frenken et al. 2007), social networks (Sorenson 2003), or institutions (Murmann 2003).

The standing of industrial geography as a melting pot for diverse research and grand theories concerning industry-spatial topics is apparent. It is therefore important to make use of theoretical approaches for empirical investigation, which enable the researcher to put different strands of research into practice. Porter (1990:3), however, again realizes that theoretical contributions are "often conflicting, and there is no generally accepted theory" for explaining industry development. According to Malmberg (1994), and Storper and Harrison (1991), the number of theoretical contributions and conflicting explanations has led to the emergence of a growing body of concrete economic geographic research which is conducted primarily in the form of industrial case studies and has flourished over the last decades (Murmann and Homburg 2001). Reviewing such studies of industry development helps identify which aspects must be considered to reach the goal of performing comprehensive research.

EMPIRICAL RESEARCH ON NATIONAL INDUSTRY DEVELOPMENT (AND EPACS)

In this section, studies conducted throughout the last 15 years are reviewed. With an emphasis on more recent studies, it reflects the current state of case study research on understanding the successful evolution of national industries (a synopsis in App. D).

In a 2001 study, Murmann and Homburg compare the evolutionary dynamics of the synthetic dye industry across different national settings. They identify factors such as specific legal environments, the availability of skills, economies of scale and scope, as well as positive feedback mechanisms between firms and national institutions as crucial for successful development and national varieties. According to their findings, the existing infrastructure and technological dynamics also influence the success of industry development.

Klepper (2002) investigates the evolution of the US automobile industry. By researching individual companies, he finds that within an establishing industry, certain types of companies are more successful than others. Particularly companies diversifying from related industries or founding spin-offs were successful because of the advantage of close ties to prior employers and their experiences. The reputation of their 'parents' even eased the access to financial resources.

Yeh and Chang (2003) investigate Taiwan's machine tool industry and notice that competitive advantages are achieved through government influences which supported the diffusion of technologies from bridging institutions. Advantages further result from flexibility, pricing, and close ties between users and producers.

In 2007, Boschma and Wenting describe the spatial evolution of the British automobile industry. Employing cox regressions, the authors argue that spinoff-dynamics, agglomeration economics, and the timing of industry entry are significantly related to firms' survival. The spatial distribution of related industries positively influences the industrial formation, because they offer a local supply of potential entrepreneurs, knowledge externalities, and skilled labor that could be utilized by the

establishing industry. Additionally, the pre-entry techno-economic backgrounds of entrants appear to be essential for firm survival. Experienced entrants sustain comparatively higher survival rates.

Yan and Hu (2008) study the causes of growth in Taiwan's bicycle industry and apply a perspective similar to Klepper's (2002). Focusing on strategic entrepreneurship, the authors find that effective collaboration and networking, an abundance of firms skilled in production, as well as government support and close ties with Japan and the U.S. cause growth.

Based on the historical importance of Britain in cotton spinning, Saxonhouse and Wright (2010) analyze this industry's globalization. They argue that historical and institutional contexts are most fundamental for a national industry to develop. These, they contend, shape a specific organization of production and learning and might enable complementary improvements in machinery and workforce skills.

Similar to the studies introduced before, Ahn and York (2011) apply a dual perspective and approach a resource-based and an institution-based view on national industry development. They discover that within a high-tech industry, the access to funding and talent in combination with supporting governmental institutions plays a central role in its establishment.

Pangborn (2012), in contrast, investigates factors that have influenced the growth and development of a low-tech industry. Regarding the analysis of empirical findings, his dissertation on New Zealand's Dairy Industry is one of the most detailed case studies on industry development available. He argues that factor-sets of drivers, enablers, and facilitators differently cause growth in different phases of development. This very low-tech industry is influenced by factors as natural resources, infrastructure, and property rights, in addition to the frequently mentioned government policies and basic economic conditions.

Weerathamrongsak and Wongsurawat (2013) reach similar conclusions about the Thai rubber industry, another low-tech industry, where success-drivers include the size of plantation areas and high production volumes.

Studies on photovoltaic industries conducted in 2013 (Lo et al. 2013, Zhao et al. 2013), observe that nationally bounded technological capabilities, governmental and institutional support, the access of relevant resources, and the particular support of R&D facilities are crucial for this industry to establish in Taiwan and continuously succeed in China.

Case studies conducted in 2014 focus on innovative and knowledge-related aspects. Ruan et al. (2014) apply a disruptive innovation approach to show that the government shapes the development of the Chinese e-bike industry through both promotional and restrictive policies. When the Chinese government banned motorcycles in cities due to environmental concerns, this accidentally created an environment for the e-bike industry to develop without any competition from the motorcycle industry. Ruan et al. (2014) therefore call for incorporating institutional factors into case study analyses.

Chaudhary (2014), in turn, analyzes the attempts at leadership of e-mobility in India. He argues that an interplay of policy, business strategy, technological competencies, and market forces shapes the growth trajectory of e-mobility industries. The local private sector, particular *demand conditions*, and policies are regarded as broad determinants of growth. More detailed, the R&D across various sub-technologies, resulting from investments in in-house R&D, leads to idiosyncratic capabilities and the building of knowledge linkages. Additionally, cheap skilled labor and a societal awareness for environmentally-friendly means of transportation support industrial success.

In a 2015 study, Altenburg et al. aim to shed light on the dynamics and determinants of EVs' technological path creation in France, Germany, China, and India. They trace the countries' differing industrial development paths and their varying choices of business and technology models back to four main drivers: Technological capabilities, *demand conditions*, political priorities, and economic governance.

Braguinsky (2015) argues that the diffusion of technological knowledge is key to industry growth. He uses a nanoeconomic approach to investigate the growth of the low-tech Japanese cotton spinning industry and concludes that only with access to "the right kind of human capital" (Braguinsky 2015:1), that which is talented and embodies and transmits knowledge within a competitive and experimenting environment, could the industry establish itself successfully. Diversity of knowledge, unfettered competition, and the governmental establishment of an institution for knowledge diffusion enabled the industry to grow.

The reviewed results are generated by (more or less) evolutionary descriptions of different industries. The studies either describe the industry's development in various development phases or stages, or provide static pictures at different points in time. The most frequently described research objects are descriptions and analyses of market and industry structures, actors, and companies. Such are studied to provide an industry picture of influencing individuals, entrepreneurs, or broader structures and interrelations. Utilizing statistical figures on imports, exports, growth rates, price changes, etc., authors predominantly describe quantitative pictures of the market and industry development (e.g. Murmann and Homburg 2001 or Boschma and Wenting 2007). Furthermore, political and governmental conditions, knowledge, learning, and innovation are researched. At the core of political research objects, authors review regulatory policies, industry subsidies, or political development plans in order to identify strengths, weaknesses, and influences of political programs (e.g. Zaho et al. 2013 or Ruan et al. 2014). Knowledge-related aspects are studied by focusing on relations between R&D facilities and private economy funds flowing for innovation. Intra- or inter-industrial relations are examined to identify how knowledge is generated, circulated, and utilized. The influences of customers and demand are investigated, as well as physical and financial resources and aspects of research and education, production, and the workforce. Only scarce attention is paid to external effects and potential social influences on the industrial formation.

Research and studies on the empirical object of investigation have been of little socio-scientific interest until today. Even though Döring (2012) argues that e-mobility might be explicitly beneficial with regard to urban areas, where distance is not as significant, socio-scientific research on e-bikes or even EPACs is limited to a small scale – most research focuses on e-automobiles or e-mobility in general (e.g. Altenburg 2014, Chaudhary 2014, Altenburg et al. 2015). König (2010) notes that it has been neglected for a long period of time and Popovich et al. (2014:43) recognize that "research on e-bikes […] is limited, particularly in comparison with the recent explosion in research about conventional bicycling." Apart from the e-bike study on China's industry development (Ruan et al. 2014), only Neupert (2011) reconstructs the historical development of the EPAC and its design metamorphosis in an end-user magazine. As emphasized by Popovich et al. (2014), other studies on industry development are only conducted in relation to the conventional bicycle industry (Larsen and Nilsson 1984, Chu and Li 1996, Chu 1997, App. D)[3]. Consulting organizations provide some

[3] In addition to industry studies, manifold socio-scientific research on conventional bicycles exists in general. For example, Burdack (2015) analyzes the spatial structures of Germany's conventional bicycle production. Spatial supply chain- and knowledge structures (Chen et al. 2009, Gabrieletto 2014), innovation diffusion

statistical market information (e.g. Stewart 2014, Hurst and Gartner 2013) or recommendations for industrial action (e.g. Schlick et al. 2011). Rather than focusing on industrial growth, socio-scientific research on EPACs is related to discussions of climate change and renewable energy (e.g. Rothfuß 2012), the development of new (urban) mobility landscapes and required governmental adjustments (e.g. Chaudhary 2014, Rothfuß 2012, Boßhammer and Booß 2015, Rudolph 2014, Van den Bossche 2003), or expected economic potential in tourism and sales (e.g. Schäfer 2012). Weinert et al. (2007) describe and analyze the societal transition from conventional to e-bikes, including EPACs. Geographic research focuses particularly on the various aspects of sustainable transportation (Rose 2012, Zhang et al. 2014), sharing opportunities (Boßhammer and Booß 2015, Zhang et al. 2014), and political funding opportunities (Rudolph 2014). Other social scientists conduct economic potential analyses (Weinert et al. 2008, Popovich et al. 2014), or attempt to solve standardization issues (Van den Bossche 2003).

The empirical research on successful industry development and EPACs reflects the variety of theoretical attempts to explain industry development. None of the reviewed studies provides a silver bullet for analyzing the German EPAC industry's development. Instead, the results again point to the relevance of considering the structural-organizational, innovative, and institutional-regulatory backgrounds of the EPAC industry's development Furthermore, the review hints at a need for further research, detectable in the theoretical and empirical research gaps outlined in the following section.

RESEARCH GAPS TO BE ADDRESSED

The scientific discourses and empirical investigations introduced point to the importance of supplementary research on national industry development. Klepper (1997:177) realizes that "mapping out the empirical terrain of how industries evolve in their formative eras has begun, but a great deal remains to be done," when it comes to the following aspects:

Call for 'history friendly' analyses and the consideration of dynamic patterns. Industries develop due to historical processes. Various elaborations, however, regard history as a subordinated byproduct of technological, societal, financial, or other developments. As a result, calls for an explicitly historical view of industrial and spatial evolution arise (Malerba et al. 1999, Boschma and Frenken 2003, Murmann 2003). Researching industry development as an evolutionary process requires capturing processes and changing historical dimensions (Schamp 2000). This inevitably highlights the importance of analyzing dynamic aspects rather than static points in time. Thus, Boyer (1988:629) argues that "a careful study of dynamic patterns should be integrated into the analysis of [industrial] growth trends."

Call for emphasis on nations, institutions, knowledge, and learning. Research on the successful development of industries predominantly considers actors, firms, and market structures as analytical

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and the organization of learning processes (Galvin 1999, Wang et al. 2010), temporal clustering (Andreae et al. 2013) or offshoring, outsourcing, back-shoring, and production networks are investigated (Gylling et al. 2015, McCourd 2013). The global bicycle industry is analyzed regarding product varieties or dominant designs (Dowell and Swaminathan 2006). Firm performances, organizational ecologies, and technological change (Randall and Ulrich 2001; Dowell and Swaminathan 2000; Yan and Hu 2008) are analyzed, as well as the product's modularity (Chen et al. 2009, Galvin and Morkel 2001), mass customization (Kotha 1995), technical and organizational innovation patterns (Hu and Wu 2011), or the creation of new markets (Burr 2006).

entities. Accordingly, Boyer (1988), Klepper and Graddy (1990), MacKinnon et al. (2002) or also Murmann (2003) point to the insufficient consideration of institutional settings and the aspects of knowledge, learning, and technological change that underlie sustained and stable growth patterns. Especially the call for more sophisticated research on institutions is connected to a national scale. Many institutions are formed by nationally bounded policies, legal settings, and wider socioeconomic and technological contexts (Malmberg 1994). Thus, technical and institutional practices of industries vary across territories (Walker 2000). It is argued that research lacks convincing explanations of national industry-influences and that traditional explanations are insufficient in explaining why some national firms compete better than others (Porter 1990). Thus, there is a need to incorporate institutional environments in empirical analysis to examine national idiosyncrasies and societal dimensions of an evolving industry (Malmberg 1994, Schamp 2000, Murmann and Homburg 2001).

Call for comprehensive and rigorous investigations. As indirectly emphasized in the preceding paragraph, it is clear that traditional explanations of production and industry patterns are inadequate in explaining the complexity of today's economic structures (Dicken 1998, Hollingsworth 1998, MacKinnon et al. 2002). Hollingsworth and Boyer (1997a) argue that theoretical literature often remains fragmented and unintegrated. Dicken and Malmberg (2001:347) criticize earlier investigations for decontextualizing "both firms and territories – of seeing them as entities separate from the broader structures of which they are a part." Accordingly, Dosi and Orsenigo (1988) consider the interconnection of single research objects as a remaining and major theoretical challenge – or as Nelson (1994:59) puts it, contemporary research seems like "a collection of pictures of 'pieces of the elephant' with large gaps in the overall picture." To fulfill the need for insufficient investigations, Dicken (1998, 2007) calls for a partial utilization of various existing theoretical bodies. Hudson (2004:467) argues that scientific "work, grounded in different conceptions of theory and synthesizing the results of different sorts of research and evidence, […] is necessary if there is to be further progress in economic geography."

Call for qualitative research. Economic research in particular is commonly criticized for large-sample cross-sectional studies that exclusively rely on econometric calculations and models to explain empirical content. It is further recognized that econometric research is inadequate in explaining changes in organizational structures over time (Murmann 2003). Economic geographers and other scholars thus call for more qualitative studies on industry development (Murmann 2003, Martin 1999). They argue that research on varying scale-dependent social, cultural, and institutional conditions of the nation state cannot be performed sufficiently by econometric models (Martin 1999). Schoenberger (1991:180) additionally recognizes that qualitative research is "particularly appropriate in periods of economic and social change, […] [but] only rarely encountered in contemporary economic and industrial geography."

Call for validation of industry studies. Elaborations on how industrial transformation comes about are characteristic of industry-related research. The empirical validation of such elaborations, however, is regarded as weakness of the research (Freeman 1994, Dicken and Malmberg 2001, MacKinnon et al. 2002, Popovich et al. 2014). It is therefore called for more empirical studies to compare the results and explanations of industrial evolution in differing national and industrial settings (Murmann and Homburg 2001, Boschma and Wenting 2007, Ahn and York 2011).

Call for research on EPACs. Popovich et al. (2014) generally deem further research on the e-bike and its trends necessary. König (2010) also notices it has been neglected for a long period of time. Research should be conducted "separate from both conventional bicycles, and mopeds, motor-scooters, and the like" (Popovich et al. 2014:44). Studies introduced previously provide

explanations for the industrial success of diverse industries, but neither the German bicycle, battery, or motor industries nor the EPAC as industrial good have been the focus of such studies. This raises the importance of analysis considering both Germany as a traditional bicycling nation and its industrial setting in connection to the new "exploding industrial field" (I 1.2).

These research gaps and the preceding sections suggest several theoretical starting points for building an analytical frame for the case study. These are summarized in the interim conclusion.

INTERIM CONCLUSION

The preceding sections review the theoretical and empirical backgrounds of the research field. Rather than providing an analytical tool or ideal solution for analyzing the development of Germany's EPAC industry, they instead demonstrate the variety of existing research and subsequent results on a theoretical and empirical level. However, they also point to a number of aspects that help identify a suitable frame for the empirical analysis:

(1) The preceding sections underscore the necessity of examining structural-organizational, innovation-related, and institutional-regulatory aspects of industry development when attempting to provide a comprehensive analysis, because these are the most important research aspects in case-study research (similarly summarized by Storper and Harrison 1991, Ahn and York 2011) and in theorizing national industry development. Structural-organizational aspects include the previously mentioned industrial and corporate structures, organization, and interrelations, including global influences. Innovation-related aspects refer to technological and research contexts and the product-related contexts and compositions of change. Institutional-regulatory characteristics describe socioeconomic institutions, influences of policy, state, capitalist environments, and social or societal influences that affect the EPAC industry's development. Because this study aims to investigate a comprehensive understanding of the EPAC industry's development, these broad strands of research must be considered.

(2) This review also highlights the relevance of investigating the EPAC industry's 'success-factors', since they offer tangible results in case study research on industry development.

(3) The case study review inspires the idea of combining different theoretical concepts to result in a comprehensive study. In the reviewed studies, scholars apply diverse and selective theoretical approaches. They then reach diverse conclusions about how industries develop. A few studies point to the use of complementary theoretical concepts (App. D). Weerathamrongsak and Wongsurawat (2013), for example, theoretically review different perspectives on competitiveness; Braguinsky (2015) reviews research not only of knowledge diffusion but also of industry life cycles; Pangborn (2012) introduces thoughts on innovation and structural industry development. Yet even though these scholars theoretically discuss connections between such approaches, they do not concretely apply different complementary concepts. Rather, their complementary discussions remain on a theoretical level. In practice, only Ahn and York (2011) employ two complementing theoretical perspectives to contribute to more comprehensive investigations and to analyze how different types of developments take place.

(4) Accordingly, the literature review also leads to the identification of research gaps remaining today. In addition to conducting another industry study that considers the sub-aspects introduced above, future research should be comprehensive and rigorous, and contain qualitative approaches as well as historical and dynamic patterns.

(5) Finally, it is clear that none of the above approaches have been implemented in relation to the German EPAC industry.

Due to these findings, theoretical approaches structuring the empirical investigation and providing a language for analysis must be selected to enable the researcher to put the different strands into practice. This is investigated in Chapter 3.

3 THEORY: ANALYTICAL FRAME OF COMPLEMENTARY APPROACHES

Chapter 2 concludes that there is no uniform procedure to research national industry development. Dicken (1998) and Hudson (2004) argue for the implementation of different theoretical approaches which together enable a comprehensive analysis.

The most comprehensive, but still tangible, description of national industry development can be reached on the level of frameworks, rather than on the level of overarching perspectives or narrow theories. Frameworks offer meta-theoretic languages and structure the identification of elements and relations to consider in empirical analysis (Ostrom 2005). They are not as broad and general as theoretical perspectives, and at the same time do not pre-determine or limit the explanatory range of empirical findings to a few cause-effect relationships as narrow theories might (ibid.).

Many of the frameworks developed in relation to national industry development can be traced to the conceptual origins of traditional approaches. A variety of such traditional "true classics" (Fagerberg and Sapprasert 2011:678) were introduced in the 1990s and are still considered important and legitimate[4]. The analytical cores of more recent frameworks remain traditional, which is why this study employs 'classics' to illustrate the essence of the frameworks' main objectives.

Following Ostrom's (2005) definition and bearing in mind the interim conclusion reached in Chapter 2, the application of three frameworks is subjectively identified as most appropriate for answering the research question. The *diamond*, the *NSI*, and the *SSP* function as structuring and analytical guides which are equipped with meta-theoretical languages for describing the EPAC industry's evolution and for exploring potential 'success-factors'. The following Sub-Chapters present these three frameworks and examine their suitability for investigating the research question.

3.1 *DIAMOND*: ORGANIZATION AND STRUCTURAL INTERRELATION

To approach the German EPAC industry's development, the *diamond*, introduced by Michael Porter in 1990, serves as an analytical starting point. Its main objectives are to explain "why particular countries succeed in particular industries," "why a nation provides an environment in which firms improve and innovate and continue to do so faster and in the proper directions compared to their international rivals," and "why a nation is a more or less desirable home base for competing in an industry" (Porter 1990:69f.). To answer these questions, the framework emphasizes

[4] To prove this interrelation of 'modern' and traditional elaborations: e.g. Maier and Beck (2000), Schamp (2000), Murmann (2003), Fagerberg and Sapprasert (2011), Bester (2012) or compare the contents of e.g. Nelson (1994), with Bathelt and Glückler (2012).

the interrelations and structural specifics of demand, factors, relations with other industries, and the interrelations and strategies of industrial players on the growth of a domestic industry.

Applying this framework as an analytical starting (Schamp 1995) point for this thesis is sensible for several reasons:

(1) The framework considers a wide variety of a national industry's structural-organizational relations, including the industrial and corporate structures, organization, and interrelations, as well as potentially global influences. Also, it is applied to "throw light on some key factors contributing to […] success" (Weerathamrongsak and Wongsurawat 2013:54).

(2) It is still relevant and has been frequently applied in empirical investigations, with either a nation-specific (e.g. Öz 2002, Wilson et al. 2014) or an industry-specific focus (e.g. Bridwell and Kuo 2005, Weerathamrongsak and Wongsurawat 2013).

(3) The framework is the first of its kind. It opens up the ideas of traditional location-choice to include contextual and dynamic viewpoints that explain the organization of production processes within their social and economic dimensions (Porter 1994, Bathelt and Glückler 2012). Bathelt and Glückler (2012) acknowledge the *diamond* as the first that analyzes national firm structures apart from their individual settings and that examines the evolution of competitive advantages from a territorial viewpoint.

(4) Expansions and adaptions of Porter's theoretical elaborations (e.g. global or regional levels of analysis (Dunning 1993, Porter 1998, Porter 2003)) consider only particular parts, or do not focus on the national level as a spatial scale.

(5) Compared to other theoretical frameworks at the edge of structural-organizational aspects, the *diamond* provides the most comprehensive explanation of national industry development. Others focus only on particular firms (e.g. Weber 1909), on local or regional patterns of an industry's development (e.g. Marshall 1920, Storper and Walker 1989, Bathelt et al. 2004), or on spatial dynamics and varieties resulting from the co-location of industrial sectors (e.g. Rigby and Essletzbichler 1997, Frenken et al. 2007), etc. Comparable frameworks in economics (e.g. history-friendly frameworks, Malerba et al. 1999) reduce real-world findings to econometrically stylized objects (Murmann 2003).

(6) The *diamond* is also well-suited to exploring the EPAC industry's setting. The EPAC is a recombined product, composed of components originating in three different industries. Thus, it is reasonable to consider the influences of other related or supporting industries. Since the industry comprises "EPAC production, component production, equipment production and specialist dealers, as well as its advocacy groups" (Ch. 1), it is also reasonable to consider the relations and strategies of different types of industrial players.

(7) Finally, commencing the analysis by applying the *diamond* contributes to addressing the research gaps revealed in Chapter 2. It is more comprehensive and rigorous than comparable others, employs verbal description and logical reasoning rather than mathematical models (Ketels 2006), and considers historical and dynamic aspects as well.

These aspects justify using Porter's *diamond* as a starting point for the investigation of Germany's EPAC industry. Its main ideas and most important contents are introduced in the following sections.

CORE IDEAS

Porter's framework relies on the fundamental idea that a successful firm's 'national home base' provides an advantageous industrial environment. Within this national environment, firms gain and sustain advantages in international competition due to constant improvements and innovation. Porter (1990) argues that advantages arise over time and due to the existence of four attributes figuratively arranged as a *diamond* (Fig. 1): *Factor conditions, demand conditions, related and supporting industries*, as well as *firm strategy, structure, and rivalry*. Each attribute interdependently affects every other. Every industry must be considered unique, because it has its own attribute-compositions and backgrounds of development (Porter 1991). Thus, an industry's *diamond* can only be revealed by understanding the processes by which the industry emerges within a nation and by which it achieves international competitiveness.

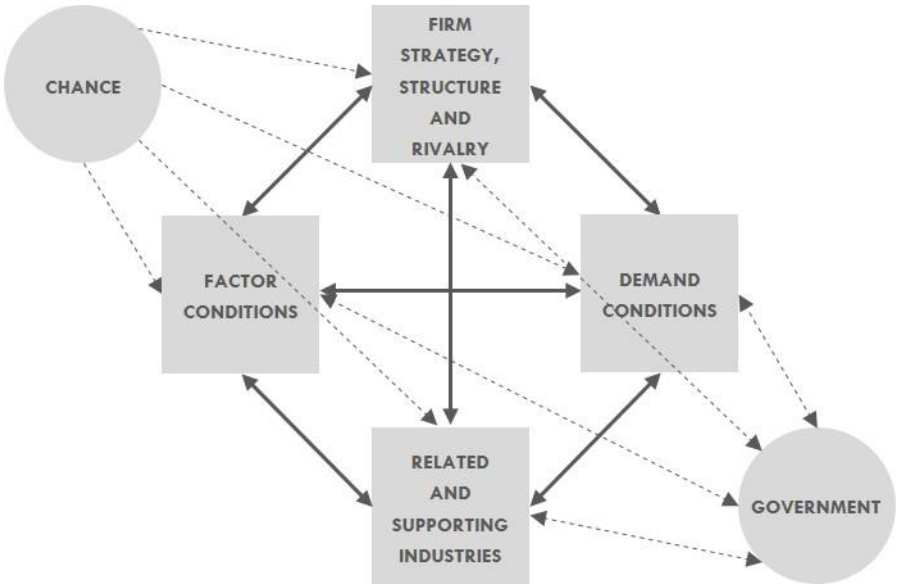

Figure 1: SKETCH – THE *DIAMOND*
(source: author's elaboration based on Porter 1990:127)

Factor conditions comprise human, knowledge, physical, and capital resources, as well as the existing infrastructure, and describe the inputs necessary to compete in a given industry. The factors most important to competitive advantage are created through idiosyncratic nation- and industry-related processes. Advantages, however, can also result from selective factor disadvantages, because companies might be forced to innovate or build specific relationships. The *diamond's* interrelations reveal that a strong home *demand* and domestic *rivals* could affect the constitution of industrial *factor conditions*, as well as the priorities for factor-creating investments. *Related and supporting industries* could create or stimulate the creation of transferable factors (Porter 1990).

Demand conditions describe the structure of the home demand for the industry's product and provide a picture of buyers' needs. The composition of demand shapes the way firms perceive, interpret, and respond to buyer's needs. Demand influences competitive advantage particularly when it provides a clear and early picture of buyers' needs or if it pressures local firms to innovate faster and achieve more sophistication than foreign rivals. The composition of demand is, for example, influenced by internationally successful industries producing complementary products. The positive image of world-class *related and supporting industries* could spill over and benefit the

emerging industry's demand structure. Sophisticated *factor-creating mechanisms* could encourage participation by foreign firms that are attracted to the nation's products. Furthermore, intense *rivalry* might increase home demand, make it more sophisticated and could build a national image as an important competitor (ibid.).

Related and supporting industries emphasize the presence or absence of national supplier industries and related industries that are internationally competitive. The presence of strong related and supplying industries influencing the investigated industry is labeled a 'national cluster'. This is characterized by close vertical and horizontal relations in production (Bathelt and Depner 2003). *Related and supporting industries* could stimulate the national innovative capability from the suppliers' side. *Specialized factor* pools might be transferable to and therefore affect the *related and supporting industries*. A large or growing domestic *demand* might further stimulate the growth and expansion of supplier industries, whereas domestic *rivals* could encourage the formation of more specialized suppliers as well as related industries (Porter 1990).

Firm strategy, structure, and rivalry refers to the conditions within the nation that govern how companies are created, organized, and managed. This attribute further emphasizes the structure of domestic rivalry. Porter states that the goals, strategies, and ways in which the firms of an industry are organized vary widely among nations. A competitive advantage results from a suitable match between different strategic choices. Porter (1990) argues that new entrants could emerge from *related and supporting industries*. *Factor abundance* or *specialized factor-creation* could also spawn new industry entrants. Thus, world-class *users* and *related and supporting industries* could enter supplying industries. An early product penetration could further feed new entries (ibid.).

Additionally, Porter (1990) cites chance events and the government's role as influencing a particular industry. Chance events refer to occurrences that have little to do with national circumstances and are outside the power of firms and governmental influences. Examples include natural disasters, wars, or basic technological breakthroughs Government action directly and indirectly influences each of the four determinants both positively or negatively. Considering such influences of the government or external chance events outside of the firm's control completes Porter's analytical framework.

The empirical application of this approach leads to a detailed descriptive analysis of a developing national industry setting. Porter's work does not explain the procedure, the required data, or the methods of data collection that result in such description. Indirectly, however, these can be derived from his own empirical work, which is why one of his most famous examples is introduced below.

EMPIRICAL APPLICATION

Porter (1990) analyses the German printing press industry to illustrate his ideas.

Porter traces König's professional career and the developments of evolving industrial firms. He generates a 'family tree' showing the interdependencies, connections, strategies, and rivalries of the industrial players. Additionally, he discusses the establishment of specialized factors such as printing press schools, resulting from these interdependencies. Further, he finds that due to high wages German print shop owners became sophisticated customers, desiring highly productive machines that required fewer operating personnel. Thus, the German printing press industry provided highly productive machinery and quality, and although it was not among the world's largest, it became one of the world's most sophisticated printing press industries. Focusing on related and supporting industries, Porter further notes that industries for paper, paper machinery,

ink, or typesetting-systems grew in tandem with the printing press industry and stimulated competitive advantages. The resulting firm structure is, what Porter (1990:190) describes a "German printing cluster."

Concrete conclusions about the sources of advantage, however, cannot be drawn from the description, which reads more like one big story than a scientific analysis. Several scholars such as Öz (2002) and Bathelt and Glückler (2012) criticize this and other weakness that are important to consider before applying the diamond to the EPAC Industry.

CRITICAL REFLECTION

As indicated above, although the *diamond* serves as an analytical starting point, it is neither an all-embracing framework, nor is it free from criticism. The following reflection on Porter's own application identifies several conceptual weaknesses and addresses the most relevant criticism of other scholars.

For example, it reveals slightly chaotic and unrelated descriptions. In theory, Porter clearly distinguishes the elements of the *diamond* and their interrelations. In practice, however, different theoretic attributes are either not considered or are described inconsistently. Considering *factor conditions*, for example, Porter only emphasizes the role of workers and education when describing the German printing press industry. He does not consider potentially influencing *factor conditions* such as the physical and capital resources or infrastructure. Other elements, such as the role of R&D, are considered, but not stringently analyzed. R&D is instead diffusely captured at different stages of the printing press industry's analysis without integrating its role into the overall context. Finally, it must be noted that Porter only emphasizes the characteristics of the *diamond*'s attributes that are particularly remarkable. He fails to present the 'common' or 'normal' aspects and therefore also the interplay of 'specific' and 'normal' characteristics. Reviewing such interplay, however, might be important for capturing the whole picture of the industry-specific development and advantage. To avoid these weaknesses and empirical insufficiencies, this investigation of the German EPAC industry strives for a more structured description, which also supports a more scientific character of the empirical description.

Öz (2002) summarizes several other important criticisms of Porter's framework. He argues that the *diamond* is lacking in formal analytical modelling, failing to present methodical difficulties and clear definitions of key terms. In this thesis, this problem is partially solved by using the 'blueprint' example introduced above in a more structured way to reach an analytical standard. The required data and methods for data collection and utilization are derived from this 'blueprint'.

Öz (2002) further points to difficulties definitively locating the source of advantage, and Bathelt and Glückler (2012) criticize Porter's analysis as predominantly descriptive rather than explanatory. However, neither of these criticisms apply to this analysis of the EPAC industry. The application of Porter's framework serves first and foremost to provide a theoretical language and structure for describing the developing EPAC industry. Thus, the descriptive nature of this approach is not a significant weakness. As Porter also does not finally locate the sources of competitive advantages because of being too descriptive, this study subjectively explores potential 'success-factors', identifiable based on the description generated to narrow down the results.

More importantly, Öz (2002), Bathelt and Depner (2003), Bathelt and Glückler (2012) and other scholars criticize the insufficient presentation of socio-cultural embeddedness and the role of institutional and governmental aspects, as well as interaction and learning between branches and

firms. Porter also fails to recognize the role of technology and therefore innovation during the industry's development process. These final criticisms are, compared to all other aspects, very fundamental and cannot simply be added or diminished somehow. However, they can be relativized by considering that research on national industry development does not currently have any all-embracing approach that covers all important aspects affecting it (Ch. 2).

Despite the fundamental criticism, Porter's framework is still one of the most prominent and acknowledged approaches for the analysis of industrial competitiveness (Davies and Ellis 2000, Öz 2002, Ketels 2006, Kasperk et al. 2010, Bathelt and Glückler 2012) and suits this thesis' analysis. The case-related justifications reflected that and the most fundamental criticisms are addressed by the following Chapters of this thesis.

3.2 *NATIONAL SYSTEM OF INNOVATION*: INSTITUTION, INNOVATION, LEARNING

As revealed in Chapter 3.1, Porter's approach does not sufficiently allow retracing the innovative and institutional-regulatory backgrounds of developing industries. Therefore, his approach must be complemented. A suitable complement is the *NSI*, "an alternative, and supplementary [framework], focusing device which puts interactive learning and innovation at the center of analysis" (Lundvall 1992b:1), and considering "a set of institutions whose interactions determine the innovative performance […] of national firms" (Nelson and Rosenberg 1993:4f.).

According to a literature analysis on *NSI*, the matured approach emerged in various nuances after 1985. Lundvall provided the earliest of the most influential contributions in 1992[5] (Fagerberg and Sapprasert 2011). Therefore, his elaboration is applied in this study. The contributions of Lundvall are particularly important because his work is embedded in a setting of relationships between social factors (e.g. shared culture, values, and institutions), and learning, innovation, and competitiveness (ibid.). To investigate his basic argument that learning and innovation processes differ in space due to nation-specific conditions, structures, and institutions (Lee and von Tunzelmann 2005), Lundvall considers aspects related to R&D, enterprises, finance, and the public sector (Lundvall 1992b).

Applying this framework as a supplement to the *diamond* is appropriate for diverse reasons:

(1) Similar to Porter's approach, the *NSI* is a framework, rather than "a formal theory in the sense of providing specific propositions regarding causal relations among variables" (Edquist 2006:186).

(2) The framework considers structural-organizational and institutional-regulatory aspects of intra- and inter-firm organization, political and capitalist influences, and social matters that affect R&D and innovation. It mainly emphasizes innovation-related backgrounds of national development, including technological and product contexts.

(3) Empirical studies frequently utilize the *NSI* to explain the competitive advantages of different countries (e.g. Nelson 1993) or national industries (e.g. Fuller 2009, Lo et al. 2013).

(4) Although the original aim of the *NSI* is to explain why some nations compete more successfully than others, industry development plays a pivotal role in answering this question. The *NSI* traditionally emphasizes "the working of the national system in its own right" (Lundvall 1992b:17), instead of presenting single industry cases. Nevertheless, Lundvall argues that the *NSI* needs to

[5] Important contributions, including different conceptual nuances, were made by Freeman (1987), Lundvall (1992a), Nelson (1993) or also Edquist (1997).

remain open for adjustments to different research questions. Additionally, *NSIs* are reflected within leading national industries (Lundvall 1992a, Schamp 1995, Bathelt and Glückler 2012). Therefore, diverse empirical applications focus on specific industrial contexts as sub-systems (Nelson 1993, Peter 2002) of an *NSI* (e.g. Yeh and Chang 2003, Kaiser and Prange 2004, Gu and Lundvall 2006, Umemura 2014, Bartholomew 1997). Germany, for example, "continues to have strengths in vehicles, mechanical engineering, and certain electrical and chemical related industries" (Allen 2009:375), which is why an application of the approach to the emerging EPAC industry as an *NSI* sub-system is feasible.

(5) Over time, the *NSI* has been further developed in diverse directions. The main objectives, however, remain the same, regardless of whether the framework has been advanced toward policy-orientation (Balzat and Hanusch 2004), regional anchoring (Cooke et al. 1997), technological aspects (Carlsson and Stankiewicz 1991), the triple helix idea (Etzkowitz and Leydesdorff 2000), or business systems (Lundvall and Maskell 2000). Even the development of *sectoral systems of innovation* (Breschi and Malerba 1997), which focuses particularly on sets of new and proven products, cannot outcompete the *NSI* in this study's context, because it focuses on high-tech industries, is not explicitly space-related, and does not equally consider the relevance of learning and knowledge-transfer as Lundvall does (ibid., Lee and von Tunzelmann 2005).

(6) In comparison, other theoretical frameworks cannot serve as equally suitable complements to Porter's framework, considering the research question. Frameworks in mainline economics that consider technological advancements and institutional factors of industry evolution, econometrically over-simplify reality (e.g. Malerba et al. 1999). Other approaches focus only on design aspects (Abernathy and Utterback 1978), products, technologies, and technological paradigms (Schumpeter 1961, Arthur 1989, Lipsey et al. 2005), or linear processes (Malecki 1991), etc. and are thus less comprehensive.

(7) Lundvall's NSI concept is particularly well-suited to the analysis of the German EPAC industry because it encourages differentiated considerations of innovation and technology. As a recombined product incorporating several technologies, the EPAC is dependent upon R&D to support continuing improvement and optimization. The NSI identifies R&D structures influencing both the product and the industry, and shows their interrelations with other influencing factors like the financial and public sectors.

(8) Finally, it is reasonable to apply Lundvall's *NSI* to further address the research gaps revealed in Chapter 2: It focuses on a nation, institutions, knowledge, and learning and provides a comparably comprehensive approach that employs a historic and evolutionary viewpoint (Edquist 2006). Similar to the *diamond*, it employs a verbal description rather than econometric explanations.

These aspects justifying using the *NSI* as a complement to the *diamond* for this thesis. The following section introduces the main objectives and ideas of the *NSI* in greater depth.

CORE IDEAS

Lundvall (1992b:2), very vaguely defines a *NSI* as "a number of elements and the relationships between these elements. [These] interact in the production, diffusion, and use of new and economically useful knowledge." He bases his 'version' of the *NSI* on the assumption that the most fundamental resource for innovation in the modern economy is knowledge, regarding innovation as a ubiquitous phenomenon with an alterable and cumulative character. The most important process is learning. How a system gets interactive learning to work well is crucial for innovation and the development performance of a national economy (Gu and Lundvall 2006).

Edquist und Lundvall (1993) argue that learning is an interactive and socially embedded process. "Individual agents and organizations increase their knowledge in technical matters, not in isolation from each other, but in a process of interaction, involving learning from each other as well as producing new knowledge and innovations in cooperation" (Edquist and Lundvall 1993:267). Thus, the everyday experiences of workers, production engineers, or sales representatives influence the agenda determining the direction of innovative efforts.

As a result, processes driving innovation can only be understood in the greater institutional and cultural context. The historical development of a nation state, as well as its formal institutions, institutional actors, language, norms, and rules, therefore influence the appearance of a specific NSI (Bathelt and Glückler 2012, Lundvall 1992a), so that the nation is assumed to be the appropriate boundary for the description of innovation systems (Lee and von Tunzelmann 2005).

Actors within the same national-institutional context have similar expectations, motivations, norms, and conventions. These guide everyday actions in production, distribution, or consumption, and enable joint problem-solving, or encourage competitive behavior. Specific industrial sub-systems pre-structure dealing with routine problems and economic bottlenecks and structure the constitution of a *NSI* (Lundvall and Maskell 2000).

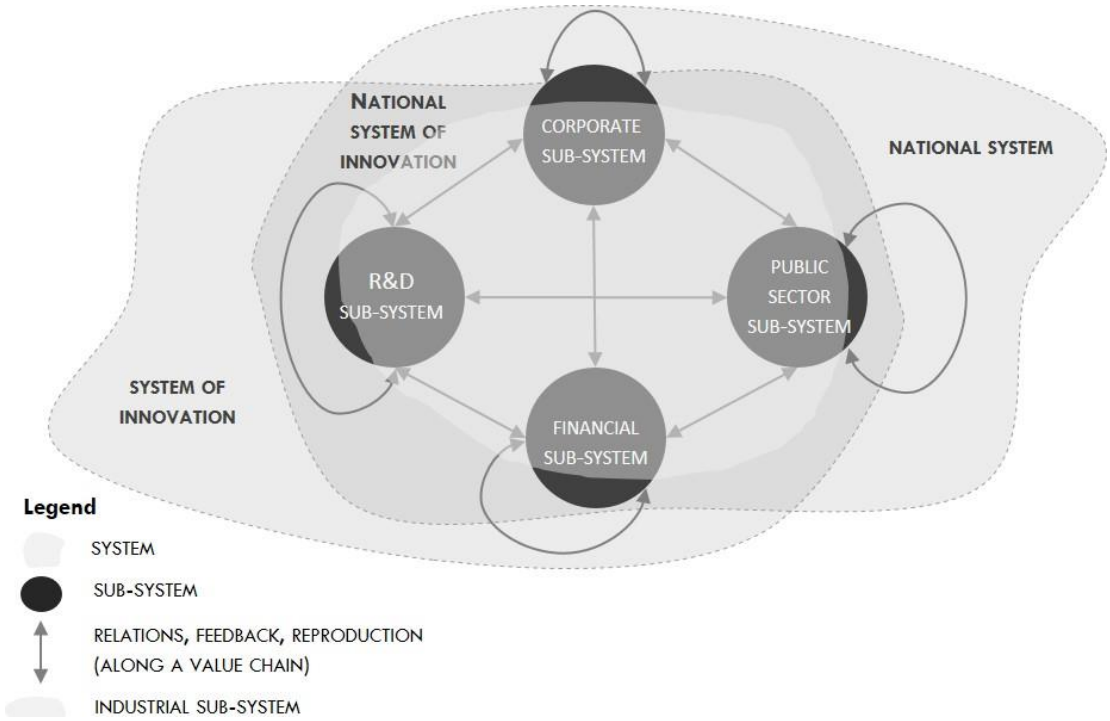

Figure 2: SKETCH – THE *NATIONAL INNOVATION SYSTEM*
(source: author's elaboration inspired by Yeh and Chang 2003, Umemura 2014)

A *NSI*, according to Lundvall (1992b), comprises the *social* and *dynamic* aspects of a *national system* and of a *system of innovation* (Fig. 2). The *national system* describes elements and relationships located or rooted within a nation state. The *system of innovation* describes elements related by the production, diffusion, and use of new economically useful knowledge (Lundvall 1992a). Processes of learning and interaction are considered *social* aspects, influenced by *dynamic* feedbacks along a value chain (Lundvall 1992c). National idiosyncrasies are especially expected in the context of and in the relationships of internal firm organization, *inter-firm relationships*, the role of the *public sector*, the institutional set-up of the *financial sector*, as well as *R&D intensity and R&D organization*.

According to Lundvall (1992b) the *internal firm organization* (*corporate sub-system*, Fig. 2) is important to the system because most innovations are developed by firms. Learning and knowledge flows occur between employees and affect a firm's innovative capability.

Inter-firm relationships (*corporate sub-system,* Fig. 2) are important in structuring the system because cooperation and other kinds of relationships are necessary supplements to competition. They enable formal or informal exchanges of technical knowledge and research externalization. User-producer relationships are regarded as important because each group holds different types of knowledge.

The *public sector* (*public sector sub-system,* Fig. 2) and the *financial sector* (*financial sub-system,* Fig. 2) are important as they are involved in financial support of science and innovation and other influencing activities. National technology policies and funding programs, approval procedures and laws, interventions in technical standards, and other regulations influence the *NSIs* constitution (Lundvall 1988). Regulations and standards similarly influence the rates and directions of innovation. The *financial sector* frames the formation of new start-ups, capital availabilities, and funds flowing for innovation, and influences the commercialization of technology through national financial patterns.

Finally, Lundvall (1992b) identifies the *R&D intensity and R&D organization* (*R&D sub-system,* Fig. 2) as important in terms of its resources, competencies, and organization. It especially influences knowledge transfers between industry and science. For example, learning takes place in specialized R&D centers that transform local experiences and laboratory experiments into more general knowledge and disseminate it through training and publications (Gu and Lundvall 2006). While universities are considered important for basic research, their influence on the *production system* is considered of little importance (Lundvall 1988). The performance of *NSI*s and thus industrial success, is commonly measured by indicators that measure the results and efficiency of R&D, such as patents or publications. International position is indicated by market shares in the *NSI* literature.

Lundvall's work does not explain the procedure, the required data, or the methods of data collection that result in such performance descriptions. Indirectly, however, these can be derived from different empirical applications of the *NSI*, which is why the following section deals with the framework's implementation in empirical analyses.

EMPIRICAL APPLICATION

Reviewing one exemplary application from Lundvall himself, like that provided by Porter (1990), is not possible for the *NSI*. Apart from a few publications on the Danish and Chinese *innovation system* (Edquist and Lundvall 1993, Gu and Lundvall 2006), Lundvall only contributes to the

framework's theoretical elaboration (Edquist 2006). His empirical contributions emphasize different sub-aspects of the two *NSIs* and are inconsistently approached. The Chinese *innovation system*, for example, is analyzed regarding the shift toward a market-oriented economy and highlights the influences of specific industries such as the machinery industry (Gu and Lundvall 2006). Edquist and Lundvall (1993) focus on exemplary industrial 'development blocks'.

Analyses of single industries as sub-systems of *NSIs* enable researching scholars to draw more concrete pictures of national and industrial relations (e.g. Kaiser and Prange 2004, Lee and von Tunzelmann 2005, Bartholomew 1997, Yeh and Chang 2003 or Umemura 2014). Since each of these scholars approach the different industries differently, however, their applications are at times contradictory and as such do not offer a consistent 'blue-print' for analysis.

All of these studies, however, describe the elements mentioned by Lundvall against the national background and in the context of their historical development. The financial system, for example, is commonly analyzed regarding bank influences or the role of venture capital (VC). Also public technologies and innovation policies, which influence the R&D intensity and orientation, as well as the formation of firms and the procurement of further funding are in focus. Regarding the corporate system, firm engagements in development programs, cooperation or in-house R&D is considered. In this context, influences of internal and external knowledge providers are discussed and further political, financial, and R&D interrelations are revealed.

These descriptions, however, remain fragmented and unintegrated and do not come to concrete conclusions about the reasons for successful industry development. To avoid such short comings, the next section critically reflects upon the concept in relation to this thesis' research setting.

CRITICAL REFLECTION

Although the *NSI* is introduced as a suitable complement to Porter's *diamond* for analyzing the evolving EPAC industry, studying the *NSI* and its empirical investigations in detail reveals further weaknesses and critical aspects.

Perhaps the most fundamental problem is Lundvall's "broad" (1992b:12) definition of the *NSI*. According to scholars such as Luhmann (1984), conceptualizing a system requires sharp definitions and distinctions of elements, systems, sub-systems, and relationships. "Clearly defined concepts are [also] necessary in order to identify empirical correspondents to theoretical constructs and to identify the data that should be collected" (Edquist 2006:203). Unfortunately, Lundvall obfuscates his framework with inconsistent use of the terms system, element, organization, and sector. Within his theoretical elaboration each term is used to describe equal but also differing objects. For example, R&D is indiscriminately referred to as system, organization, and element. Financial influences are equally described as elements, systems or sub-systems. As a result, all descriptions, conceptions, and assumptions are vague and can hardly be applied without concrete examples. To address this problem, this thesis applies Lundvall's framework using more consistent terms. Figure 2 merges all related 'elements' (e.g. *internal firm organization* and *inter-firm relationships*) into a sub-system. The four resulting sub-systems are subordinated to the intersection of the national system and the system of innovation. They are theoretically interrelated among themselves and each other. The industrial sub-system is a 'layer' within the main intersection and differently interacts with each of the four aggregated sub-systems. This approach leads to a more consistent analysis.

It must also be stated that aside from these definitional issues, Lundvall's *NSI* fails to be systemic. Peter (2002) argues that the approach is 'systemic', because success only results from interaction

and that, for example, not only the amount of accessible R&D funds or of existing research institutes leads to success, but rather their 'interaction'. Merely labeling interrelations as systems or elements, however, does not at all result in a systemic analysis. Such would require the careful analysis of every single entity within the system, considering its position, role, and meaning for the whole system and the system's surrounding environment. Lundvall, however, describes unilateral relations and influences rather than systemic interdependencies. For example, he argues that the *public sector* and the *financial sector* are important in influencing R&D activities, but does not hint at reciprocal relations. This results in a linear and unconnected rather than an interdependent and cross-linked description. Although this is a very fundamental and conceptual weakness, it does not necessarily affect this description of the EPAC industry. The approach still provides a comparatively "holistic" (Edquist 2006:185) view on the innovation-related development of the EPAC industry, and since this study only attempts to use its analytical language, it is not a requirement that the framework be systemic.

Reviewing empirical applications of the *NSI* reveals problems similar to those of Porter's empirical contribution. The theoretical and empirical approaches are not congruent with each other. Most commonly, neither a systemic viewpoint is applied, nor is the real evolution of processes retraced. Country or industry characteristics are mostly loosely coupled to *NSIs*, and several of the theoretical aspects are omitted in empirical application. Analyses of concrete forms of interaction and differing innovation-influences related to technology receive scant attention. The contribution of Gu and Lundvall (2006) further shows that sometimes the most important aspects of learning and knowledge flows are superficially summarized by statements like "the central theme for the reform was to rearrange the relationship between knowledge producers and users and their relationships with the government" (Gu and Lundvall 2006:14). Unlike the criticism of Porter's framework, the diverging empirical investigations of the *NSI* might result, at least partially, from the different conceptual nuances of varying theoretical contributions and the framework's openness. This study aims to avoid these criticisms through a more cautious application of the theoretical framework and satisfies the need to identify required data by operationalizing the data from different case studies. While previous empirical applications of the *NSI* include little emphasis on innovation and 'success-factors' other than quantitative figures on patents and R&D expenditure this study counteracts that by subjectively investigating further 'success-factors'.

Additionally, Lundvall does not consider the influences of spaces for learning on the constitution of a *NSI* or its sub-systems. The introductory Chapter, however, states that an EPAC's production cycle is related to a trade fair where dealers seasonally order their products. Accordingly, they seem to acquire new knowledge about the product- or technology-related development at such trade fairs. Therefore, the potential influence of places or spaces for learning are considered in the EPAC industry's description as necessary.

Finally, Kaiser and Prange (2004), as well as Balzat and Hanusch (2004) argue that institutional patterns receive too little attention in this approach. Lundvall does consider the *public sector* system's impact on processes of innovation and R&D, but as no research approach is all-embracing, his main focus is on the aspects of innovation and learning rather than on institutional settings, which is why this criticism is accurate.

The *NSI* is a suitable complement to Porter's (1990) *diamond* for cautiously investigating innovation-related aspects and several related structural-organizational and institutional-regulatory backgrounds. It is not, however, suitable to generally investigating institutional-regulatory forces on national industry development and idiosyncratic national conditions (Zhang 2012). Thus,

another framework is introduced in Chapter 3.3 to conscientiously answer this part of the research question.

3.3 *SOCIAL SYSTEM OF PRODUCTION*: INSTITUTION, REGULATION, COORDINATION

Chapters 3.1 and 3.2 reveal that the complementary applications of the two preceding frameworks have not sufficiently considered the institutional-regulatory backgrounds of industry development.

In contrast to *diamond* and *NSI*, the *SSP* is "very much concerned with identifying the various institutional mechanisms [namely markets, hierarchies, associations, networks, communities, or the state] by which economic activity is coordinated, with understanding the circumstances under which these various mechanisms are chosen, and with comprehending the logic inherent in different coordinating mechanisms" (Hollingsworth and Boyer 1997a:i). Thereby the *SSP* aims to understand the behavior and performance of contemporary capitalism. The framework considers wide-ranging institutional-regulatory aspects that support answering the research question.

Complementing the *diamond* and *NSI* with this approach is sensible for additional reasons:

(1) Like *diamond* and *NSI*, this approach is considered a framework (Hollingsworth 2000).

(2) Although the *SSP's* aim is to explain contemporary capitalism generally, industry development plays a pivotal role in approaching this. For example, Germany's traditional industries and their structures and organization are highlighted to explain the German 'version' of a *SSP* (Hollingsworth 1997). An approach that focuses on a national surrounding, but embeds the investigation of industry development within this national approach aids the analysis of EPAC-related regulatory and institutional peculiarities.

(3) Even though, the framework has barely been applied over time, it recently has received attention for empirical investigation of nations and industrial coordination within nations (e.g. Moszyński 2015, Staab and Nachtwey 2016).

(4) The *SSP's* theoretical ideas can be recognized in plenty of recent approaches. It forms the basis of other comparable frameworks such as *national production systems*, *social systems of innovation and production*, *social structures of accumulation*, *varieties of capitalisms*, *comparative institutional analysis* or *vintage regulation* (Bathelt 1994, Amable 2000, Lundvall and Maskell 2000, Hall and Soskice 2001, Boyer 2005, Hayter and Patchell 2011). These frameworks, however, are narrower in scope, and either neglect the institutional dimension, focus only on markets as key institutions, remain fragmented and unintegrated, exclusively compare different economies, or are represented as econometric models. They only consider the role of governmental influences, or the embeddedness of single institutional mechanisms, actors, or transactions. Despite these more recent theoretical approaches, the *SSP* remains the most comprehensive framework considering institutional-regulatory backgrounds, and is therefore appropriate for application in this thesis.

(5) Employing a comprehensive framework like the *SSP* is suitable for the EPAC case because the industry is affected by the coordination of associations, supplying relations, and governmental regulations (Ch. 1). The *SSP* clarifies in which way these and further modes shape the industry development.

(6) Finally, the approach addresses previously mentioned research gaps. It allows a comprehensive and rigorous analysis, is a "narrative" (Moszyński 2015:2) approach that contains qualitative and

quantitative information, and traces history patterns. Furthermore, it can be used as a tool to grasp the embedded and dynamic socio-institutional dimensions (Schamp 2000) of the industry's development.

Reflecting on the omissions of the *diamond* and *NSI* and the aim of this research, the *SSP* offers a purposeful and complementary description. The following section introduces it in greater detail.

CORE IDEAS

The fundamental argument of Hollingsworth and Boyer (1997a) is that different economic coordination mechanisms together place constraints on the defined needs, preferences, and choices of economic actors. Those interact within a *SSP*[6], which is defined as "the way that the following institutions or structures of a country or a region are integrated into a social configuration: The industrial relation system, the system of training of workers and managers; the international structure of corporate firms; the structured relationships among firms in the same industry on the one hand, and on the other firms' relationships with their suppliers and customers; the financial markets of a society; the conceptions of fairness and justice held by capital and labor; the structure of the state and its policies; and a society's idiosyncratic customs and traditions as well as norms, moral principles, rules, laws and recipes for action […]. All these institutions, organizations, and social values tend to cohere with each other, although they vary in the degree to which they are tightly coupled with each other into a full-fledged system" (Hollingsworth and Boyer 1997b:2, Hollingsworth 1998:485ff.).

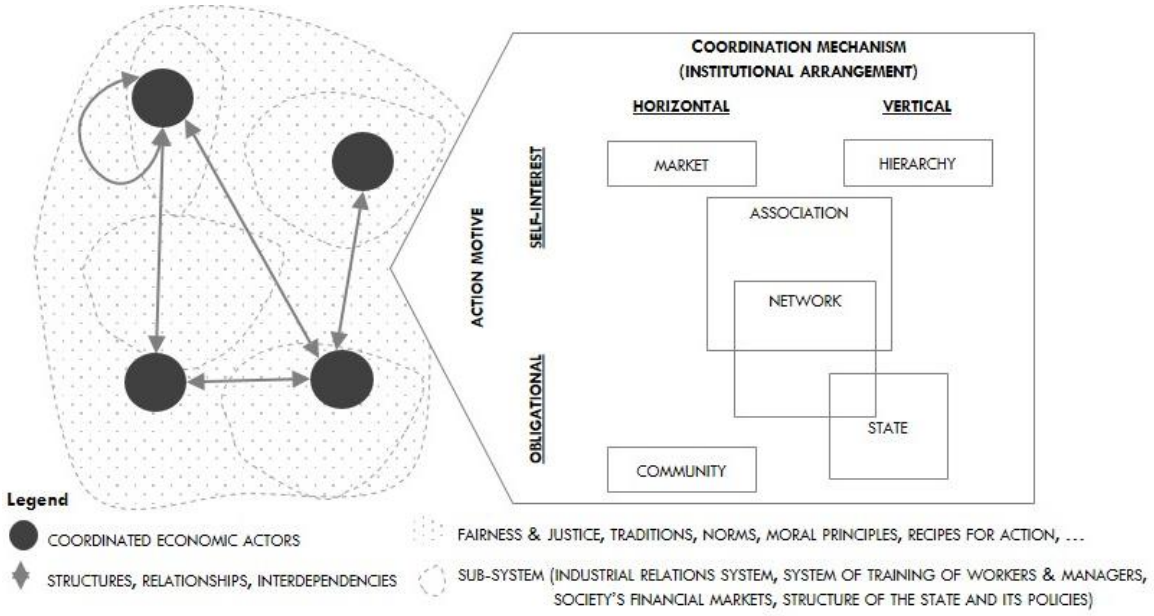

Figure 3: SKETCH – *INSTITUTIONAL ARRANGEMENTS* AND *SOCIAL SYSTEMS OF PRODUCTION*
(source: author's elaboration, partially based on Hollingsworth and Boyer 1997a)

[6] In general, a *production system* is characterized by an input-output structure (sets of production units of different sizes, linked together), a governance structure (power and authority) and a territorial boundary (Storper and Harrison 1991).

SSPs evolve because the actors and institutions are embedded into a culture, "in which their logics are symbolically grounded, organizationally structured, technically and materially constrained, and politically defended" (Hollingsworth 1998:485). Individual actors and organizations such as producers, suppliers, researchers, or labor, transact in order to develop, produce, and distribute goods or services. In transacting, actors must solve various problems, for example, determining output quantity, establishing prices, or communicating information about product quality to consumers (Hollingsworth and Boyer 1997b). The different coordination mechanisms provide the actors with vocabularies and logical frameworks for pursuing their goals, defining what is valued, and shaping the norms and rules by which they abide (Hollingsworth 1998).

Economic coordination occurs along two axes: One spatial-territorial and one economic-sectoral (Hollingsworth 1998). The coordination modes can be distinguished into a self-interested agent and a more sociological viewpoint (Fig. 3), depending on which obligations to and compliance with social rules are the guiding principles shaping human action. Further distinctions can be made along a horizontal and vertical axis. At one extreme, horizontal coordination takes place when many and equal agents interact. At the other extreme, inequality in power results in asymmetric coordination (Fig. 3).

The market coordination occurs when transactors remain autonomous, each actor representing his interests. Prices are regulated through contracts so that no further interaction is required. It is organized by free entry and exit and bilateral or market place exchanges.

Communities are based on trust, reciprocity, or obligation, and oppose the market on the horizontal axis. Informal memberships evolve over long periods of time and voluntary exchange occurs based on social solidarity and a high degree of trust. Moral principles and social norms are individual and collective means of compliance.

Along the vertical axis, actors joined within an organization or a firm are highly integrated in a hierarchical arrangement. Such occur in complex organizations which tend to become bureaucratic and are restricted to members. Exchange occurs based on asymmetric power and bureaucratic rules. Members are socialized into corporate cultures, and sanctions and asymmetric power are used as means of compliance.

Associations, networks, and state intervention are necessary to enforce rules for transacting patterns. Associations are formal organizations with reputational effects. In contrast to all other coordination mechanisms, they predominantly coordinate actors engaged in similar activities. Collective means of compliance are characterized by some degree of compulsion and partially private administration.

Networks are organized by semi-formal memberships and bi- or multilateral exchanges. Exchange happens on a voluntary basis over a specific period of time. It is characterized by resource dependencies and contractual bonds. Furthermore, personal relationships and trust built outside the economic arena shape the networks' constitutions.

The state is the coordinating mechanism which sanctions and regulates the other mechanisms. Simultaneously, it can also be an economic actor by engaging directly in production or exchange relations. It is also a public hierarchy, with unilateral action and indirect and global political and economic exchange. Its collective means of compliance are coercion and social rules of norms.

Together, these mechanisms shape an *SSPs* constitution. An explanation of how to analyze this, required data, and methods for data collection, however, is not provided in Hollingsworth's and Boyer's (1997a) publication. Partially, these can be derived from Hollingsworth's (1997) empirical

application of the framework. As one of three examples, he analyses Germany's *SSP*. This is introduced below.

EMPIRICAL APPLICATION

Hollingsworth describes the German *SSP* in connection with traditional industries. His description is structured by focusing on financial markets, business associations and trade unions, the system of training for labor and management, the industrial relations system, the structure of firms and their relationships with suppliers and customers, and the role of the state.

Narratively describing the coordinative structures and interrelations of these thematic bundles, Hollingsworth (1997) reveals that the German *SSP* is a *diversified quality system of production*. It includes a high degree of social peace, a workforce that is highly trained, a flexible labor market, a relatively high level of worker autonomy, a financial system with close ties between large firms and banks, as well as a high degree of stable and long-term relationships between assemblers and their suppliers. Collective institutional arrangements are of particular importance, because they link together economic actors with relatively high levels of trust (ibid.).

Similar to Porter's *diamond*, however the description does not get to the heart of the explanation and reads like a narrative rather than an analysis. Further important weaknesses are critically reflected below to show how the framework can still be purposefully applied.

CRITICAL REFLECTION

The *SSP* is barely discussed, applied or criticized by scholars other than Hollingsworth himself (e.g. Hollingsworth 1998, Hollingsworth 2000). However, this does not mean that it is free from criticism.

The perhaps most obvious weaknesses of the approach are the missing definitions, the high theoretical complexity, and the difficulties in empirical application. For example, the authors define a *SSP* by the enumeration of several "institutions or structures," which in turn are not defined (Hollingsworth and Boyer 1997b:2). Similar difficulties occur regarding coordination mechanisms, which are also labeled as "institutional arrangements." Occasionally, there is a reference to "institutional arrangements of economic coordination mechanisms." As the theoretical core focus is meant to be on institutional coordination, its explanation and definition must be the framework's indispensable prerequisite. Instead, the authors neither define, nor stringently use the terms introduced. This thesis avoids definitional issues by focusing on the investigation of the well-defined coordination mechanisms influencing the EPAC industry: Framing conditions, *financial markets, industrial relations system, system of training of workers and managers* and the *structure of the state and its policies*. Similar to the application of Porter's framework this thesis aims to provide a more 'analytical' rather than narrative industry description in order to maintain the description's scientific character.

Relating *production systems* to socio-institutional aspects of economies is a sensible but highly complex idea. This complexity might be one reason for the non-existence of diverse empirical applications. As Hollingsworth (1997) himself illustrates, the application of the *SSP* is only possible if some of the contexts introduced in theory are simplified. This thesis addresses these issues by approaching the EPAC industry as embedded into Germany's *SSP*. This eases the assessment of

the framework, since it can rely on Hollingsworth's (1997) elaboration. Based on his pre-structured arguments the characteristics of the EPAC industry can be emphasized as theoretically intended.

Comparable to criticism of Lundvall's work, it must be stated that although the *SSP* is also called a systemic approach, it does not fulfill the requirements of being systemic in the last instance. While it is much more detailed and enhanced considering elements, relations, and sub-systems, the systemic complexity cannot be maintained in empirical application. Yet once again, it can be argued that this weakness does not hamper describing the EPAC industry, because such requires a far-reaching description but not explicitly a systemic one.

Finally, Hall and Soskice (2001) criticize the consideration of institutions as still insufficient. They, however, refer to institutions as influencing organizations rather than 'rules of the game'[7]. Accordingly, this criticism is not as significant in this case, because the two preceding approaches already focus on various important structural-organizational peculiarities. By viewing the three theoretical frameworks as complementary, this shortcoming ultimately does not carry weight.

Therefore, the combination of *diamond*, *NSI*, and *SSP* is particularly suitable for answering this thesis' research question. This is compared, contrasted, and summarized in Chapter 3.4.

3.4 INTERIM CONCLUSION: REFLECTIONS ON THE FRAMEWORKS' COMPLEMENTARITY

Based on this thesis' research question and the fact that no all-embracing procedure to approach the question exists, a more comprehensive analytical frame is required to provide a theoretical language for guiding this thesis' analysis. The literature argues for the implementation of different approaches, complementing each other. To result in a 'greater' validity (Bryman 2006) of the findings and to capture a more complete and contextual portrayal of the units under study, Denzin (1989) points to the value of utilizing different theoretical approaches.

The analytical frame developed for this thesis thus contains three theoretical frameworks, complementing each other in various respects, that have not been jointly applied in case studies before. The *diamond*, the *NSI*, and the *SSP* (Tab. 1) are chosen as representatives of traditional approaches for investigating competitive advantages of industries and nations.

Of course other theoretical approaches could also have been applied (De Vaus 2001) to explain the German EPAC industry's development. For example, approaches such as *related varieties*, *varieties of capitalism*, *regulatory theories, history friendly models* or ideas introduced by scholars such as Van de Ven and Garud (1989) seem likely alternatives. In the context of this study, however, the application of such approaches would bring several disadvantages. *Varieties of capitalism* or *regulatory* approaches typically compare the diversities of contemporary economies. Approaches such as *related varieties* support the analysis of regional economic structures and the complementarities of economic sectors. Such aspects, however, are either not questioned or almost covered by one of the chosen approaches (e.g. Porter's emphasis on *related and supporting industries*). Other approaches in turn only emphasize quantitative explanations and omit spatial specificities or other important aspects. Chapter 3 discussed in depth why the combination of the exact three selected frameworks (Tab. 1) is particularly suitable for this thesis.

[7] Nevertheless, a general problem in theoretical research related to institutional settings is the identification of what kind of research object is really addressed by the term "institution".

Table 1: CONTRASTING *DIAMOND, NSI*, AND *SSP*
(source: author's elaboration)

	PORTER (1990)	LUNDVALL (1992B)	HOLLINGSWORTH AND BOYER (1997B)
		theory related	
QUESTION	why do countries succeed in particular industries; why do certain nations provide an environment where to innovate better; why a nation becomes a more desirable home base for competition	how nations become internationally competitive; which potential effects of relations between firms or sectors within the domestic economy on innovation and learning; which impact of this on international competition	how economic institutions are structured; how contemporary capitalism behaves and performs
EXPLANATORY AIM	industrial competitiveness	national competitiveness	comparative advantage of nation
FUNDAMENTAL THOUGHT	nation provides advantageous environment for successful firms	knowledge is most fundamental resource for innovation and competitiveness; learning is most important process	economic coordination mechanisms place constraints on the definition of needs, preferences and choices of economic actors
ORIGINAL FOCUS	industry in nation	nation [+ industry in nation]	nation
VIEW	interrelated	pseudo systemic	pseudo systemic
OBJECTS	*firm strategy, structure, and rivalry*; *demand conditions*; *factor conditions*; *related and supporting industries*; chance; government + their interrelations	*corporate sub-system*; *public sector sub-system*; *financial sub-system*; *R&D sub-system* + learning and knowledge flows amongst them	*society's financial markets*; *industrial relations system*; *system of training of workers and managers*; *structure of state and its policies* + their coordination modes + social environment
EXPLICIT METHOD	none (verbal description)	none (verbal description)	none (verbal description)
ANALYTICAL LEVEL	framework	framework	framework
ANALYTICAL PROCEDURE	retracing development of an industry, by description of all attributes	description of various influences on the single attributes	description of various influences on the single attributes and their coordination mechanisms
CONCLUSION	unconcrete; only summary of all descriptive parts	unconcrete; only summary of all descriptive parts	unconcrete; only summary of all descriptive parts
WEAKNESS	application: chaotic, unrelated, inconsistent, incomplete	application: chaotic, unrelated, inconsistent, incomplete	application: inconsistent, incomplete, simplified
	theoretic: definitions, method, source of advantage, institutions, innovation	theoretic: definitions, vague concept, method, no system, spaces of learning, institution	theoretic: definitions, high theoretic complexity, method, no system
UNIQUENESS	first that widens traditional location choice toward contexts and dynamics; first view on nat. industrial advantage	learning at the center of *national innovation system*	institutional view with coordination and regulation, considering societal idiosyncrasies
ACTUALITY	frequently applied; basis for other concepts	frequently applied; basis for other concepts	few but recent application
THEORETICAL DEVELOPMENT	relies on original objectives and main thoughts	relies on original objectives and main thoughts	relies on original objectives and main thoughts
COMPARATIVE SUPERIORITY	more comprehensive	more comprehensive	more comprehensive

	PORTER (1990)	LUNDVALL (1992B)	HOLLINGSWORTH AND BOYER (1997B)
		thesis related	
RELATION TO QUESTION	structural-organizational	innovation-related; [related institutional-regulatory + structural-organizational]	institutional-regulatory; [related structural-organizational]
CONTRIBUTION TO GAPS	comprehensive; historic and dynamic; qualitative; nation	comprehensive; evolutionary; qualitative; nation; institution; knowledge; learning	comprehensive; historic; qualitative; nation; institution
	together all three as comprehensive and rigorous; an industry study; on EPACS		
EPAC-FIT	*related and supporting industries*; structure and strategies of players; high demand	EPACs technological setting; pressure to innovate; SMEs access to finance; role of government	types of coordination
ANALYTICAL FOCUS	national industry	national industry as *NSI* sub-system	national industry embedded into German *SSP*
ANALYTICAL PROCEDURE	German printing press industry as blueprint; more structured	no single blueprint; more structured, reflected and cautious	no blueprint but embedded into German *SSP*; more structured, reflected and cautious
CRITIQUE REACTION	more structured; operationalization based on empirics	more consistent terms; spaces for learning; more cautious application; operationalization based on empirics	simplification according to originator; operationalization based on empirics

Porter's *diamond* (Tab. 1) is chosen as the analytical starting point. It investigates in which national environments and due to which industrial structures competitive advantage can be generated. It is the narrowest of the three frameworks, because it 'only' allows investigating industrial organization and diverse interrelated industry-structures within a country.

As a second framework, the *NSI* is chosen (Tab. 1) to be applied subsequently to the *diamond*. It is a broader approach, kept more open and flexible. It emphasizes "interactive learning anchored in the production structure and in the linkage pattern of the system of production" (Lundvall 1992b:17). Thus, the *NSI* allows investigation of innovation-related backgrounds and the related institutional and structural-organizational peculiarities of a developing industry or nation. Compared to the *diamond*, it must be stated that while Porter emphasizes the structures and organization of a national industry setting, the *NSI* points to the knowledge-generating processes within nations. This clearly distinguishes both approaches. Nevertheless, both use a similar vocabulary for their investigations and Lundvall (1992b:17) argues that "basic elements overlap, but their ordering is different." This enables the relating of findings from both applications to each other.

The analytical frame of this study is completed by the *SSP*, which puts focuses on the organization of economies and economic interaction (Tab. 1). It allows the identification of national institutional-regulatory aspects and their related organizational-structural peculiarities. As Boyer and Hollingsworth (1997:50) argue that an analysis could focus on the "coexistence of alternative types of coordinating mechanisms in the same product market area," it also allows the emphasis of specific EPAC-related insights. In relation to *diamond* and *NSI*, the approach can be regarded as framing the others on an even broader level. The other way round, *diamond* and *NSI* can be understood as somehow embedded into Germany's *SSP*, because the *SSP* emphasizes the institutional forms of coordination and regulation that result in the *diamond*'s and *NSI*'s structures, interrelated entities and innovations.

To avoid an undifferentiated combination of the different theoretical approaches as seen in Ahn and York (2011), a careful clarification of the way in which *diamond*, *NSI*, and *SSP* can be used together (or not) is necessary before commencing their empirical application. The approaches can be used together to the extent that they independently provide viewpoint-specific answers to parts of the research question, which can ultimately be discussed on a shared empirical level. Since this study aims to integrate three frameworks, and not, for example, a framework, a theory, and a perspective, it is relatively easy to link the findings, as all frameworks attempt to provide 'holistic', 'systemic' or interrelated views. Together these three frameworks enable a closely-knit description of the German EPAC industry and its structural-organizational, innovation-related, and institutional-regulatory backgrounds and aid the exploration of 'success-factors'. As frameworks, however, none points to concrete results or conclusions. This particularly suits an open-ended investigation of the EPAC industry by not pre-determining the results. Unfortunately, it also requires more analytical effort to come to several conclusions on how the EPAC industry developed successfully. But apart from this additional expense, the frameworks' joint application addresses the research gaps outlined in Chapter 2: They provide comprehensive and rigorous descriptions; they contain qualitative information; they emphasize historical aspects and dynamic patterns; they incorporate national settings, institutional, regulatory, and knowledge-related aspects. To avoid diluting the frameworks' scale- and viewpoint-specifics, however, they cannot simply be merged into one broad and comprehensive description. A theoretically justifiable complementary combination is only possible when the approaches are clearly distinguished and thus subsequently applied, thereby maintaining the frameworks' unique terminology. For example: Porter questions the success of industries within nations, whereas Lundvall examines national competitiveness in general. Hollingsworth and Boyer, in turn, explicitly aim to understand comparative advantages. Accordingly, the approaches originally focus on different scales. As required by the research question, their terminologies differ as well. While they consider the same elements (as already mentioned by Lundvall 1992b) and objects of investigation, which eases the relation of different findings to the industrial setting later, each framework approaches such objects from its unique viewpoint. Considering corporate aspects as an example, the *diamond* focuses on an industry's firms' strategic and structural relations in general. The *NSI* emphasizes innovations resulting from corporate developments, inter-firm partnerships, etc., while the *SSP* emphasizes the ways in which such relationships and structures are coordinated and regulated within the investigated economy. Considering these constraints and requirements, the complementary combination of *diamond*, *NSI*, and *SSP* best suits the purpose of this study and can be realized as visualized in Figure 4.

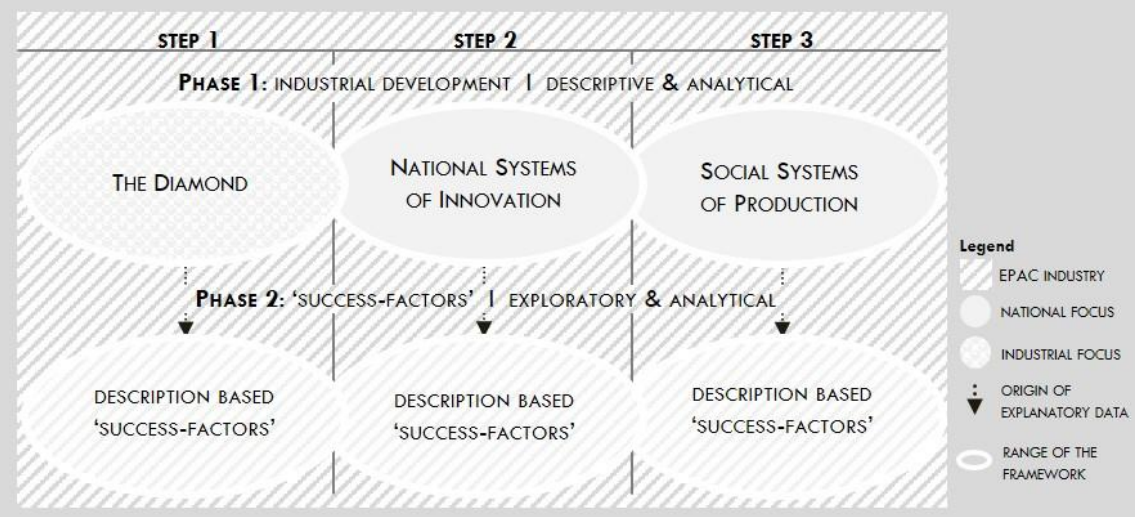

Figure 4: THEORETICAL FRAMEWORKS EMBEDDED INTO THE EPAC CASE STUDY
(source: author's elaboration)

Applying three frameworks to the empirical setting requires different data. Which data to collect, how to collect it, or even how to prepare and analyze it to obtain an appropriate application is not prescribed by any of the frameworks' originators (Tab 1). Therefore, a suitable approach for data collection as well as strategies for preparation, utilization, and analysis is developed and introduced in Chapter 4.

4 METHOD: TOWARD IMPLEMENTING THE ANALYTICAL FRAME

Applying the theoretical frameworks' terminologies guides this study's industry description and frames the affiliated exploration of 'success-factors' to answer the research question. This objective requires a differentiated methodical approach which also considers the methodical aspects of the aforementioned research gaps. To further provide "transparency to enable scrutiny of [the] combinations of research methods, designs, data, techniques and analytical frameworks" (Pike et al. 2015:17), Chapter 4 puts its emphasis on developing a methodical approach for implementing the three frameworks in this case study. The frameworks' originators do not specify data requirements, nor do they explain how to gather, prepare, or utilize data. Untangling their exemplary applications (Ch. 3), however, enables a rough operationalization of required data (Ch. 4.1). This can be collected by desk researching statistical or qualitative information and by conducting guided expert interviews (Ch. 4.2). To produce empirical descriptions as exemplarily introduced in Chapter 3, the data is analyzed following the ideas of qualitative content analysis (Ch. 4.3). Chapter 4.4 summarizes the fit of the methodical and analytical frame for this study.

4.1 DATA OPERATIONALIZATION

Reviewing the three frameworks' application examples offers clues to which empirical circumstances can be assigned to the respective theoretical contents. For each framework, general variables can be identified (Schnell et al. 2013) and operationalized. Those are outlined in three operationalization tables that also consider how the different kinds of data can be collected. In

comparison with other empirical studies applying the frameworks, the operationalizations are verified and adjusted. Most variables can be only vaguely characterized and present more of a theoretical orientation for data collection than tangible operationalizations. This is grounded in the omissions of specifying required data and the framework's inconsistent translation from theory into practice (Ch. 3). In order to reasonably apply the frameworks for empirical analysis, the application examples reviewed in the preceding Chapter serve as 'blueprints' for the empirical investigation.

In his empirical application of the *diamond* to the German printing press industry (Ch. 3.1), Porter indirectly operationalizes the *diamond*'s four main attributes as well as governmental influences, chance events, and framing conditions as indicated in Table 2.

Table 2: OPERATIONALIZATION OF FRAMEWORK I: *DIAMOND*
(source: author's elaboration)

DIAMOND'S ASPECT	OPERATIONALIZATION*	DATA COLLECTION
FRAME	industrial evolution and history	Ch. 5.1
	cultural influence	qual. secondary
GOVERNMENT	development plans, branch specific policies and reforms tax reduction/adoption substitutions and other investments technology and innovation policies	qual. secondary
	education, training and research facilities	qual. primary/secondary
FACTOR CONDITIONS	human resources quantity of employees education of employees	quant. secondary, qual. primary/secondary
	physical resources access to branch-specific resources	qual. primary/secondary
	knowledge resources (science, technology, market) research facilities market reports	qual. primary/secondary
	capital resources amount and cost of capital to finance industry national exports and international trade	qual. primary/secondary, quant. secondary
	infrastructure	qual. secondary
DEMAND CONDITIONS	demand market structure composition of home demand market growth national willingness to pay	quant. secondary
	sophisticated demand consumer background demanded goods/demand segmentation purchase criteria	qual. primary, qual./quant. secondary
RELATED AND SUPPORTING INDUSTRIES	formal alliances and joint ventures	qual. primary/secondary
	influence external industries	qual. primary/secondary
FIRM STRATEGY, STRUCTURE, RIVALRY	production strategy	qual. primary
	organizational firm structure	qual. primary/secondary
	interrelation and cooperation	qual. primary/secondary
	levels of rivalry	qual. primary/secondary
CHANCE	breakthrough in basic technology	qual. primary/secondary
	external political development	qual. secondary
	major shift in foreign market demand	qual. primary/secondary

* this table is based on Porter (1990) and is edited and verified by insights of Bridwell and Kuo (2005), Kasperk et al. (2010), Öz (2002), Weerathamrongsak and Wongsurawat (2013)

In contrast to Porter's own application of the *diamond*, the *NSI* is differently translated into empirical content (Ch. 3.2) by different scholars. Empirical studies focus on different settings and variables and are therefore structured differently. This might result from Lundvall's (1992b) aspiration to keep the framework open and flexible. Thus, however, no single empirical elaboration can serve as a 'blueprint' for the EPAC industry's investigation. Rather, all investigations provide supplementary details to each other's description. Therefore, the description of the *NSI*'s EPAC sub-system is operationalized on a supra-blueprint level that joins the indirect operationalizations of different empirical studies as pictured below:

Table 3: OPERATIONALIZATION OF FRAMEWORK II: *NSI*
(source: author's elaboration)

***NSI*'S ASPECT**	**OPERATIONALIZATION***	**DATA SOURCE**
FRAMING CONDITIONS	national and industrial history	Ch. 5.1
	institutionalized patterns of behavior	qual. primary/secondary
ELEMENTS	public sector-system public actors political funding of research laws and approval procedures technology and innovation policies	qual. primary/secondary, quant. secondary
	corporate system amount and segmentation of players internal structures	qual. primary/secondary
	financial system funds flow for innovation availability of venture capital technology commercialization finance of science and R&D patterns of industry financing financial markets and business start-ups	qual. primary/secondary, quant. secondary
	R&D system influence and structure of industrial research influence and structure of university research degree of commercial orientation	qual. primary/secondary
RELATIONSHIPS, FEEDBACKS, REPRODUCTION (learning and innovative capacity)	technological accumulation in related sectors	qual. primary/secondary
	formal and informal knowledge exchange forms of product- and process-optimization joint ventures, networks, alliances for innovation forms of search-solution processes levels of intra- and inter-firm interaction user's involvement in innovation linkages with foreign research institutions	qual. primary/secondary, quant. secondary
	capital flows and funding	qual. primary/quant. secondary
	utilization of foreign technology	qual. primary/secondary
EXEMPLARY PERFORMANCE INDICATORS	product trade	quant. secondary
	patents	quant. secondary

* this table is based on Lundvall (1992a, 1992b), Kaiser and Prange (2004), Bartholomew (1997), Allen (2009), Umemura (2014), Keck (1993), Grupp et al. (2002), Polt et al. (2010), BMBF (2016a) and Yeh and Chang (2003)

Finally, Hollingsworth (1997) considers very general variables for the description of the German *SSP*. He describes the 'institutions and structures' and their modes of coordination by using empirical data as visualized in Table 4:

Table 4: OPERATIONALIZATION OF FRAMEWORK III: *SSP*
(source: author's elaboration)

SSP'S ASPECT	OPERATIONALIZATION*	DATA SOURCE
FRAMING CONDITIONS	technology of the product complexity, quality	qual. primary, qual./quant. secondary
	culture, structure of civil society, social values customs traditions shared beliefs norms rules laws moral principles recipes for action, expectations degree of social peace	qual. primary
INSTITUTIONS AND STRUCTURES	society's financial markets quality or price competition size, structure, influences	qual. primary/secondary
	system of training of workers and managers vocational training facilities public education	qual. secondary
	industrial relations system relations between banks, firms, customers, suppliers, unions, associations	qual. primary/secondary
	structure of state and its policies substitution and regulation policies	qual. primary/secondary
COORDINATION MECHANISMS	markets	qual. primary/secondary
	communities	qual. primary/secondary
	networks	qual. primary/secondary
	associations	qual. primary/secondary
	private hierarchies	qual. primary/secondary
	state	qual. primary/secondary

* this Table is based on Hollingsworth's (1997) and is added and verified by insights of Hollingsworth's and Boyer's (1997) and Moszyński's (2015)

To gather the data visualized in Tables 2-4, a suitable method for data collection is required. This is presented in Chapter 4.2.

4.2 DATA COLLECTION AND PREPARATION

The three Tables presented in Chapter 4.1, as well as the publications reviewed to generate them, indicate that the required data are either qualitative or quantitative and can be collected from primary or secondary sources. Some of the publications emphasize particular methods for data collection. For example, Polt et al. (2010), or Weerathamrongsak and Wongsurawat (2013) research the *diamond* and the *NSI*, based on personal interviews, surveys, strategic documents, development plans, or statistics. Other scholars who research industry development use different kinds of data triangulation and research on interview data, strategic documents, or statistics. The combinatory use of different data sources in the study of the same phenomenon (Jick 1979, Scherer 1970) aims to compensate strategic weaknesses, causes of errors, or other disruptive elements (Schnell et al. 2013). The combination of qualitative and quantitative data results in a stronger credibility and integrity of the findings (Bryman 2006) and "extend[s] the breadth and range of enquiry" (Greene et al. 1989:259).

According to the already established research procedures related to the frameworks, it is initially attempted to collect as much relevant data as possible by desk research of secondary sources. Gaps in data are supplemented by gathering further information from primary sources. The following section introduces this procedure in detail and critically evaluates it against the background of the EPAC industry as research object.

SECONDARY DATA COLLECTION

Quantitative data. Statistical data is gathered to retrace growth rates (*diamond*), patents (*NSI*), development figures of associations (*SSP*), and other quantitative information. Such statistical data is obtained from the Federal Statistical Office (*destatis*), the European Statistical Office (*Eurostat*), the United Nations Statistics Division (*INDSTAT*), the German and European bicycle associations (*ZIV* and *COLEBI*), and other providers of statistical data. However, the availability of such EPAC data is very limited. Almost no data on EPACs were collected before the year 2007, due to of the industry's insignificance. Even after the beginning of data collection, most data are only available on aggregated levels such as detectable in *NACE* or *WZ* classifications. Exclusive EPAC data is limited to figures on import, export, production, and sales (App. B). Apart from that, only limited and incomplete information about model-shares, brand-shares, patents and other data exists. Additionally, not all data are available for the same time spans, which lowers the potential for comparisons. Data on equal variables offered by different databases further vary regarding the concrete statistical numbers. Even within the industry these gaps in statistical data are well-known and recognized as problematic for future planning (I 2.10). Taken together, this results in a limited database for analyzing the industry's development. This impedes the statistic traceability of the detailed development.

Qualitative data. Qualitative secondary data is collected to describe developmental aspects such as political development plans (*diamond*), Germany's financial system, or research and education standards (*NSI*, *SSP*). It contains documents such as documented enterprise strategies or statutory sources and includes all information gathered from the internet, policy reports, or news broadcasts and agencies (e.g. Kasperk et al. 2010). Documents are communication tools that are authored for a specific purpose. They set laws, rules, or guidelines (e.g. relevant for *SSP*), but are limited in their ability to trace processes (Flick 2009). The analysis of such qualitative secondary information is regarded as a supplementary strategy to other forms of data collection (ibid.). Regarding the EPAC industry and the German industry location, such data are infrastructural development plans, enterprise websites, trade journals, online articles, associational news, and federal websites.

In sum, however, not all data required can be gathered from secondary sources. Thus, primary data collection as introduced below is required for a detailed industry analysis.

PRIMARY DATA COLLECTION

Qualitative primary information is required to address the remaining gaps in data. Information on firm strategies (*diamond*), learning environments (*NSI*), or shared beliefs (*SSP*), which are not, or only insufficiently, accessible by desk-research, can be gathered in interviews with actors who have specific industrial knowledge. The following sections thus introduce a procedure for such data acquisition and preparation.

Expert interview. Interviews with actors who have industry specific knowledge are called *expert interviews* and are often part of methodical triangulations (Meuser and Nagel 2011). In conducting

expert interviews, the aim is to carve out supra-individual industry knowledge (ibid). Experts are interviewed as representatives of specific action-fields. Although the term 'expert' is not clearly defined, it explicitly refers to the interview-partners' 'special knowledge', 'socially institutionalized expertise', and contextual knowledge (Pfadenhauser 2009, Meuser and Nagel 2011, Kaiser 2014). When conducting expert interviews, however, it is necessary to take the subjectivity of all gathered data into account. It only reflects subjective viewpoints and perceptions, which cannot be generalized. Experts are often selected in connection to their professions and can be diverse within industrial spheres. The EPAC industry comprises participants such as EPAC manufacturers, suppliers, dealers, and associations (Ch. 1). But also consulting, political or research facilities can influence the industry (Ch. 1 and 4.1). Accordingly, all involved actors and organizations can be subordinated to two broader categories. The *intra-industry*-category (II) reflects all industrial actors along the value chain. It is grouped into EPAC producers, EPAC component producers, and dealers. The *extra-industry*-category (EI) includes such actors whose occupations relate to EPACs on a non-industrial basis (Tab. 5):

Table 5: CATEGORIES' RELEVANT FOR THE EPAC INDUSTRY
(source: author's elaboration)

ORGANIZATION/ACTOR CATEGORIES	
INTRA-INDUSTRY: MAIN INTERVIEW PARTNER	**EXTRA-INDUSTRY: ADDITIONAL INTERVIEW PARTNER**
E-PRODUCTION	ASSOCIATION
E-DEALER	CONSULTING
E-COMPONENT-PRODUCTION	POLITICS
E-COMPONENT-DEALER	RESEARCH

Guiding questions. Expert interviews are often guided by thematic questions (Meuser and Nagel 2011). Such can be designed based on the theoretical background and the empirical object (Mayer 2009). They structure the interviews' course and allow the comparison of different answers. According to the contents of the three frameworks, the guiding questions for this thesis (App. B, Tab. 14), are divided into three thematic blocks. The first set of questions is related to the EPAC industry's development in general and Germany as a location. The second block of questions deals with firm developments and innovation. The last block focuses on institutional, regulatory, and coordinating environments. Since expert interviews enable the researcher to gather non-formalized knowledge, to clarify questions remaining from desk research and to validate and deepen findings (Kaiser 2014), two types of questions guide this thesis' interviews. Questions such as "Which have been the leading companies and important industrial actors?" validate desk-research's findings, for example, establishing which actors are particularly important. Questions such as "In case of technical questions or problems, whom do you ask for help? Why?" extend the researcher's empirical and non-formalized knowledge about the industry. All questions are non-suggestive, begin with "What happens if," "Take one exemplary […] and describe," "Who," "Why," "How," and attempt to encourage the respondent to elaborate. Additionally, the interviews are only guided by broad and semi-structured questions, which similarly allow the respondents to narrate (Marotzki 2011) and enable spontaneous reactions to the respondent's answers. Not every guiding question is asked in every interview. The questions are roughly categorized according to the type of interview partner (Tab. 5 and App. B, Tab. 12). Consistently asking the same broad set of questions, however, allows comparison of the interview results (Wessel 1996). This method of

primary qualitative data collection from industry-related actors is "more sensible than other survey methods to historical, institutional and strategic complexity" (Schoenberger 1991:180).

Pretests. The designed guideline for this study was pretested during five exploratory talks (Tab. 6). This allowed an iterative design of the guiding questions and increased the thesis' construct validity during data collection (De Vaus 2001, Gibbert et al. 2008). Constant improvements and adjustments of the guiding questions throughout the pretests, led to more tangible answers and reduced the risk of missing important contexts. The questions' comprehensibility was tested as well as the interviews' duration. All pretests took between 36 minutes and 153 minutes. Two were conducted on the phone, whereas three took place during personal meetings.

Population. To conduct suitable interviews, it is necessary to select the appropriate interview partners. Based on the categories visualized in Table 5, a total of 465 organizations and individual actors can be desk-researched as the sample's population, which can then be differentiated into the sub-populations as defined in Table 5. 200 industrial producers, located in Germany can be identified based on digital brand databases provided by the *German Patent and Trademark Office* (DPMA) and *greenfinder*, *e-bike-finder*, *ebike-base*, and *vcd e-Rad-Datenbank* (App. A, Tab.10-11). Those represent the sample's population of EPAC producers (Tab. 5). The dealer sub-population comprises all 235 *vsf.*-member dealers (dealer association *Verbund Service und Fahrrad g.e.V*) in addition to the five biggest German dealer chains of shops identified in the internet. Five association representatives, four researchers dealing with EPAC-research, ten political actors who work on infrastructural EPAC integration and ten consultants who are thematically experienced are identified based on internet research and exploratory talks. Some of those 465 actors and organizations operate within more than one category and must be regarded as hybrids.

Stratified sampling. Based on this population, the sampling's objective is to represent each classification type within the *intra-industry*-category twice, in order to omit the analysis of individual statements. At least one player from the *extra-industry*-category must be interviewed to validate and extend the statements of the *intra-industry*-actors. This sampling follows a stratified random sample. That means the population and its features are known in advance and the sampling procedure is a one-time event, following the fixed plan. The sample's size is predetermined and the sampling ends when the whole sample is investigated (Flick 2009, Schnell et al. 2013). Actors mentioned as especially important for the industry's development by the stratified randomly sampled interview partners, however, are systematically and selectively interviewed in addition. This choice of interview partner grants the authenticity of the main statements (Baxter and Eyles 1997). This statistical sampling (Flick 2009) results in the following interview structure:

Table 6: OVERVIEW – CONDUCTED INTERVIEWS
(source: author's elaboration)

SEQ. NO.	ACTOR CATEGORY	FIRM ORIGIN	DURATION	TYPE	QUOTE
	EXPLORATORY TALKS				
1.1	CONSULTING	DE	0:37h	phone	I 1.1
1.2	CONSULTING	DE	2:33h	personal	I 1.2
1.3	ASSOCIATION/POLITICS	DE	0:36h	personal	I 1.3
1.4	E-PRODUCTION	DE	0:57h	personal	I 1.4
1.5	RESEARCH/POLITICS	DE	0:52h	phone	I 1.5
	INTERVIEWS				
2.1	E-COMPONENT-PRODUCTION	DE	0:51h	phone	I 2.1
2.2	E-PRODUCTION/E-DEALER	DE	0:59h	personal	I 2.2
2.3	E-PRODUCTION	CH	1:54h	personal	I 2.3
2.4	E-COMPONENT-DEALER	JP	1:43h	personal	I 2.4
2.5	E-PRODUCTION	TW	1:34h	personal	I 2.5
2.6	E-PRODUCTION/CONSULTING/POLITICS	DE	1:12h	personal	I 2.6
2.7	E-PRODUCTION	DE	1:37h	personal	I 2.7
2.8	E-PRODUCTION/E-DEALER/E-COMPONENT-DEALER	DE	2:11h	phone	I 2.8
2.9	RESEARCH	DE	0:52h	personal	I 2.9
2.10	E-COMPONENT-PRODUCTION	DE	0:49h	personal	I 2.10
2.11	E-PRODUCTION	DE	2:06h	personal	I 2.11
2.12	ASSOCIATION/POLITICS	DE	0:58h	personal	I 2.12
2.13	E-PRODUCTION/E-DEALER	DE	1:12h	personal	I 2.13
2.14	E-COMPONENT-PRODUCTION/E-COMPONENT-DEALER	JP	1:17h	personal	I 2.14
2.15	E-PRODUCTION	DE	1:08h	phone	I 2.15
2.16	E-PRODUCTION/E-DEALER	DE	0:55h	personal	I 2.16
2.17	E-COMPONENT-PRODUCTION	DE	0:59h	personal	I 2.17
2.18	E-PRODUCTION	IN	1:05h	phone	I 2.18
2.19	E-PRODUCTION/E-COMPONENT-PRODUCTION	DE	1:03h	personal	I 2.19
2.20	E-COMPONENT-PRODUCTION	DE	1:23h	personal	I 2.20

In retrospect, the sampling encountered a few obstacles. One randomly selected *intra-industry* interview partner refused to participate for seasonal reasons. Regarding the *extra-industry* category, all interview requests to non-hybrid political actors remained unanswered. Two of the selectively planned interviews could not be realized, a market leader refused for a lack of time and an association representative did not show up. The final sample (Tab. 6) contains *extra-industry* experts, market leaders, niche suppliers, firms that collapsed and start-ups in their phases of market entry and afterwards. The *intra-industry* representatives also reflect diverse product segments. All 20 interviews took between 58 minutes and 132 minutes. Apart from four interviews, all data was gathered in personal meetings.

Data preparation. If agreed upon, the interviews[8] are voice recorded to completely process the data for the following analysis. Following the interviews, the voice records are completely transcribed by means of the computer program *F4* (App. B). The transcription is not reduced to single passages in order to take arguments of Robert Kaiser (2014) into account. He states that in case of partial transcriptions, such information could get lost that only become relevant in the broader context, not visible at the time of a single transcription. If interview respondents do not agree to voice recording, notes on their contents are taken (App. B).

[8] All interviews were conducted in German language. Only important quotes are translated as 'representative quotes'.

Finally, all data gathered through primary and secondary sources, are collected within one database that contains documents, statistics, and interviews. It is difficult to grasp all relevant actors, data, and information, because, as exploratory talks revealed the industry is strongly related to handcrafts and as little professionally organized. Nevertheless, the researcher's positionality throughout data collection partially counteracts this obstacle. Because of a personal affinity for the research topic and long existing technical and political background knowledge, the researcher is, with a certain distance, somehow personally related to the *community of practice* (Herod 1999). This eases communication and also results in the disclosure of sensitive information, because the researcher is perceived as a competent interlocutor. This mixture of distance and closeness to the field of investigation supports the collection of more extensive data, which is analyzed as presented in the following Sub-Chapter.

4.3 QUALITATIVE DATA ANALYSIS

This Sub-Chapter shows how the data operationalization, collection, and preparation leads to the analysis of all EPAC-related data according to the three frameworks. As these are verbal descriptions rather than econometric analyses, a qualitative approach to data analysis is required. This is inspired by Mayring (1995), who developed a procedure for systematic, rule-guided, and qualitative text analysis.

The *qualitative content analysis* "tries to preserve some methodical strengths of quantitative content analysis and widen[s] them to a concept of qualitative procedure" (2000:1). It emphasizes the reduction and categorization of empirical data as most important for qualitative analysis. Important data categories are developed based on theoretical approaches or empirical data (Mayring 1995). These categories can be regarded as translations of the research question into an evaluation scheme. Definitions, examples, and coding rules are generated for each such category to exactly determine under which circumstances a text passage must be coded. Text passages containing different thematic aspects, are subordinated to the developed analytical category system (Flick 2009). This automatically leads to an audit of the categories' completeness and, if necessary, to inductive adjustments. Using this procedure, the amount of data is reduced to passages relevant for the categories and accordingly, for answering the research question. Thus, not the inherent structure but rather thematic aspects of the text material are at the core of analysis, which is why the *qualitative content analysis* is related to the qualitative paradigm (Flick 2009). The text reduction in form of selective categorizations is conducted by the researcher and as such is a procedure guided by subjective valuations. Although other researchers might partially categorize the data differently, diverging procedures are understandable even to dissidents due to transparent definitions of the codes and logical reasoning. Additionally, including representative quotes in the data analysis provides the greatest possible transparency and traceability of analysis (Baxter and Eyles 1997). Such are defined as original quotes or other text passages that define and at the same time illustrate a category. An explication and validation of obscure interview statements follows the coding of all text passages. This is conducted as a qualitative validation, either by re-interviewing the experts, or by comparing the statements with other data. A paraphrasing of the categorized text passages follows, as well as the cross reference of interview statements to the theoretical approaches on a higher level of abstraction. In general, the validity of this kind of research is maintained due to the consideration of diverse and partially contrary interview statements (Eisenhardt 1989). To further maintain the categories' validity, Mayring (2000) finally demands other scholars verify all categories and subcategories.

The basic ideas of Mayring's procedure are applied in this study to utilize the gathered data. To ensure the content's validity, however, the procedure is adjusted to the specificities of the research question, the analytical frame, and the data requirements:

(1) Mayring's (2000) intended application of the procedure to the analysis of transcripts and other sorts of recorded communication. In the context of this study, however, not only transcripts but also political documents, market reports, statistics, and other data gathered from the secondary sources are considered and implemented.

(2) Mayring's procedure is adjusted in consideration of the descriptive and the exploratory part of the research question. Conducting a description of the German EPAC industry along the three theoretical frameworks requires a different approach toward category development than exploring the development's 'success-factors'. Thus, this thesis implements a deductive as well as an inductive approach toward category development. At first, a deductive category system (App. C, Fig. 28 category system A) following the three guiding frameworks is developed along the theoretical concepts (Kaiser 2014). Its structure follows the three operationalization tables presented in Chapter 4.1. Following Mayring's procedure based on these categories leads to a dense description of EPAC industry's development from the three differing viewpoints, supported by representative quotations (Ch. 5.2.1, 5.3.1, and 5.4.1). Immediately following each description is an attempt to explore the particularly identifiable 'success-factors' of development. Therefore, a second category system (App C, Fig. 28, category system B) is inductively developed based on each of the three preceding descriptions. Each description leads to the inductive identification of different success-influences. These are aggregated to overarching 'success-factors', which form the category system B (App. C, Fig. 28). The development of category system B leads to the application of Mayring's procedure a second time. As a result, each interview is ultimately coded six times, twice in relation to each framework. This indirectly provides a quality control mechanism, because potential omissions in coding can be identified during one of the other categorization procedures. However, because each framework resembles the others with regard to different content-related aspects, it is a challenge to differentiate which data and text passages should be subordinated to which theoretical framework. For example, interrelations regarding funds flowing for R&D must be subordinated to the *NSI*, whereas interrelations regarding the regulatory impact of funds flowing for R&D must be subordinated to the *SSP*.

(3) To maintain the categories' validity, Mayring (2000) calls for cross-checking by other experts. This cannot be satisfied within this study. To attempt to meet this demand, other studies applying the same frameworks are used to – at least partially – verify the categories derived. For category system A, this occurs during the operationalization process. Category system B draws upon the studies reviewed in Chapter 2.

To easily implement this methodical procedure, the computer program *MAXQDA Release 12* is employed. It simplifies the generation of categories and the coding of text passages. Furthermore, the program provides functions for memo-generation or the filtering of single text passages and categories. This eases data explication and analysis.

4.4 INTERIM CONCLUSION: INTERPLAY OF THE METHODICAL AND ANALYTICAL FRAMES

Before implementing the empirical analysis in Chapter 5, this final Sub-Chapter merges the overarching research design with the fit of its analytical and methodical frames. Under consideration of structural-organizational, innovation-related, and institutional-regulatory

backgrounds, this study aims to answer how the German EPAC industry developed successfully until today and which 'success-factors' were particularly influential.

The *diamond*, the *NSI*, and the *SSP* are applied to guide the industrial description from different theoretical viewpoints and to provide the researcher with a guiding and analytical description language (Fig. 5). To reach this goal, the frameworks are operationalized according to empirical examples. Primary and secondary data is collected through desk research and expert interviews. According to Bryman (2006) the implemented data are some of the most frequently utilized ones. A large database is generated, and based on the ideas of Mayring (2000), it is prepared and utilized for the *deductive* application of the three frameworks. Resultant from each framework's description three *inductive* analyses, again guided by Mayring's ideas of recognizable 'success-factors' follow (Fig. 5). Accordingly, the theoretical and analytical frames are developed in respect to each other.

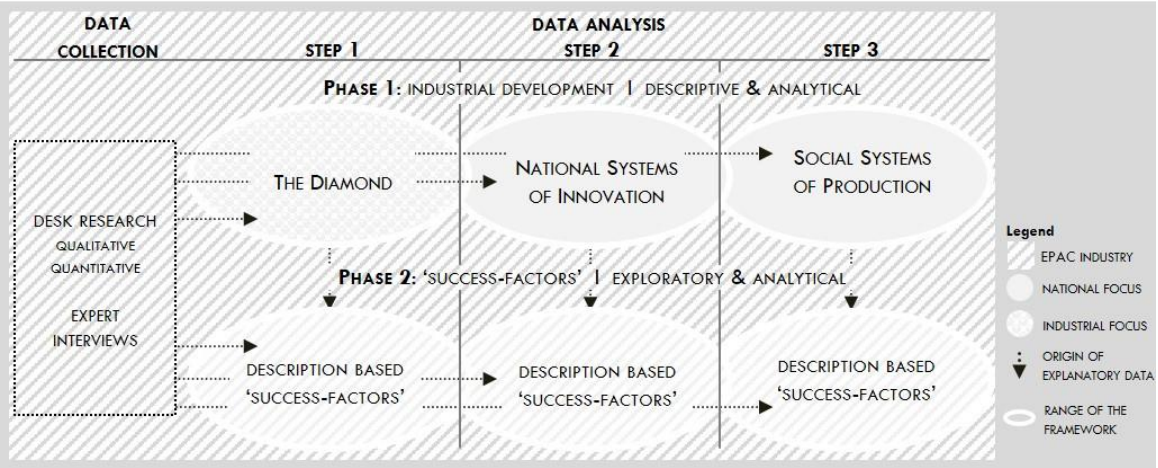

Figure 5: INTERPLAY OF METHODICAL AND ANALYTICAL FRAME
(source: author's elaboration)

As a result, this study can be expected to generate three detailed and complementary descriptions of the EPAC industry's development. These descriptions are expected to allow the identification of several even more detailed, but subjectively formed, influencing 'success-factors'.

The research's transparency is ensured by the systematic derivation of theoretical and analytical approaches, by detailed descriptions, and by the provision of representative interview quotes. Validity is ensured by pretesting the interview questions, through the composition of the sample itself, and by explicating obscure data. Finally, the findings are qualitatively validated in comparison to other empirical research. It would be suitable, and perhaps more expedient, to secure an expert for reviewing this thesis' findings. However, a fixed appointment with the most expertised industrial actor[9] was short-term cancelled and could not be rescheduled due to the actor's unavailability.

Following Flick (2009), this thesis provides a qualitative research process, containing several quantitative information. The theoretical approach is set in context of the empirical object and oriented toward the research question, as are the chosen methods of data collection and preparation.

[9] According to all interviews.

No theoretical hypothesis testing[10] as typically included in this kind of research process is approached, but rather the descriptions resulting from the application of the frameworks are interpreted in search of potentially influential 'success-factors'. Such a linear procedure has already been developed by other scholars (e.g. Mayring 2001[11]) and is frequently applied in socio-scientific research. Even though several research steps are circularly designed, this research process approaches a linear model (ibid.) and is empirically applied in Chapter 5.

5 FINDINGS AND DISCUSSION: HOW THE GERMAN EPAC INDUSTRY DEVELOPED

To answer the research question, this Chapter investigates the German EPAC industry's development based on the research design developed in the preceding Chapters. Bicycles, batteries and motor technologies initially developed independently of each other and were invented many years before EPACs entered the mass markets of contemporary economies The foundations of important EPAC-inventions coincided with different phases of European and especially German industrialization. Chapter 5.1 briefly sketches Germany's industrial history and the historical development of the EPAC's main components. The following Chapters (5.2-5.4) provide detailed analyses of the EPAC industry's development and its influential 'success-factors' guided by the *diamond*'s, the *NSI's*, and the *SSP*'s idiosyncratic views. Chapter 5.5 summarizes all findings and reflects the strengths, weaknesses, and particular value generated by complementing the three frameworks.

5.1 BEFORE THE INDUSTRIAL LAUNCH: BRIEF HISTORY OF THE EPAC'S DEVELOPMENT

This Sub-Chapter briefly outlines the early development of Germany's industrial formation with a focus on mobility technologies. It examines the historical development of the EPAC's technologies and provides the reader with brief background information. The description ends in year 1994, when legally binding rules for the production and use of EPACs were implemented in Germany. This study regards that point in time as the beginning of the EPAC industry's development.

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[10] Accordingly, this study does not aim to explicitly test any framework related theoretical hypotheses. As previously indicated, since frameworks have no concrete hypotheses, this would not even be possible in a strict sense. In a broader sense, the frameworks, of course, serve hypotheses on how international and industrial competitiveness is shaped. Öz (2002), for example, regards Porter's *diamond* model as a sum of four main hypotheses – namely the attributes relevance for international competition. As the focus of this study, however, is on the empirical object, such broad hypotheses are not at the center of research interest. Nevertheless, the frameworks' suitability for this study's analysis and the value of the three complementary approaches is evident.

[11] Mayring (2001:10) titles this a „joint flow model for qualitative and quantitative research" and mentions 6 steps to consider. (1) explication and specification of the research question (Ch. 1), (2) explication of theoretical background (Ch. 2 and 3), (3) empirical background (Ch. 1), (4) methodical approach (Ch. 4), (5) results (Ch. 5 and 6), (6) conclusions and implications (Ch. 5.5- 7).

GERMANY'S INDUSTRIAL HISTORY

Germany's industrial history can vividly be traced in relation to the *Kondratiev waves* and Schumpeter's work on *long waves* (1961). Between 1790 and 1845, Germany's industrialization began with the use of the steam engine and the development of a textile industry (Schamp 2000), followed by the emergence of an industry for the production of steel and machine tools. Simultaneously, an industry for steam-engine and ship-building evolved (ibid.). The abolishment of trade barriers between German states in 1834 increased trade in goods. The success of the first operating railway lines between Nuremberg and Fürth encouraged German companies to build their own locomotives. The demand for coal rose quickly, mining areas were booming, and steel for railways was produced. Thus, the success of German railway construction is regarded as the main impetus for the country's industrialization. Export activities began (ERIH 2016) and the production of industrial goods further increased. In 1882, 35% of the German workforce was employed within the secondary sector. Just eight years later, the industrial workforce exceeded the agricultural workforce for the first time. After 1895, the automobile and new industrial activities associated with it developed. Near the end of the century, German firms established electrical engineering and chemicals as new industrial fields as well (Schamp 2000, ERIH 2016). In all manufacturing industries, Germany had an export surplus by 1913. The last pillar of industrial activity appeared along with the 'economic miracle' after 1945, when the electronics, telecommunications, and aerospace industries started to evolve (Kulke 2010). Since the German reunification, internationalization and foreign trade have grown rapidly. Exports grew from about €340 billion in 1991 to about €1,100 billion in 2015 (destatis 2015a). Four of the ten most important German exported commodity groups (motor vehicles and parts, machines, electronic goods, other vehicles) were related to the technical characteristics of an EPAC (destatis 2015b). Due to offshoring and outsourcing activities (Contractor et al. 2010), the secondary sector's workforce decreased from round 45% in 1970 to 27% in 2007. However, it is still central to Germany's gross value added, amounting to €701,177 billion in 2015, which makes a share of more than 25% (destatis 2016).

EPAC'S EARLY HISTORY

The brief outline of the EPAC components' early history is divided into four technologies: The bicycle, electric motors, accumulators, and the EPAC itself.

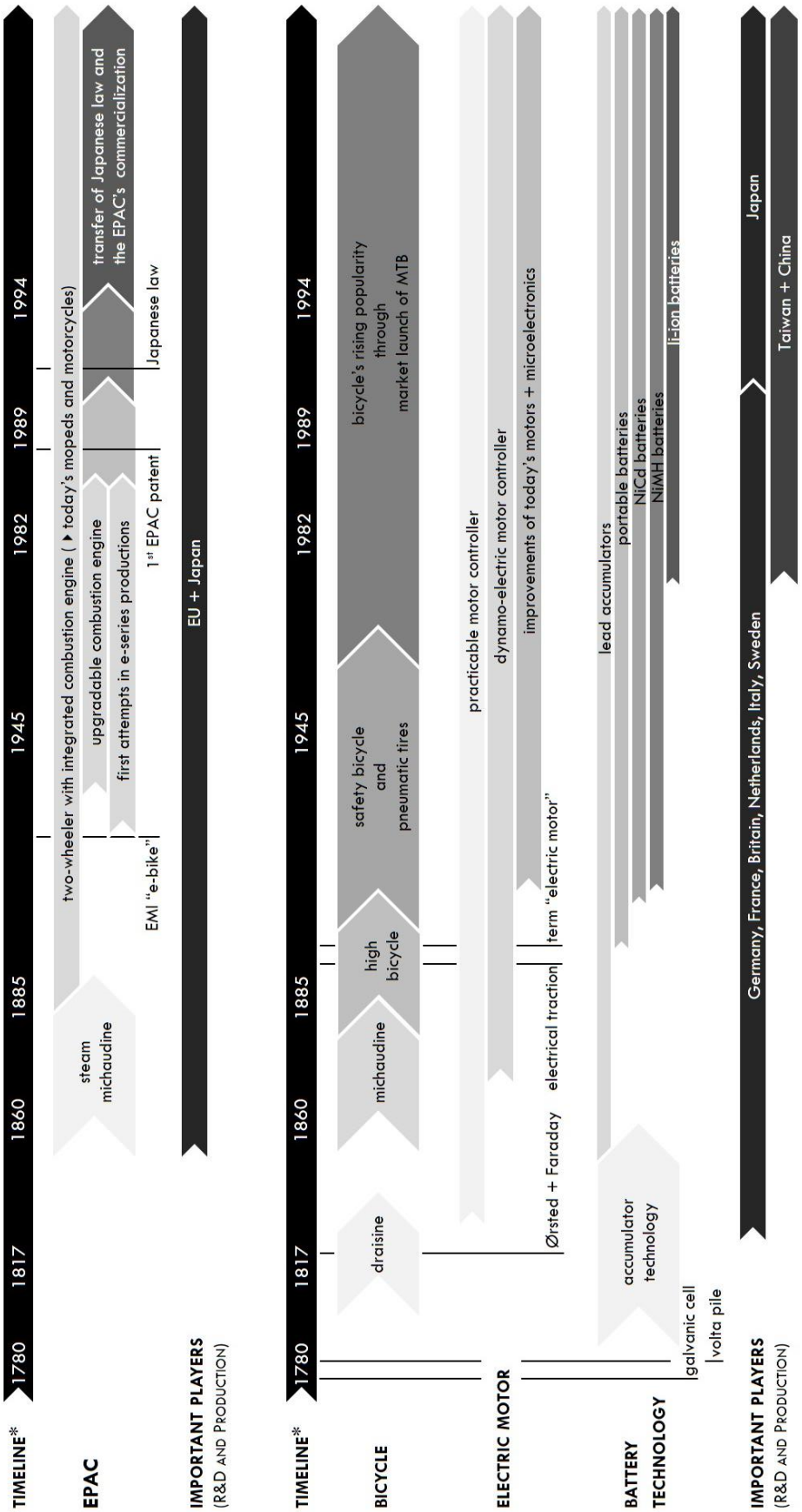
The generally accepted history of conventional bicycles began with the running-machine-invention of the German Baron Karl von Drais, in 1817 (Wilson 2004). The so-called *draisine* was suppressed by the authorities and by 1821 had virtually died out (ibid.). Between 1850 and the 1860s German and French craftsmen managed to combine cranks and pedals at the axis of the running-machine's front wheel. Its first industrial production was realized in 1868 (Dittmann 1998). With the beginning Franco-Prussian war in 1870, progress was made in Britain (VDFI 1927). The front wheel was enlarged, Dunlop invented pneumatic rubber tires, wooden frames were replaced by steel frames, and the high bicycle was born. It was what the British called a *bicycle* for the first time (ibid.). It was dangerous to ride (Wilson 2004) and it was not until 1890 that the inventors relocated the center of gravity to between the wheels, displaced the saddle toward the back wheel, downsized the front wheel again and, used a chain for power transmission (VDFI 1927). This so-called *safety bike* is very similar to the conventional bicycles of today (Wilson 2004).

In 1821, Hans Christian Ørsted detected how to deflect magnetic energy (Dittmann 1998). In combination with Michael Faraday's discovery of electromagnetism, it laid the groundwork for the development of electric motors (Dittmann 1998, König 2010). 28 years later, a German-Russian

physicist developed the first practicable electric motor integrated into a boat (ibid.). The fundamental developments of today's common electric motors were finished around 1910. They were further specialized and increasingly applied in any kind of microelectronics and processors from that time onwards (Dittmann 1998).

Based on the discoveries of *galvanic cells* and *voltaic piles* (1780-1800), the German Johann Wilhelm Ritter developed the earliest prototype of rechargeable batteries, also called secondary cells or accumulators, in 1802 (GRS 2013). The first lead accumulator was developed around 1850 (König 2010). Such were regarded as the most important precondition for the development of the first economically practicable EVs (ibid.). In 1888, two Germans laid the foundations of today's portable batteries (GRS 2013). Soon after, the first nickel-cadmium (NiCd) battery was introduced in 1899. Three years later, the American Thomas Edison made discoveries that led to the first nickel-metal hybrid (NiMH) battery (GRS 2013). In 1976, a Briton began the first basic research on lithium-ion (li-ion) batteries (Whittingham 1976), which are the preferred types of batteries for today's electric bicycles.

According to these developments, first attempts at the construction of electric bicycles were made in the 1880s (Neupert 2011). Due to a lack of funds, for example, Daimler's first 'car' (1885), was a motorcycle. It was composed of von Drais' running-machine with an integrated combustion engine (ibid.). Due to the combustion engine's early stage of technological development, EV's were poplar vehicles around 1900. But even before World War I, the combustion engine gained position and e-mobility intermediately died out (ibid.). Between 1930 and the years of the 'economic miracle' EVs, especially bicycles with different types of motors-controls, experienced several renaissances during periods of fuel shortage (ibid.). In 1982, the idea of today's EPACs evolved. The German Egon Gelhard developed the core principles of the EPAC and first attempts in its serial production followed. Pioneering products, however, were technically and optically unconvincing. They weighed up to 30kg, had battery ranges of about 20km, and the electric assist worked only rudimentarily (ibid.). Japanese firms tried to market fast e-bikes which required the wearing of helmets and the displaying of insurance plates, but such barriers prevented a positive response in Japan. To avoid legal obligations, Japanese firms adjusted their electric bicycles to the legal basis of a conventional bicycle by applying Gelhard's idea of a power assist in 1989. Thus, the 'bicycle's character' could be maintained because electric motors only assisted the rider's own muscle power (ibid.). According to Neupert (2011) those legal foundations leveraged the EPAC within contemporary bicycle industries. In 1994, the Japanese law was implemented in Germany and later on a European level. At that point in time, exactly three e-bike models were available on the world market (ibid.). In light of the newly implemented legal preconditions, however, the conditions rapidly changed.



* the time intervals are not completely displayed to scale

Figure 6: DEVELOPMENTS LEADING TO TODAY'S EPACS
(source: author's elaboration)

In accordance with this historical background, the investigation of the developing German EPAC industry begins with the year 1994, when the Japanese legal foundations were implemented in Germany. The exploratory talks revealed that the EPAC was a rare means of locomotion until 2007 (I 1.1.-I 1.5), and statistical data on the industry's development were not even officially collected in Germany until 2007 (ZIV 2016 internal data). The period of time between 1994 and 2007 can thus be regarded as a first 'pioneering' development phase (P1). After 2010, the mid-motor (App. A, Fig. 17) evolved as a dominant propulsion form (Flaig 2015). Statistical data reveals that a mass market and an increasing industrial production have simultaneously evolved since then (ZIV 2016 internal data). The EPAC industry's development can thus, as seen in other empirical studies (e.g. Pangborn 2012, Zhang et al. 2014), be divided into three main phases of development (Fig. 7): The pioneering phase (P1), a transitional phase between the beginning of statistical recognition and the already established mass market (P2), and the phase of mass production, existing since 2010 (P3).

Figure 7: PHASES OF THE GERMAN EPAC INDUSTRY DEVELOPMENT
(source: author's elaboration)

Of course, these phases can only be regarded as approximate timeframes. Nevertheless, they are useful for structuring the three frameworks' empirical applications in the following Chapters and in counteracting inconsistent, history-eliding, or chaotic descriptions as criticized in Chapter 3. Applying the three theoretical approaches to the EPAC industry traces its formation from the introduced macro geographic and economic viewpoints and elaborates answers to the research question. Each description follows the structures introduced in Chapters 3 and 4.

5.2 THE GERMAN EPAC INDUSTRY'S *DIAMOND*

This Sub-Chapter presents the application and analysis of Porter's *diamond*. Following the three temporal phases outlined in Chapter 5.1, the industry's development is described, using Porter's terminology in Chapter 5.2.1. Chapter 5.2.2 explores the 'success-factors' identified by the application of Porter's framework.

5.2.1 Empirical Application of Porter's *Diamond* Framework

This Sub-Chapter describes the EPAC industry's development following the structure of Porter's (1990) description of the German printing press industry. *Domestic firm structure, rivalry, and the strategies of German competitors, specialized factor creation, sophisticated home demand,* and *the German EPAC cluster* are the considered attributes. Chance and governmental influences, which, according to Porter, are only of secondary importance, are integrated into the four attributes' descriptions. To avoid an overly narrative description, the individual sections conclude with a short summary emphasizing their implications for the EPAC industry's successful development and thus for answering the research question. This improves explanatory power of Porter's contribution to

the understanding of the EPAC industry's development by highlighting the interrelations of the *diamond*'s attributes throughout the whole analysis.

DIAMOND'S FRAMING CONDITION

P1-3. Germany's EPAC *diamond* is framed by a very basic cultural affinity for bicycles, what researchers call a 'cycling culture' (Ebert 2010). Cycling is popular in Europe, especially in 'bicycle nations' such as Germany, France, Italy, or the Netherlands (ibid., I 2.17). Because the prototype of today's bicycle was invented in Germany and further developed in European countries (Ch. 5.1), German citizens were early sensitized to the related product and cycling has become an established means of transport. Furthermore, domestic citizens have developed an ecological awareness (I 2.9, I 2.13) which is over ten times higher than the global average today (BMUB and UBA 2015). This might be responsible for the common use of environmentally friendly means of transport and the integration of cycling into the planning and development of domestic traffic infrastructures. These cultural preconditions have shaped the formation of the developing EPAC *diamond*.

EMERGING FIRM STRUCTURE, STRATEGIES, AND RIVALRY OF GERMAN COMPETITORS

After 1994, when the EPAC's legal status was officially regulated by the federal authorities, an EPAC industry formed with companies located throughout Germany.

Structure of Domestic Rivals. P1. Due to the product's technological setting, the emerging firm structure originated in various related and supporting industrial fields. Early attempts in establishing EPACs were made by companies producing electric motors (e.g. *Heinzmann AG*), batteries (e.g. *Ansmann AG*), conventional bicycles (e.g. *ELEKTRORAD-SERVICE*), or bicycle components (e.g. *Alfred Thun GmbH & Co. KG*)[12]. Thus, each firm initially engaged in establishing the EPAC industry had specialized knowledge regarding the construction of different EPAC parts. None, however, could access all factors (Porter 1990) required to independently develop, produce, and sell a complete quality EPAC (I 2.8, I 2.11, I 2.20). In addition to general deficits in *factor endowments* like human and knowledge resources (Porter 1990), firms without a professional background in the conventional bicycle industry experienced difficulties establishing successful distribution channels, as they could not fall back upon established relationships (I 2.20) with specialized dealers (Ch. 1). Thus, various joint ventures emerged to produce and sell competitive products in the initial phase of the industry's development. In this phase, the industry was almost exclusively characterized by owner-run SMEs owning only one EPAC brand (App. A, Fig. 22-23, Tab. 10-11). Such firms stood out with their belief in and dedication to the product over the period of non-profitability (I 2.2, I 2.8, I 2.11, I 2.15, I 2.20). Subordinate to the pressure of stockholders, publicly traded companies and other large firms could not justify introducing the product as it was not yet economically advantageous (I 2.19, I 2.20).

Accordingly, the structure of domestic rivals was, in Porter's (1990) terminology, initially shaped by the influences of related industries and disadvantageous *factor conditions*. This led to the structural-organizational specifics of close cooperation, which continued in the following development phase.

[12] Official data on founding and bankruptcy dynamics does not exist (destatis 2016:code52411, ZIV internal data).

P2. With further industry development, several spin-offs in related and supplying industries emerged. For example, employees of major conventional bicycle companies, who were convinced of the product's technological benefits or sales potential established their own EPAC production or dealer shops (I 2.2). Firms which had initially aimed to establish an independent EPAC production – despite the difficulties mentioned – either disappeared from the market or turned to cooperation and subcontracting.

> Even Thun, one of the world's largest producers of bicycles' inner bearings, planned to produce EPACs. But it was really hard for them to establish a reasonable product. They couldn't stand it and quickly disappeared from the market (I 2.8).

Despite such obstacles for single firms in gaining position, the German enterprise *Robert Bosch GmbH* began to develop an EPAC component design bringing together motors, battery packs, and sensors, in 2008 (Huber 2014, Lee 2014).

P3. *Bosch's* market entry followed in 2011, introduced by a strong marketing campaign, and coincide with a beginning mass demand and an emerging supply from several formerly conventional bicycle producers (Verhelst 2015). Conventional bicycle producers who trusted the global player's automotive- and battery-tool-expertise were inspired to participate in EPAC production (I 2.20). *Bosch* became the most important mid-motor-system supplier within the German as well as the European EPAC industry (Flaig 2015)[13]. At that point in time, EPACs entered the German mass market. Producers and dealers who were predominantly one-brand-SMEs increasingly had to compete against a few major companies with annual sales of more than €50 million (Burdack 2015). Financially strong conventional bicycle companies such as *CUBE*, *Cycle Union*, *Derby Cycle*, *MIFA* or the *Winora Group*, typically holding more than one brand, began to invest in their own EPA- and motor-designs. By 2014, already 24% of all EPACs were supplied by major conventional bicycle producers (Statista 2015b). Noticing *Bosch's* success in supplying 50,000 motor systems per year to *CUBE* alone (I 2.11), other motor and part suppliers attempted to imitate this success. Financially strong companies such as *Brose* or *Continental*, representing German workmanship and originating in related industries, recognized the EPAC's economic potential and entered the industry as suppliers. They served as stimulators improving *factor endowments*, such as the industry's assets or its highly technologically skilled workforce (Porter 1990). As *Bosch*, however, established a leading industrial position, it became harder for other producers to introduce their products, and previously accepted and leading motors, such as *BionX*, "vanished into thin air" (I 2.5). The remaining motor suppliers split the market into different niche-segments within which they continued operating (I 2.13, I 2.20). Several conventional bicycle producers, like *Riese & Müller*, rearranged their product portfolio and began exclusively producing EPACs. Start-ups were attracted by rapid developments in sales (I 2.3, I 2.16). Different motors, specific types of EPACs, and upgrades for conventional bicycles were further developed (I 1.2). Several start-ups, such as *Radkutsche* or *Coboc*, joined the industry, whereas others, such as *Grace*, were bought up by major companies, or disappeared from the market (e.g. *Vitalbike*) (I 1.2, I 2.11, I 2.13, I 2.16). Finally, foreign companies such as *HeroEco*, owner of the brands *A2B* and *F4W*, relocated their production to Germany in order to reduce issues with quality control and

[13] Today, *Bosch* holds a market share of about 40% in Germany (Flaig 2015). With an expected compound annual growth rate of 9.3% between 2013 and 2020, the mid-mount motor is the fastest growing segment worldwide (Hurst and Gartner 2013). According to Hurst and Gartner (2013:2) this is "in part due to strong competitors." In Germany, 90% of all motor systems today are mid-motors. Before *Bosch* entered the market it was split evenly 50/50 between mid-motors and hub-motors (sketch, App. A, Fig. 17) (I 2.20).

earn the label 'Made-In-Germany' (I 2.18, I 2.19). The industry itself and even established cooperative relationships became more competitive. Today, more than one third of the at least 450 EPAC, EPAC component, and driving system producers selling their products in Germany (App. A, Fig. 22-23, Tab. 10-11) are domestic firms.

This indicates increasing demand and competition which influence the organization and structure of the developing industry. Still, this rivalry is largely shaped by the industrial participation of firms originating from related industries, which at the same time enable the EPAC industry's advancement of *factor endowments* (Ch. 3.1).

Developing Strategies of Domestic Rivals. P1-3. The increasingly competitive development in the recent past indicate diverse strategic orientations of industrial players. These strategies concern product quality, pricing and distribution channels, portfolio and target groups, design, aspects of customization/duration of the product cycle, production efficiency, and brand popularity. During the initial stages of development, enterprise decisions were not necessarily determined by economic and strategic decision making. As described, participation was primarily motivated by the opportunity to demonstrate technical abilities and an enthusiasm for the product. Firms, however, have evolved their strategic orientation. Today, differentiation in price and quality strategies as well as the companies' chosen distribution channels are closely intertwined with and influenced by the domestic demand structure. For example: *MIFA* and *Derby Cycle* are both companies that produce their EPACs in Germany and provide high quality in international comparisons. *MIFA's* strategy is to supply lower quality and cheaper products to 'greenfields'[14], whereas *Derby Cycle* exclusively supplies higher quality products to specialized dealer shops. In comparison, *MIFA* sells more EPACs than *Derby Cycle* but earns less revenue due to cheaper prices (I 1.4, I 2.11, I 2.19). Dealer associations such as the *ZEG*, who produce their own EPAC brands in Asia for financial reasons and then import and sell them in bicycle and EPAC wholesale trade, earn medium margins at medium quality levels. With the rise of the internet, start-up firms engaged in direct sales (I 2.13), offering different product segments at differing qualities and price levels. Rivalry also exists in the supplied product portfolios, reflecting variations in the purchase criteria of buyers (also Porter 1990). EPACs produced in P1 and P2 are described as "granny bikes" (I 2.20), as "silverbacks" (I 2.6), or as having a "geriatric nimbus" (I 2.18), since they are characterized by a low-entry and an upright sitting position. Since the beginning of P3, much more variety has appeared on the market. New electric bicycle designs emerged and mountain bikes of brands like *HAIBIKE* and *CUBE* have become very popular (I 2.20, ZIV 2016a). EPAC producers like *Freygeist*, for example, strategically produce only one type of urban EPAC, whereas *HNF Heisenberg* offers trail, urban, fully and touring EPACs. Today, all segments of conventional bicycles also exist as EPACs (I 2.9, I 2.12). Correspondingly, EPAC component producers exhibit similar differences regarding their product portfolios. *Brose* for example only produces a motor, whereas *Bosch* produces a complete propulsion system including motor, battery, display, and further equipment. *Shimano* in turn, produces the complete propulsion system and further integrates a gearshift (I 2.4, I 2.10, I 2.11). Differentiation strategies are also evident in the EPACs' designs. As illustrated in Appendix A (Fig. 18-21), various companies aim to hide the non-conventional bicycle components (e.g. *Coboc ONE SOHO*), to simply add and adjust them to a conventional bicycle (e.g. *Flyer C8*), to functionally integrate them (e.g. *Stromer ST1*), or to provide an aggressive e-optic (e.g. Conway *E-Rider*). Other firms aimed to differentiate by supplying

[14] Within the EPAC and conventional bicycle industry that includes the supply of products to grocery stores (e.g. *Metro*, *Aldi* or *Real*), building centers (e.g. *OBI*) and other stores.

customized products or by having explicitly long or short product lifecycles. They either aim to provide new models each season (e.g. *Cube* or *Haibike*) or to work on one model for several seasons before introducing completely new designs (e.g. *Merida* or *Centurion*). EPAC producers such as *Cube* further differentiate by an extreme efficiency in assembly and production (I 2.14). Finally, rivalry also exists regarding the degree of the producers' brand's popularity (I 2.4, I 2.5, I 2.10, I 2.20). Both EPAC producers (e.g. *Velo de Ville* or *Riese & Müller*) and EPAC component producers (e.g. *Shimano* or *Brose*) aim to be recognized and demanded by potential customers.

Accordingly, considering the industrial players' strategies in the context of the research question, Porter's (1990) description language points to the influence of diverse differentiation strategies on the industrial structure, organization, and internal competition. Quality-based strategies are set in relation to the *demand conditions* and further influenced by firms' access to factors such as financing production.

SPECIALIZED FACTOR CREATION

The ability of German EPAC firms to advance both products and manufacturing during the developmental phases 1-3, has only partially been characterized by specialized *factor conditions* and creation. Due to the governmental and cultural framing conditions, traffic infrastructure has been continuously planned compatible to bicycling (specific cycle paths, traffic lights, parking spots, etc.) for the last 30 years. Infrastructural specifics include to the construction of several cycling high ways (e.g. *RS1*), safe parking spots, and interconnected mobility services (I 2.4, I 2.6). Infrastructural expansions remain on the political agenda (BMVBS 2012). This supports the increasing usability of the new products. Indirectly, the cultural and political framing conditions further support access to financial resources. As societal environmental awareness and the familiarity with EPACs has increased, it has been easier for start-ups to acquire private funding. Additionally, "human resources" (Porter 1990:74) with educational backgrounds in engineering disciplines may have been acquired from related industries. At the same time, German firms have been coping with high *factor costs*. Wages and social benefit costs are higher and working hours shorter than in competing (e.g. Asian) nations (Porter 1990). This disadvantage, however, has led to further *factor creation*. In P3, engineering-intensive suppliers began to engage in informal apprenticeships for their customers to ensure a continuously high-quality oriented international competitiveness.

In sum, the German EPAC industry's *factor conditions* are influenced by government's institutions, cultural framing conditions and by the related industries' structuring effects, which in turn, influence the EPAC's usability and thus demand (Ch. 3.1).

SOPHISTICATED HOME DEMAND

As the EPAC industry's structure and product portfolio have changed between 1994 and today, the role of consumers and sophisticated demand has changed as well.

P1. When the EPAC reached market maturity, no demand existed for the product. Suppliers and producers tried to generate and supply a domestic demand by targeting advertising to people with physical constraints or to the 'generation 60+' (I 2.3), whose daily mobility could be improved through the use of EPACs.

> The first producer who built quality-EPACs in large volumes carried busloads of pensioners and retirees to the factory and offered plant tours and test rides (I 2.6).

Even though producers could not rely on sophisticated demanders to optimize their products, many employees in EPAC-producing companies were professional athletes and thus had sophisticated demands and ideas for improvement. Additionally, the structure of established distribution channels led dealers to be important sophisticated customers due to their expertise (I 2.11).

Accordingly, the end-customers' demand did not decisively initially influence the industry's structure and development. Rather, the industrial workforce served as sophisticated 'customers', which Porter (1990) subordinates to *factor conditions*.

P2-3. Younger customers have been attracted by new product segments and designs (I 2.4) and the whole German EPAC industry has gained international recognition as service- and quality-oriented (I 2.20). As a result, foreign demand for German products has increased, contributing to further adjustments and optimization. The emergence of web-platforms for comparing prices, equipment, quality, and diverse features has developed and increased the customers' sophistication as well as industrial competition, so that dealers are no longer the main sources of feedback. In developmental phase 3, the supplied product portfolio expanded significantly and each conventional bicycle segment is similarly offered as EPAC today. As the industrial rivalry has restructured itself during phase 3, EPACs branded by *Kalkhoff* and *Haibike* (major players in conventional bicycle production) and equipped with mid-motors have been in highest demand since 2012 (Delius Klasing Verlag internal data, Statista 2015c). *Bosch's* propulsion systems are in highest demand, because customers trust the product's workmanship and the brand's quality. High-tech-equipped EPACs (e.g. with *Magura*-brakes and suspension forks) are increasingly sold and especially demanded by German customers (I 2.8). Between just 2013 and 2014, the average price of an EPAC increased by about €150 (statista 2015b). With an average sales price of €2.553 in 2015, the most sophisticated German consumers had by far the highest willingness to pay (Lüttig and Nachtnebel 2015, CONEBI 2016). The increasing demand has been framed by general governmental discussions about sustainable mobility as well. Some German *Länder* (e.g. North Rhine-Westphalia, Bavaria or Baden-Wuerttemberg) have established EPAC-leasing as part of *Business Mobility Management.* It includes tax reductions for employees and employers and is thus an indirect EPAC-subsidy which stimulates domestic demand. Germany offers the largest European sales market. In 2015, 40% of all European (EU) EPAC sales occurred in Germany (CONEBI 2016). The growing demand for products 'Made-In-Germany' has coincided with the previously described market entrance of trustworthy German companies originating in *related and supporting industries*.

Thus, the *demand conditions* are ultimately affected by the influences of governmental activity, competitors originating from related industries, the increasing numbers of industrial actors and their strategic orientations, as well as by chance events such as upcoming Internet platforms for price and equipment comparisons. These mutual influences result in a sophisticated demand which largely shapes the industrial structure and organization today.

THE GERMAN EPAC 'CLUSTER'

Due to the EPAC's construction as a product combined of parts originating in different industries, national inter-industrial relations, which Porter (1990) calls a 'national cluster' have played a pivotal role in industrial growth.

P1. Initially, the firm structure was characterized by actors with professional backgrounds as conventional bicycle producers (e.g. *Panther*), electric motor producers (e.g. *Heinzmann*), and

battery producers (e.g. *Ansmann*). Together they enabled the construction of the EPAC and formed the industrial structure introduced in the preceding section.

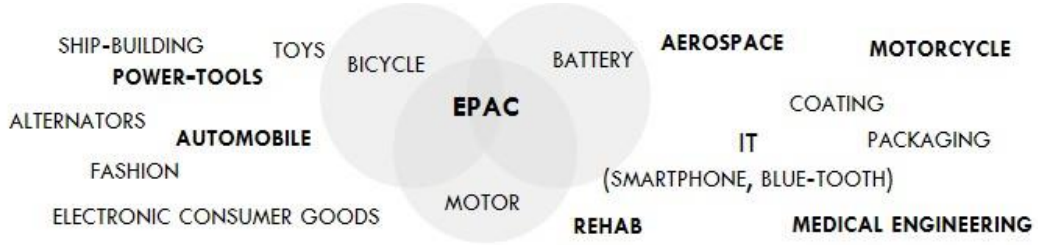


Figure 8: THE EPAC'S INFLUENCING INDUSTRIES
(source: author's elaboration based on I 2.2, I 2.3, I 2.4, I 2.9, I 2.14, I 2.18, I 2.20, Schlick et al. 2011)

P2-3. Over time, EPACs have continually improved in technology and in 2007, the foreign development of marketable li-ion batteries further stimulated development (I 2.8, I 2.15). In cooperation with related battery assembly and production companies, such as Europe's leader *BMZ Karlstein GmbH*, technologies have been professionally adjusted in order to halve the batteries' weights while doubling their performance (I 2.8). With increasing industrial professionalization, relations with *related and supporting industries* (Figure 8) have strengthened in order to collect ideas for R&D, and product and process innovations, as well as to screen for potentially transferrable technologies. Industries requiring electrical engineering have been important contributors to the EPAC's development, as have the German automotive and motorcycle industries through the scaling of suspension forks or disc brakes to conventional bicycles and EPACs (I 2.14). Production processes (I 2.5) and material-related ideas (I 2.20) from leading firms in medical engineering (e.g. *Siemens*, *Fresenius Medical Care*, *Bayer*), aerospace (e.g. *Liebherr*, *Airbus Group*), as well as power-tools (e.g. *Trumpf*, *Stihl*, *Bosch*), have also been adapted by EPAC firms located in Germany. Further mechanical or electrical industries (Figure 8) stimulate the EPAC's technological development regarding colors and design, gears, connectivity, electronic components and materials processing. Additionally, employees within the EPAC industry originally employed in other industries provide new insights. Cost-intensive developments are undertaken by major financially-sound firms in supplying industries (e.g. *Bosch*). Simultaneously, potential customers have become even more aware of the product because trustworthy, high-quality companies they know from other products have begun to engage in the industry. Customers, in turn, have stimulated the engagement of more related firms (e.g. *Brose*) due to estimated growing sales potentials.

In these respects, German EPAC producers have continuously benefited from a distinct national structure of related firms. The importance of *domestic demand* and *related and supporting* actors for the industry's structure has mutually reinforced each other, as indicated in Chapter 3.1. In sum, this attribute appears to be very important for the industry's formation and structural-organizational backgrounds.

SUMMARY AND IMPLICATION: MERGING THE STRANDS OF THE *DIAMOND*

Based on this first industry description, guided by Porter's theoretical language, several conclusions can be drawn for understanding the industry's development and particularly its structural-organizational backgrounds. They also indicate the legitimacy of applying Porter's framework to better understand the development.

The description illustrates that the interrelations of *firm strategy, structure, and rivalry*, *related and supporting industries*, and *demand conditions* have been particularly important for the formation of the EPAC industry's structure. Interdependently they have enabled the formation of today's industrial structure (see conclusions above). Simplified, this is summarized in Figure 9. The development of today's organizational structure is framed by a specific cultural background and partially influenced by governmental action and chance events such as the rise of internet or the foreign development of li-ion batteries.

Using Porter's language, the industry was able to form based on initial inter-firm relations such as joint ventures between firms from *related and supporting industries* that allowed it to compensate for selective *factor disadvantages* against the background of a high awareness for sustainable modes of transportation and the bicycle's long standing position in daily life. This resulted in the formation of a small and familiar industry structure, formed by idealistic actors with secondary profit expectations. Over time, especially *Bosch's* product penetration has inspired further firm entrants originating in *related and supporting industries* or start-ups. *Bosch*, *Brose* and other large enterprises shifted the industry toward increasing professionalism in structure and organization. The brand reputation of such players from world-class *related and supporting industries* has spilled over to benefit the EPAC industry in building a national image and increasing recognition as important international competitors. In mutual interdependency this has led to a large and growing home demand, which at the same time has stimulated the growth and specialization of EPAC component suppliers. Specialized dealers, athlete-employees, and sophisticated end-customers shape both domestic demand and attempts to professionalize the industrial organization in the face of increasing international competitiveness. The professionalization in structure and organization has additionally been supported by *factor creating mechanisms* that enable the provision of capital and industrial training, resulting in the production of high-quality goods.

While the *diamond* provides an initial overview of the industry's formation, further exploration of constant technological improvements and the important role of *related and supporting industries* requires an application of the *NSI* in a later Chapter. Similarly, revealing the influences of government, cooperation, and joint ventures maintains and strengthens the call for another description from the *SSP*'s viewpoint.

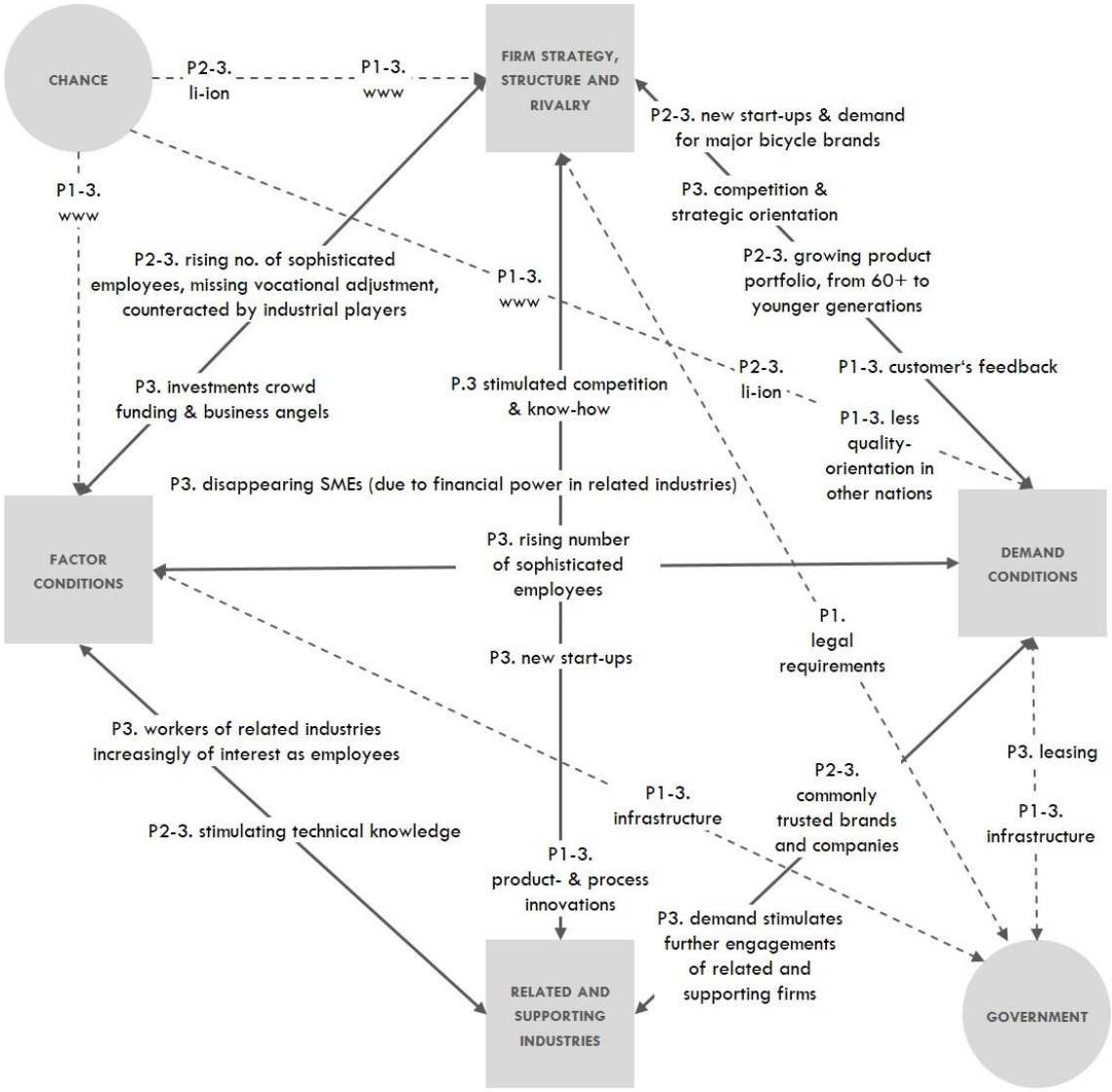


Figure 9: SKETCH – GERMANY'S EPAC-*DIAMOND*
(source: author's elaboration)

THE FINDING'S VALIDITY

In a brief evaluation of these results' validity, it can be stated that the development described only partially resemble the results of other applications of Porter's *diamond*. The developing German printing press industry (Porter 1990), mentioned in Chapter 3.1 for example, was not shaped by other already established industries, but instead influenced the formation of a variety of *related industries*. *K&B*, the first large printing press enterprise could only successfully locate in Germany because "the king of Bavaria was actively trying to attract industry to the region" (Porter 1990:183). But like the EPAC industry, the printing press industry became increasingly competitive over time and companies also competed based on high-quality differentiation strategies. Although the printing press industry was established around the 1900s, it already had to cope with higher *factor costs* than other countries, just like the emerging EPAC industry. Stronger differences emerge when considering Weerathamrongsak's and Wongsurawat's (2013) application of the *diamond* to analyze Thailand's rubber industry. This very agricultural and low-tech industry largely depends on *factor conditions* like climate and other natural resources. The *home demand* is not as influential, because

export plays a major role, and *related and supporting industries* do not as significantly influence the industry. Of course, these applications of Porter's attributes differ according to the specific country, the number of engaged companies, the particular industry, as well as the time of its formation. Accordingly, these examples do not reveal explicit correlations or directly comparable results. This is the case because "every industry is unique, with its own sources of competitive advantage and its own evolutionary path" (Porter 1990:179). Nevertheless, the reviewed studies resemble each other in the degree of analytical detail and have similar designs, indicating the overall attempted validity of the preceding analysis.

In addition to the findings of this Sub-Chapter, this theoretically guided description hints at several influences, even more concrete than just the interrelation of the *diamond*'s attributes, that have particularly fostered the EPAC industry's development. These 'success-factors' are analyzed in the following Sub-Chapter.

5.2.2 Exploring Influential 'Success-Factors' Derived from the *Diamond's* Application

Based on the description of the attributes' interdependencies and the findings of Chapter 5.2.1, six concrete 'success-factors' particularly influencing the successful industry development can be identified. These are directly or indirectly addressed in the preceding Sub-Chapter. The 'success-factors' are important at different stages of the development and can be identified through the interplay of the *diamond*'s attributes. The *distinct national structure of related and supporting industries*, role of *sophisticated customers*, *'green' mobility anchored in daily life*, *SME-structure and industry's size*, *trust in established enterprises,* as well as *professionalization dynamics* present themselves as particularly influential 'success-factors'. Each of the following sections is introduced by two representative quotes and explains the identified 'success-factor' regarding its importance, theoretical anchoring, and temporal relevance.

DISTINCT NATIONAL STRUCTURE OF RELATED AND SUPPORTING INDUSTRIES

> Soon we'll be able to show service reminders on the display so that the cyclist sees when service is due. […] That is an idea originating the automotive sector (I 2.4).
>
> One of our engineers, for example, worked on remotely controlled cars in the electric toy industry before. And we have just strengthened our team with someone who used to be responsible for dynamos in motorcycles (I 2.14).

The *distinct national structure of related and supporting industries* describes the important influences of other domestically well-established industries on the formation of a German EPAC industry.

This 'success-factor' is easily identified by Porter's emphasis on a 'national cluster' of *related and supporting industries*, and also apparent in connection to *firm strategy, structure, and rivalry*, *factor creation*, and *demand conditions*. This 'success-factor' was most influential in the formation of the industry. Because the EPAC contains product parts, originally produced in traditional German industries, the distinct structure of reputable and technically experienced firms enabled the joint construction of the first high-quality products. This 'success-factor' has continuously (Figure 10) affected technological and design improvements. Major related and supporting industrial players have possessed the human and financial resources required for continuing progress and meeting an increasing demand. The *distinct structure of related and supporting industries* has also provided

impetuses for professionalizing industrial structures. This 'success-factor', directly addressed by Porter, is significant.

SOPHISTICATED CUSTOMERS

> Since my early childhood, I had an affinity for bicycles […] I then ended up in professional cycling. So I decided to do my apprenticeship in the bicycle industry. […] Against this background, one thinks differently in terms of putting more emphasis on stability rather than exclusively on visual appearance (2.2).
>
> Today, we offer *Magura*-brakes, suspension forks, seven or eight gears. This leaves nothing to be desired. But it's also what is actually demanded on the market. You could not place a €900 EPAC next to it and the customers would only buy the cheap one. That does not work (I 2.8).

The importance of *sophisticated customers* refers to their influence on guiding the designs, product segments, and qualities toward those in high demand.

The importance of *sophisticated customers* can be identified by the *diamond*'s *demand conditions*, and in connection to national framing conditions, *firm strategy, structure, and rivalry*, and *related and supporting industries*. It has influenced all phases of development (Figure 10). Generally, the societal framing conditions and governmental intentions in improving Germany's cycling infrastructure support the formation of a national pool of sophisticated end-customers. Initially, however, it was employees with athletic backgrounds in conventional bicycling who were highly sophisticated in developing high-quality products. When the products were placed in specialized retail stores, another quality-demanding link was added to the value chain. The dealers began to play important roles as partially experienced and high-quality customers, demanding product designs close to their preferences. With increasing sales, product-popularity, and online-comparisons, real end-customers have become increasingly sophisticated as well. Similarly, the growing willingness to pay has stimulated a demand for high quality products that might also reflect social prestige. The domestically demanded products have undergone required and desired design adjustments which are now demanded in foreign markets. This stimulated demand, in turn, has encouraged the steady industry entry of new firms and increased the pressure to continuously meet high quality standards in production. Thus, the 'success-factor' has influenced all phases of development and is particularly important to understanding the industry's successful formation.

'GREEN' MOBILITY ANCHORED IN DAILY LIFE

> We grow up with bicycling in Europe. Everybody has a grandma and a child who cycles. It's part of our cultural DNA. I mean, bicycling and Europe, that goes hand in hand (I 2.10).
>
> Bikes became a status symbol for those who view cars as silly (I 2.9).

'Green' mobility anchored in daily life indicates the established position of bicycles within the German society and the potential interdependency with a general domestic ecological awareness. Together, these circumstances are important prerequisites for developing a generally accepted product and thus establishing an industry.

The 'success-factor' can be identified through the *diamond*'s national framing conditions and the interplay of the *related and supporting industries*, *factor creation*, and *demand conditions*. It constantly shapes the industry throughout all phases of development (Figure 10). Initially, it affected the impulses to begin informally experimenting with bicycle-related technological

improvements. Cycling's anchoring within society, infrastructural pre-conditions (cycle paths, parking spots, etc.), and the awareness of environmental issues all contributed to the actors' of *related industries* impulse to combine the three technologies into an EPAC. The ambitions and high profit expectations of related companies that joined the industry at a later stage have been framed by the mobility's popularity and anchoring in everyday life, which has also eased companies' access to funding. Additionally, customers are already aware of the usefulness of the newly developed product, because due to cycling's societal anchoring, its basic operating modes were familiar. Regarding bicycling as a matter of course has finally led to partial political subsidies in form of tax reductions in the recent past. This once more reflects the important influence of the 'success-factor' *'green' mobility anchored in daily life.*

SME-STRUCTURE AND INDUSTRY'S SIZE

> It is a small and manageable industry. Manufacturers' representatives know each other and only calling cards change sometimes (I 2.4).
>
> What counts is: a) 1000 ants can't be mistaken and b) we live in a society and work in an industry where people talk (I 2.15).

The 'success-factor' *SME-structure and industry's size* covers the peculiarity that the industry is, compared to traditional German industries, very small and that about 99.5% of all domestic players identified are SMEs (App. A, Fig. 22-23, Tab. 10-11). This is important for the industry's development, because it enabled the product's creation, eases cooperation, and has led to educational factor creation.

The 'success-factor' can be identified through the interdependencies of *firm strategy, structure, and rivalry, related and supporting industries,* and *factor creation*. It mostly shaped the industry throughout the initial phase of development (Figure 10). Due to the producers' different skills, they cooperated to address gaps in technical expertise and to introduce a marketable product. The small industry-size eased cooperation and access to an established distribution channel. Once again the industry's SME-structure simplified initial development, because owners were free from profit-oriented decision making and could show persistence in developing and improving a product they believed in. With the expanding market and the industry entry of new firms, personal SME-relations have become less characteristic and industrial competitiveness has increased. *Professionalization dynamics* accompanied the increasing industrial participation of *established enterprises* that customers and producers of related products trusted in. Nevertheless, personal industrial relations have continued to enable *factor creation* and, for example, promoted intra-industrial further education. Accordingly, personal relations have remained supportive and important until today.

TRUST IN ESTABLISHED ENTERPRISES

> I can only presume that the bicycle industry is a very *hemdsärmelig* one. It did not originate in the business sector but rather from handcrafts. I can imagine that they needed this kind of impulse to get the courage to jump in. Because, when *Bosch* decided to take up e-mobility, 13 German producers of conventional bicycles immediately jumped on – even though they had nothing to do with e-mobility before (I 2.12).
>
> *Bosch* is just a very old and well-known name. It's a byword for quality and longevity (I 2.20).

The 'success-factor' *trust in established enterprises* indicates the shift toward mass production and consumption of EPACs in Germany. It relies largely on the general association of major companies

(e.g.) with producing innovative, viable, and high-quality products. Amongst others, such associations directed the EPAC industry toward rapid growth by causing positive feedbacks.

This 'success-factor' is identifiable in the interplay of *firm strategy, structure, and rivalry*, *related and supporting industries*, and *demand conditions*. It has influenced the industry's development from the beginning, but has become particularly important since *Bosch* entered the industry (Figure 10). Initially, it paved the way for companies such as *Heinzmann* or *Ansmann* to enter contracts with conventional bicycle producers and to jointly develop and produce the first German serial EPACs. When *Bosch* entered the industry in 2008, however, it was associated with a professional organization, expertise in fine and electro mechanics, strong financial power, impressive marketing campaigns, and impeccable workmanship. In short, *Bosch* was associated with special abilities. The resulting trust in the enterprises' expertise and quality products extend toward consumers and potential EPAC producers (e.g. *Cube*) and competitors (e.g. *Brose* or *Shimano*). Other related industrial players were sensitized by *Bosch's* strategic orientation and followed the example. Today, the industry benefits from the participation of *Bosch, Shimano*, *Brose*, *Continental* and other well established, trustworthy enterprises who stimulate the product's demand due to high quality and brand reputation.

PROFESSIONALIZATION DYNAMICS

> Maybe the industry is not as professional and structured as the automotive industry or others. In the beginning, [large engineering companies] had their difficulties understanding the bicycle companies. Because they just sing a different tune. To exaggerate: *Bosch* had to take off the tie. And the bicycle producers had to wear a shirt instead of a hoodie during the meeting. But we are on our way. Because they affect us (I 2.5).
>
> We are a North German producer. We talked in German and Low German. Now, we slowly establish internationally and speak English. […] Work has become completely different (I 2.19).

The 'success-factor' *professionalization dynamics* affects most firms acting within the EPAC industry. It influences SMEs that initially produced conventional bicycles and start-ups which underwent rapid structural changes, and indicates restructurings within these companies resulting from the industrial participation of professionally organized companies such as *Bosch.* Such inter-firm influences guide the industrial set-up toward being perceived as more professional and reliable in quality and increase the industry's international reputation.

The 'success-factor' can be identified through internal feedbacks within the *diamond*'s attribute *firm strategy, structure, and rivalry* and by observing the interdependencies of this attribute with *related and supporting industries*, *demand conditions*, and *factor creations*. Following the initial phase of development, characterized by 'informal fiddling' with new ideas, *professionalization dynamics* have increased in tandem with the product's overall establishment (Figure 10). *Bosch's* introduction of its first marketable propulsion system was supported by an extensive and effective marketing campaign. Thus, the enterprise, its internal organization of in-house R&D, and its professional and automated steps of production were noted by other companies. Further large and professionally organized companies, such as *Brose* or *Shimano*, began supplying the EPAC industry. Less professionally organized firms, in turn, have attempted to follow these examples regarding the establishment of more professionally structured internal and inter-firm processes. The large firms have begun to support these attempts by improving intra-industrial continuing education. Apart from that, start-ups increasingly influence a modernization in distribution channels

by exploiting the internet for sales. All these processes have led to an increasing international industry reputation as professionally organized.

SUMMARY AND IMPLICATION: AFFECTING 'SUCCESS-FACTORS'

This Sub-Chapter identifies and explains different 'success-factors', crucial for the industry's development according to the findings of the applied *diamond*. The 'success-factors' are directly or indirectly addressed by Porter's (1990) argument of advantages resulting from different attributes' interdependent linkages. As revealed in Chapter 5.2.1 and in Chapter 5.2.2, not all these interrelated factors are equally important in each phase of the development. Figure 10 visualizes the mutually dependent interplay of the success factors in relation to temporal evolution. In the beginning of the industrial formation, the underlying influence of *'green' mobility anchored in daily life* was highly important, just as the *SME-structure* and the *distinct national structure of related and supporting industries*. Jointly, these preconditional factors enabled the establishment of the first products. Less influential in the beginning were trustworthy and *established enterprises* and a *professional* industrial organization. These factors became important along with the industrial formation and growth. They could have even been counterproductive in the initial stage, because they would have complicated development partnerships and other cooperative relationships. With increasing *professionalization* and the participation of well-known and trustworthy companies, the importance of personal interrelations within the small industry has partially declined, but nonetheless remains important to enable further *factor creation*. Similarly, *related and supporting industries* remain important but are not as indispensable as they were when providing the initial impetus for creating the first product.

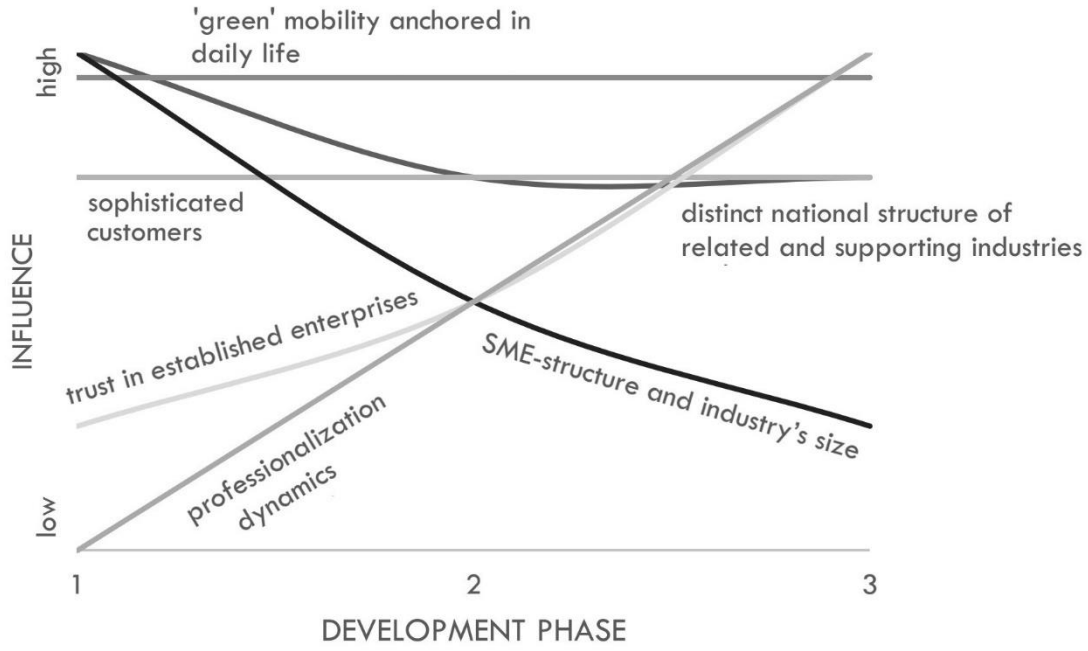


Figure 10: SUCCESS FACTORS DURING THE PHASES OF INDUSTRY DEVELOPMENT BASED ON PORTER'S FRAMEWORK
(source: author's elaboration)

THE FINDING'S VALIDITY

There is no overlap between this study and the findings of Weerathamrongsak and Wongsurawat (2013). In the Thai rubber industry, the number of producible units and amount of accessible land for agriculture are the most influential 'success-factors'. But other national industry studies, while not explicitly applying the *diamond*, reveal several similarities (App. D). Larsen's and Nilsson's (1984) work on the Danish bicycle industry, for example, similarly reveal demand influences as particularly important. Chu and Li (1996) who investigate Taiwan's and South Korea's bicycle industries point to the significant role played by SMEs. They only very vaguely emphasize the SMEs' "emergence at the right time," which was a result of "collected effects of past policies and accumulated experiences of commercialization that existed before" (Chu and Li 1996:51). Klepper (2002) and Boschma and Wenting (2007), who investigate the British and the U.S. automobile industries, reveal that linkages with related industries are drivers of success. Chaudhary (2014) who investigates the Indian e-mobility sector, in turn, emphasizes the importance of societal awareness for environmentally friendly means of transport in reaching industrial success. He also points to the influencing role of *demand conditions* resulting from increasing incomes. This reflects how diverse particularly important influences can be for the success of industry development and is why the real importance of the identified 'success-factors' cannot be generalized regarding other industries. Relating the findings to other studies, however, points to relevance of the identified 'success-factors' in the context of other mobility-related industries.

All findings are finally summarized, and related to the limitations and contributions generated by the application of Porter's *diamond*, in Chapter 5.2.3.

5.2.3 Interim Conclusion and Reflection: Porter's Limitations and Contributions

Porter's approach toward understanding competitive advantages of nations and accompanying the successful evolution of industries aids understanding of the EPAC industry's development in various respects and is limited in its contributions in other respects. To reflect the value of applying Porters framework, the most influential strength and weaknesses are visualized in Table 7 and summarized in the empirical context below.

Table 7: IMPORTANT CONTRIBUTIONS AND LIMITATIONS OF THE *DIAMOND* ON THE EMPIRICAL CONTEXT (source: author's elaboration)

	CONTRIBUTION	LIMITATION
empirical	reveals structural-organizational aspects provides a detailed and extensive picture of the development, explicitly related to the industry perfectly emphasizes the industrial interrelations with other industries and, within the industry, diverse strategies, and the influences of demand	mostly focuses on industrial actors and demand, thereby neglecting influences of other players (e.g. politicians, unions, associations)
conceptual	addresses the gaps of selective and econometric analyses and of neglecting historic aspects theoretical conception of interrelations is easily transferrable to empirical case	argues that constant improvements result in advantage, but does not allow the consideration of innovations or technical development no concrete conclusions can be reached very narrative character rather than scientific simplified reality, thus not every influence identifiable

As indicated in Table 7, the industry's development identifiable by Porter's viewpoint show that structural-organizational backgrounds are important to understanding their evolution (Ch. 5.2.1). In short, the *diamond's* 'answer' to the research question is: The initially characteristic SME firms were largely attracted to cooperation and *inter-firm relationships* and thereby structured the industry's formation by joint ventures with players originating from other industries. They proved to have stamina regarding the profit-earning capacity of their products. Due to different strategies, engagements of start-ups, and further related players, the industry grew. Under the influence of large and professionally organized enterprises, the industry shifted from unprofessionalism to a more orderly organization of production processes and relationships and the industry began to create specific factors. This led to further success, international reputation, and an increasingly sophisticated end-customers' demand which, due to their needs and expectations, has structuring influences on the industry.

The identified influential 'success-factors' (Ch. 5.2.2) similarly point to the industry's specific structural-organizational background. As mentioned, the *distinct national structure of related and supporting industries*, the *sophisticated customers*, the *SME-structure and industry's size*, and the *professionalization dynamics* shaped the industry's structure and organization, leading to successful development. Also the *trust in established enterprises*, which enables the enterprises' successful positioning and thus their structuring influences on the industry, is identified as a 'success-factor'. Finally, while *'green' mobility anchored in daily life* does not immediately influence the industry's structural-organizational constitution, it can be regarded as an underlying precondition for this to evolve.

According to these findings, and as expected from a theoretical viewpoint, Porter's framework provides a suitable approach for the analysis of structural-organizational aspects. It proves to be relatively comprehensive, covering more facets of industry development than an analysis of a single firm. The descriptive analysis reveals that the framework suitably addresses the research gap of selective and econometric analysis. By approaching different phases of development, the *diamond* also enables the consideration of several dynamic and history-related aspects.

Nevertheless, it proves to also contain weaknesses for the empirical analysis. For example, and as indicated in Chapter 3.1, it is empirically impossible to draw concrete conclusions about the reasons for success by applying Porter's approach alone. Even though it allows descriptions of processes and developments in detail, pointing to concrete influences on the industry's success plays only a minor role in Porter's framework. Thus Chapter 5.2.1's summary cannot provide a concrete conclusion.

The application of Porter's approach extends and structures the researcher's knowledge about the industry, its success drivers, and the backgrounds of development. To address the limitations in generating empirical information, the findings of Porter's approach are supplemented by an empirical investigation of Lundvall's *NSI* in the following Sub-Chapter.

5.3 GERMANY'S *INNOVATION SYSTEM* AND THE EPAC INDUSTRY'S SPECIFICS

To account for the omissions of learning, the role of technology, and innovation in the *diamond* (Ch. 3.1 and 5.2.3), this Sub-Chapter applies Lundvall's *NSI* to the EPAC industry. It differs from the *diamond*-application conducted in Chapter 5.2, as it predominantly focuses on the macroeconomic implications of learning and knowledge exchange within the emerging industry. Following the three development phases described in Chapter 5.1, the industry's development is described in Chapter 5.3.1. As in the previous analysis, Chapter 5.3.2 explores success influences identifiable in the application of Lundvall's framework.

5.3.1 Empirical Application of Lundvall's *NSI* Framework

Following the theoretical approach of Lundvall (1992b) and the analytical structures of Yeh and Chang (2003), Kaiser and Prange (2004), and Umemura (2014), this Sub-Chapter contains a descriptive analysis of the developing German EPAC industry as a sub-system of its *NSI*[15]. Accordingly, the *corporate sub-system* (*internal organization of firms* and *inter-firm relationships)*, the public-sector sub-system (*role of the public sector)*, the *financial sub-system* (*institutional set-up of the financial sector)* and the R&D system (*R&D intensity and R&D organization)* are examined. To avoid an overly narrative description, the single sections conclude with short summaries emphasizing their implications for the EPAC industry's successful development and thus for answering the research question. Despite implementing adjustments to counteract the framework's weaknesses introduced in Chapter 3.2, it is important to consider that – even though an *innovation system* is at the core of analysis – it is not a systemic approach. The emphasized objects are mutually connected, but unlike Porter's *diamond*, the diverse unilateral influences are generally only directed to the *corporate* and the *R&D sub-system*. This nevertheless leads to several interesting findings, clarifying the research question.

[15] In detail, the German *NSI* itself is analyzed by Keck (1993) and Grupp et al. (2002) who focus on historic development; and by Allen (2009), Polt et al. (2010), and BMBF (2016b) who study the structure, performance and specifics of the current system.

CORPORATE SUB-SYSTEM

Since most innovations are developed by firms (Lundvall 1992b, BMBF 2016b), the structure of Germany's enterprises is relevant to its *NSI*. They generate the value-added resulting in national economic advantages. As characteristic of the German industrial sector (BMBF 2016a, Statista 2015a), both SMEs and large enterprises have influenced the knowledge-structure of the *NSI's* EPAC sub-system in different ways over time. Generally, it can be stated that the average amount of investments for R&D within the industry has remained constant at around 1.3% of the annual revenue (destatis 2016:code42231) and that

> many employees within SMEs are all-rounders; whereas the employees in growing companies become more and more specialized (I 2.2).

P1. The first German companies producing mechanical EPAC parts did not have a high degree of professional organization (Ch. 5.2.1). Their 'in-house' R&D consisted primarily of informal knowledge exchanges between workers of different responsibility areas (I 2.2, I 2.5), more commonly known as day to day small talk (Lundvall 1992b). In the event of technological problems, other employees were consulted. Conversely, larger firms producing electro-technical EPAC part could conduct R&D within dedicated departments (I 1.4). They utilized and adjusted existing intra-firm knowledge of related products to the EPAC's parts (I 2.11, I 2.20). Because the industry was comparatively small (Ch. 5.2.1), trust-based, informal knowledge-exchange evolved between participants along the value chain as well as between competitors. Personal relationships led to development partnerships and other formal relations (I 2.3) that aimed to benefit from each other's technical knowledge and jointly create and finance the first high-quality products (Ch. 5.2.1). Thus, the innovative capability in the initial development phase can be described by the "new use of pre-existing possibilities and components" (Lundvall 1992b:8). From the initial development phase onward, inter-firm learning was further stimulated by the influences of *ExtraEnergy e.V.*, an independent association supporting e-mobility in Germany. In addition to other activities, the association conducts product tests and notifies producers of technological shortcomings, enabling product enhancements before market launch (I 1.3).

Expressed in Lundvall's (1992b) language, the corporate EPAC sub-system was initially characterized by different types of *internal firm organization* and *inter-firm relationships* which led to close cooperation and joint R&D. These structural-organizational characteristics influenced the firms' abilities to innovate, learn, and conduct research.

P2. Corporate activities during the professionalization phase were characterized by the increasing participation of companies producing electro-technical EPAC parts (Ch. 5.2.1). Corporate groups utilized and expanded existing internal R&D capabilities. At *Bosch*, for example, two automotive developers were assigned to research an electric drive for EPACs following a corporate analysis of industrial 'future fields' in 2008. Utilizing existing knowledge about automotive technologies and power tools (Huber 2014), *Bosch* was able to develop its prototype of a propulsion system by 2009 (Ch. 5.2.1, Lee 2014). The captive spin-off *Bosch eBike Systems* was founded and staffed with experts for accumulators, motors, sensors, and electronics assigned from other departments within the enterprise (Flaig 2015). The conservative sales tradition allowed dealers to become mouthpieces of the end-user's feedback (Ch. 5.2.1). This was important for further technological improvements, because dealers have acted producer- and brand-independently and are technologically more sophisticated than the conventional end-users (I 2.8, I 2.10, I 2.11). Employees originating in professional cycling, mainly employed by SMEs, were important knowledge sources in R&D (Ch. 5.2.1) as well, because they held dual positions as users and producers. Yet the high costs of implementing such SME-made in-house R&D (I 2.2, I 2.5) emerged as an obstacle to innovation in

start-ups and SMEs. Series productions of new product developments required the manufacturing of specific and expensive tools, which were not always fundable due to unprofitable quantities in guaranteed sales. Necessitated by the search for solutions to such problems in financing R&D, personal *inter-firm relationships* and formal knowledge exchanges increased with industrial growth. Further joint ventures established in this connection (I 2.5), and financially weaker actors, such as mechanically specialized SMEs, solved R&D issues by engaging with specialized suppliers (I 2.5).

> We then participated in a joint venture in Fürth. They developed motors and then specialized themselves – together with us – in EPACs. That was a combination of both know-hows and all could learn from one another (I 2.19).

This development indicates that the corporate EPAC sub-system has not only been related to the EPAC industry's *R&D sub-system*, but has also been negatively influenced by an innovation-hampering *financial sub-system*. The specific structural-organizational *inter-firm relationships* and the structural closeness to *related and supporting industries*, however, partially compensated for this disadvantage. Along with intense communication and resulting technical enhancements, this shaped the industry's internal organization and innovative capabilities.

P3. Following *Bosch's* lead, large engineering companies with cross-departmental problem solving and technology-independent innovation departments began to participate in the industry (Ch. 5.2.1). Such companies have the resources to delegate employees with specialized technical knowledge to specific periods and research projects (I 2.19). Continuously evolving engineering start-ups, partially funded by venture capital, have similarly aimed to establish and professionalize internal science-based development departments (I 2.17). Knowledge is 'obtained' by young professionals formerly educated in electrical and mechanical engineering or IT (I 2.17, I 2.16). Occasionally, such in-house R&D activities have been supported by project funding from federal or *Länder* governments after the EPAC's increasing public visibility.

> There were no more funding applications related to cars. This is the only reason why our project was funded [by the public sector] (I 2.7).

As the industry has grown (App. B), established trust-based inter-firm relations have been joined by replications of competitors' unpatented incremental innovations. Such procedures of learning and unwanted knowledge-transfer have nonetheless facilitated the distribution of technological ideas and have enabled further improvements. The wider availability of dealer trainings offered by motor- and battery-component producers (Ch. 5.2.1), provides advanced informal vocational education and training (VET) to mechanics and has strengthened the feedback channel between dealers and producers. Developments in other industries have further stimulated inter-organizational industrial learning (Ch. 5.2.1). New products, materials or processes are commonly revealed at international trade fairs (I 2.20). Such trade fairs function as platforms for screening the ideas of others, collecting feedback of end-customers or dealers (I 2.17), getting in touch with other industrialists and discussing problem-solving during casual conversations (I 2.14), or even scouting by major firms of innovative product- or process-developing start-ups for potential purchase (I 1.2). Accordingly, trade fairs provide fertile ground for informal knowledge-exchanges and different learning, searching, and exploring processes, which, according to Lundvall's *NSI* (1992b), are crucial to access. As the *Eurobike* is held in Friedrichshafen (Ch. 1), the spatial proximity allows German producers to participate with minimal effort.

The *corporate sub-system* reveals that the innovation-related background of the EPAC industry's development has shifted from an early phase of close cooperation to one of increasing competition

and innovation resulting from imitation during P3. Thus, innovation has been driven by both cooperation and competition. Industrial R&D has remained important and firms have increasingly attempted to establish explicit in-house industrial R&D. Learning, which Lundvall (1992b) labels the most important process for international competitiveness, has been supported by informal and industrial VET arrangements and easy access to one of the world's most important trade fairs. Financial disadvantages have partially been countered by support of the *public sector sub-system* or VC providers. Taken together, this again indicates a close interrelation of the innovative background and the structural-organizational characteristics of the EPAC industry and their mutual dependence.

THE PUBLIC SECTOR SUB-SYSTEM

Another critical aspect for funding innovation in the German *system of innovation* is the role of government and its influence on technology diffusion (Lundvall 1992b). The German *public sector*'s support for industries includes project funding institutional funding or contract research (BMBF 2016a). As indicated above, however, the *public sector sub-system*, played only a minor role for the developing EPAC industry.

P1. Since implementing the EPAC's legal requirements in 1994, the *corporate sub-systems'* and accompanying the *R&D sub-systems'* innovative development has been influenced by the need to meet technical standards and requirements (Ch. 5.4.1). Supportive intervention as addressed by Lundvall (1988) occurred only once. In 1997, anti-dumping duties for Chinese EPAC and bicycle imports were implemented, reducing foreign competition and increasing the attractiveness of R&D of high-quality technologies (I 2.4, I 2.7, I 2.15, Central Customs authority 2016).

P2. The National Cycling Plan (BMVBS 2012) and the National Electromobility Development Plan (The Federal Government 2009) are the two main supportive political instruments to develop EPAC usage and production. The National Electromobility Development Plan was enacted in August 2009 to support research and development of battery electric vehicles, and their subsequent market preparation and introduction. It considers "cars and light commercial vehicles, but it also includes two-wheeled vehicles (personal human transporters, electric bicycles) as well as microcars" (The Federal Government 2009:2ff.). Unlike industry associations such as the German Association of the Automotive Industry (*VDA*), the German Bike Association (*ZIV*), however, has not been included as political partner. Furthermore, no budget has been allocated to support EPAC R&D in Germany (BMVI 2014).

P3. The National Cycling Plan was implemented by federal government and *Länder* in 2012 and runs until 2020. This development plan does not explicitly attempt to strengthen research or funding opportunities for EPACs, instead focusing on infrastructural developments (Ch. 5.2.1). It does, however, aim to address regulatory uncertainties and establish norms and standardized legal interpretations (BMVBS 2012), in addition to implementing required VET adjustments and adapting education in electrical engineering. Along with the National Cycling Plan, 12 EPAC-related funding projects were advanced by the federal government and *Länder* between 2011 and 2016. While grants totaling €13.6 million were awarded for research on infrastructure, transportation systems and usability (BMVI 2014), this accounts for less than 0.01% of all public German R&D funding in the period between 2011 and 2016 (BMBF 2016b). Direct governmental R&D support for the EPAC industry is limited to a few general SME or start-up funding opportunities.

This indicates that state subsidy of the EPAC industry has never been a main priority. It is certainly possible that the EPAC industry might have indirectly benefited from R&D support for other (e-mobility-related) industries (Ch. 5.2.1), due to the established imitation-practices revealed within the corporate system. Similarly, it is possible the implementation of anti-dumping duties might have indirectly increased the attractiveness of developing high-quality products. Nevertheless, state support for the EPAC industry has been indirect and minimal. The *public sector sub-system* has not been an essential influence on the industry's innovative capabilities and thus is not characteristic for successful development. The three phases further reflect the NSI's unilateral relations (one-way influence of *public sector sub-system* toward *corporate sub-system* and *R&D sub-system*).

FINANCIAL SUB-SYSTEM

Independently of the *public sector sub-system*, the *financial sub-system* is generally regarded as critical for a *NSI* as it shapes the start-up, persistence, or expansion of companies and thus influences innovation and technological development (Lundvall 1992b). Since 1992 (Keck 1993), Germany's private economy has consistently provided around 2/3 of all domestically invested research funds per year (Keck 1993, Grupp et al. 2002, BMBF 2016a).

P1. R&D within pioneering companies in the EPAC industry, such as *Ansmann* and *Heinzmann*, for example, was self-financed (I 2.20). Over time, institutional reforms improved the access to VC (Kaiser and Prange 2004, OECD 2016). EPACs and their components have been attractive products for VC funding as investors could be provided with easy understandable proof of concepts (POC) (I 2.17, I 2.3, I 2.18). In 2003, for example, the German start-up *Ultra Motor* aimed to develop propulsion systems for e-mobility. A new POC-EPAC-brand was designed and *Ultra Motor* was funded by Russian VC (I 2.18).

This again, reflects the unilateral rather than systemic relations of Lundvall's (1992b) approach. Within the EPAC's industrial sub-system, public policy and finance are one-way streets toward the generation of innovation within the R&D and *corporate sub-system*. In this first phase, the implementation of innovation and the structure of industrial firms, according to Lundvall (1992b), results from private financial support and self-funding in combination with corporate development partnerships and internal knowledge exchange.

P2-3. Since the beginning of the EPAC's industrial professionalization in 2007, federal funding for R&D for domestic SMEs increased from €783 million to €1.445 million in 2015 (BMBF 2016b), when 16% of the federal state's budget for R&D funding was spent on R&D for SMEs (BMBF 2016a). Large companies received only subsidies in the amount of 1.8% of the total federal funding for their R&D investments. Apart from increasing SME funds, professional business angels, as well as private investors and crowdfunding have continued to invest in start-ups for EPACs and components, enabling product development and participation in the industry (I 2.3, I 2.16, I 2.17). Additionally, the R&D of such start-ups has also been partly financed by *Länder*-owned VC-companies that manage public funds (e.g. *High-Tech Gründerfonds* or *BC Brandenburg Capital GmbH*) (I 2.16). Other start-ups were purchased by major companies seeking to expand their internal capabilities and product portfolios order to participate in the new industry (I 1.4, I 2.7). In 2012, for example, *MIFA* bought the brands *Steppenwolf* and *GRACE* to acquire knowledge

and enter the EPAC industry[16]. In addition to VC or public funds, traditional small SMEs have used self-funding and loans to conduct R&D (I 2.11, I 2.19). *Derby Cycle*, the largest German producer of conventional bicycles, forged a new path of conducting and financing R&D for companies within the German EPAC industry, engaging in a joint venture to conduct the development of its own motor before going public in 2011 to finance the serial production.

This demonstrates how the *financial sub-system* has structured the industrial formation and that corporate knowledge and product innovation, which stimulates the successful development (Ch. 5.2.1), has at least partially been related to financial access. It also reflects that the strategies of accessing finance are currently diverse and not limited to single companies or specific forms of capital provision, which encourages growth in the industry.

R&D SUB-SYSTEM

Finally, and as already indicated pertaining to the evolving EPAC industry, the German *system of innovation* is heavily influenced by the *R&D sub-system* (Keck 1993), which initiates technological process and product improvements for remaining internationally competitive.

Scientific R&D. P1-3. Scientific research has not heavily influenced the EPAC industry. Only in case of isolated technological problems has research been contracted with universities' chemistry or physics departments (I 2.15). Scientific research has, however, influenced the innovative capabilities of related industries and thus indirectly influenced the EPAC industry's successful development. The *Rheinisch-Westfälische Technische Hochschule Aachen* (*RWTH*) exemplifies this indirect interconnectedness. Just recently, in January 2016, it established a research office for e-mobility. Research competencies of different *RWTH* institutes working on automotive engineering, production technology, electrical engineering, acoustics, chemistry, and materials were joined and the *e-Lab* and a prototype factory for R&D on batteries and motor technology was built (RWTH Aachen University 2016). In cooperation with industrial partners, such as *BMW*, *Daimler*, *Rehau*, *Bosch* and *Thyssen*, this organization now enables knowledge-transfers between science and industry, that also benefit EPAC producers. In addition to the *RWTH*, other universities of technology (e.g. *TU Darmstadt, KIT, FH Kiel*) as well as private and state supported research institutes (e.g. *FhG*, *DLR* or *ifeu*) have begun to focus research on e-mobility. Accordingly, university graduates in engineering, who numbered fewer than 19.500 in 1995 and more than 91.000 in 2014 (BMBF 2015, Statista 2016), could increasingly contribute to technical knowledge transfers between science and the EPAC industry through employment, internships, or praxis-oriented theses (I 2.3, I 2.5, I 2.16). Sometimes these thesis findings resulted in the formation of new start-ups (I 1.17). These described influences, however, relate to research on non-mechanical EPAC-parts such as high-performance battery-cells (I 2.8, Neuberger 2010), as the commercial use of mechanical knowledge has not notably been influenced by scientific research. While improvements such as the utilization of carbon fibers or advancements in cranks and gears for mechanical application require highly specific knowledge that can be learned in universities' engineering courses (I 2.1), the application of this knowledge and subsequent development of these improvements occurs within the industry rather than in scientific facilities.

[16] According to *Eurostat* and *destatis* statistical industry data on EPAC's business developments and start-ups does not exist (European Commission 2003; destatis internal information). INDSTAT (2015) only provides data for the years 2007 and 2008 about the aggregated category "bicycles and invalid carriages".

This paragraph shows that even though university research is not primarily influential in the development of the EPAC industry, it might, according to the arguments of Gu and Lundvall (2006), indirectly benefit from a general research interest in e-mobility and the diffusion of expanded basic technological knowledge, as well as from the increasing numbers of graduates in engineering who serve as potential employees. Scientific R&D, coupled with the *corporate sub-system*, has an indirect structural influence on the EPAC industry's development resulting from its close relationship to other related industries that structure the EPAC industry's formation (Ch. 5.2.1). Finally, this section notes a discrepancy in the distribution of scientific R&D as it relates to EPAC production. While promising engineering and technological developments are at the core of scientific research, mechanical engineering receives little attention.

Industrial R&D. P1-3. Industrial research and development functions as an interface between science and the private economy (BMBF 2016a). The German *system of innovation* is generally shaped by strong business R&D in the fields of automotive and mechanical engineering. As observed in the *corporate sub-systems* description, this influences the EPAC's industrial formation and R&D directions, through the transfer of technology to the EPAC (Ch. 5.2.1). *Ansmann* and *Heinzmann*, for example adjusted their existing products to the sizes and functions of EPACs around 1994 (Heinzmann GmbH & CO. KG 2016). Generally, R&D within the German economy relies heavily on major companies (Grupp et al. 2002) and 85% of industrial R&D takes place within companies with more than 500 employees (BMBF 2016b). Such large companies (e.g. *Bosch*, *Brose*, *Derby Cycle*, *Winora* or even the *Rehau AG*) have conducted R&D within the EPAC industry from its optimization phase onward. After *Bosch* began research on its EPAC propulsion system, other automotive suppliers and related firms have tasked their R&D departments and idea shops with adjustments of already existing technology as well (Ch. 5.2.1). Start-ups with limited human and financial resources, however, founded and established R&D through the accumulation of external and commonly accessible knowledge (I 2.17) in either motors, batteries, or complete EPACs. With the exception of a few SMEs and start-ups, financially strong major players dominate due to their ability to facilitate in-house R&D. Financially weaker actors absorb new knowledge through the imitation of previous inventions (Ch. 5.2.1).

As already indicated throughout the preceding sections, innovation within the industry is strongly related to industrial R&D. EPAC improvements rely more heavily on new intra- and inter-industrial findings than on scientific R&D or public research. The success of such industrial R&D is related to the structure and organization of the engaged firms, their conceptions of learning, and access to research financing. Therefore, the innovative backgrounds of industrial success are closely related to the structural-organizational findings revealed by the application of Porter's framework (Ch. 5.2). The performance and success of these innovation influences are, in accordance with Lundvall's *NSI*, briefly presentable as follows:

PERFORMANCE

Due to the 'interaction' of the four 'sub-systems' and Germany's long-lasting and influencing competitive advantage in traditional manufacturing and engineering industries (Grupp et al. 2002, BMBF2016b), the EPAC industry's imports, exports, patent registrations, and employment figures have constantly increased (Ch. 1, App. B). In 2015, Germany was the biggest European sales and production market for EPACs (CONEBI 2016). Production has increased by more than 1000% and sales by more than 750% since 2007. EPAC exports developed from zero units in 2007 up to 140.000 in 2015 (App. B, Fig. 27) and were mainly distributed to the Netherlands, Poland, Austria and other EU countries (ZIV 2016a). Patent developments influenced companies' abilities to

innovate and to investigate technological improvements. *SRAM*, for example, stopped its production of gear hubs as the enterprise could not bypass *Shimano's* patented developments (I 2.1, I 2.15). Patenting figures (App. B, Table 13) further point to the leading position of *Bosch* that emerged during developmental phase 2. Domestic patenting activity regarding electric bicycles in general and EPACs in particular has continuously increased, and most patents applied and registered in Germany originate in domestic and supplying firms such as *Schäffler* or *Bosch.* Lundvall (1992a) ultimately regards this patenting activity as the most important indicator of the success of national knowledge flows and inter-firm learning.

SUMMARY AND IMPLICATION: MERGING THE STRANDS OF THE 'SYSTEM'

This second industry description, guided by Lundvall's analytical language, leads to several conclusions about understanding the successful development of the EPAC industry and its innovation-related and structural-organizational backgrounds.

The description indicates that the structure and organization of corporate interrelations and the *R&D sub-system* have been particularly important for the generation of an industrial potential to innovate. Shaped primarily by several unilateral influences of the *financial sub-system* and secondarily by the *public sector sub-system*, and depending on the firms' size (SME vs. large enterprise) and technological orientation (mechanical vs. engineering), different kinds of innovative capabilities have evolved (see conclusions above). Simplified, this is summarized in Figure 11.

According to Lundvall's framework, the developing German EPAC industry must be understood as a 'sub-system' of the German *innovation system*, which means that industrial enterprises are influenced and interrelated as indicated under (1). The 'sub-system's' innovative capabilities result from learning, knowledge exchange, and R&D, and thus from specific industrial structures and forms of organization, enabling the processes that lead to industrial success. This industry established successfully because learning and knowledge flows between employees within and between firms have always been well established. Formal and informal knowledge exchanges have taken place on a regular basis and range from daily small talk to formal cooperation. Scientific knowledge has been utilized in the form of an employed and well educated workforce. The EPAC industry's research as well as research within related traditional industries from which the EPAC industry could learn has continually been externalized by established imitation and recombination practices. While the government has not significantly funded research within the industry, it has funded research in related traditional industries from which the EPAC industry could learn and enhance its own products. Additionally, industry-specific research and the foundation of start-ups were enabled by self-funding and by the increasing accessibility of VC. These have been important sources of funds and have strengthened the innovative capabilities due to the product's understandable product complexity and utility.

Accordingly, the findings are closely related to the structural-organizational findings framed by the application of Porter's *diamond*. They extend the conclusions drawn in Chapter 5.2. These new insights into the mechanisms of the *public sector sub-system* and the *financial sub-system* as regulatory and partially hampering influences of the industry's development support the application of the *SSP* in Chapter 5.4.

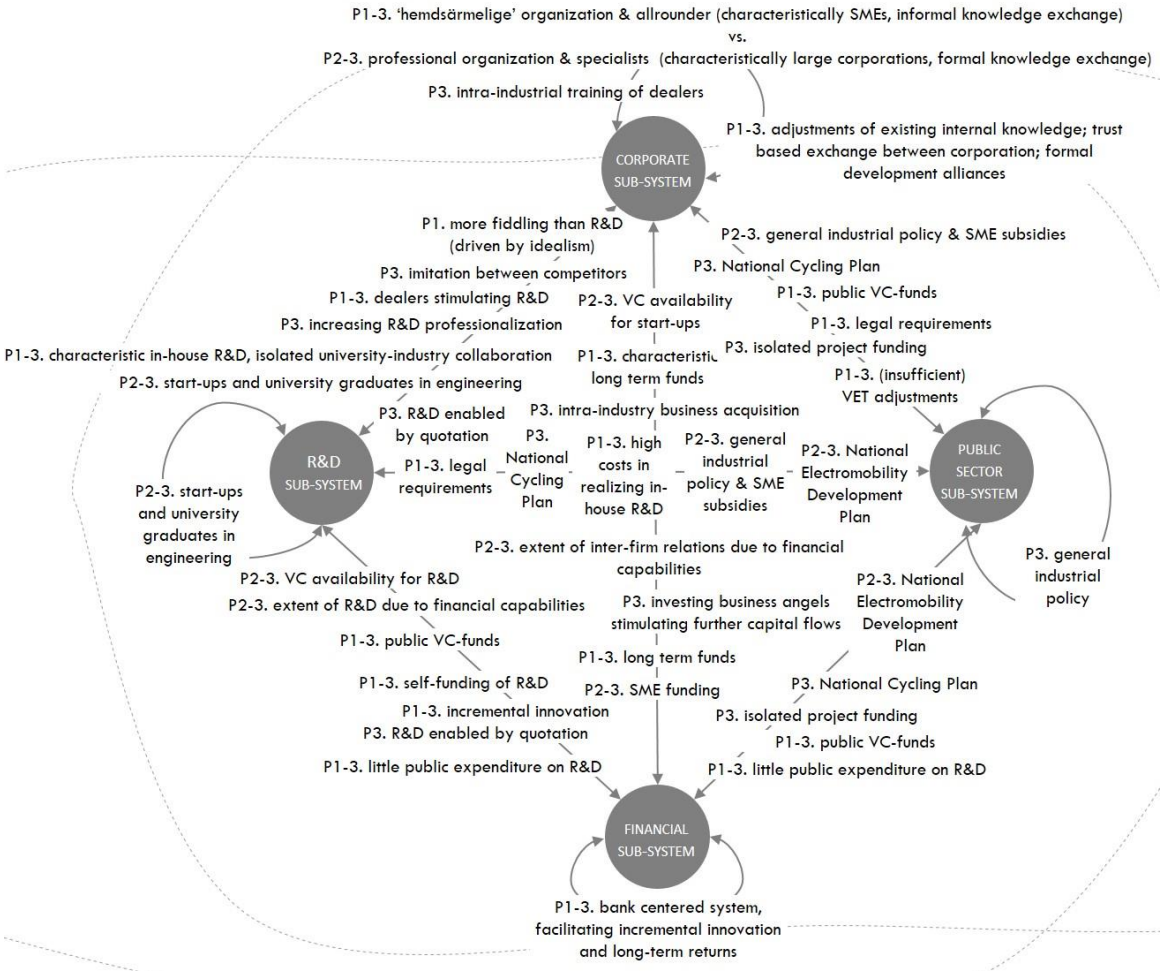


Figure 11: SKETCH – GERMANY'S *NSI* INFLUENCES ON THE EPAC INDUSTRY
(source: author's elaboration)

THE FINDING'S VALIDITY

In a brief evaluation of these results' validity, it can be stated that the development described only partially resemble the results of other applications of the *NSI*. This is a result of the approach's constitution as a framework, the particular nation investigated, and the peculiarities of the industry under review. These are magnified by the framework's diverse and diverging theoretical elaborations and the similarly differing empirical contributions (Ch. 3.2 and 4.1). Umemura (2014:816), for example, who "highlights the varying roles that the components of the system of innovation play in shaping innovative industries," finds that international research collaborations and governmental impact are influential for the Japanese pharmaceutical industry. Similarly to this study's findings, it is argued that the financial system has a limited impact on innovative activities. Another example of a dissimilar result is the case of the Taiwanese photovoltaic industry, where research and development institutes as well as universities are regarded as the most fundamental resources for innovation (Lo et al. 2013). Bartholomew (1997) finds the diffusion of knowledge between scientific and industrial communities and the formation of cross-border alliances most fundamental to biotechnology *NSIs*. Although these previous analyses point to different underlying mechanisms responsible for innovation, what they have in common is the way of understanding the *NSI* as a bundle of (inter-) related single 'systems', 'sub-systems', 'components' and 'elements'.

None of the compared applications describes and analyzes a finally systemic approach. This study is therefore comparable to previous applications of the *NSI* and can be regarded as valid.

In addition to the findings of this Sub-Chapter, and similar to the analysis of Chapter 5.2, this theoretically guided description hints at the existence of additional concrete 'success-factors' that have fostered the industry's successful development. These are analyzed in the following Sub-Chapter.

5.3.2 Exploring Influential 'Success-Factors' Derived from the *NSI's* Application

The application of Lundvall's *NSI* (1992b) extends the understanding of the EPAC industry's successful development to aspects of innovation, R&D, learning, knowledge transfers, financing, and structural-organizational peculiarities. Taking a closer look at this second description reveals four additional influences as particularly important for the successful industry development. Indirectly, the *NSI* points to the specific influence of *informal horizontal and vertical knowledge accumulation, imitation and recombination practices*, *'low' product complexity* and *(in-house) R&D in traditional industries* in framing the development's success. As in the previous analysis, each of these are underscored by two representative quotes and explained regarding their importance in development, theoretical anchoring, and temporal relevance in the following sections.

INFORMAL HORIZONTAL AND VERTICAL KNOWLEDGE ACCUMULATION

> When I do product development, I make use of personal contacts that remained from earlier employment relations first, to see which direction the wind is blowing. I gather all information and then exchange it with my colleagues (I 2.2).
>
> If you know one another, this kind of contact can also exist among competitors. You chat and exchange information. […] The secret matters are kept private. But they are not what makes the difference. Because such would be too early in development as that you could benefit from such information (I 2.15).

The 'success-factor' *informal horizontal and vertical knowledge accumulation* describes the necessary and easily available access to new knowledge within the industry. Low barriers for knowledge circulation and unregulated information exchange all along the value chain enable technical problem solving and R&D progress and stimulate intra-industrial feedbacks.

This 'success-factor' can be identified through the *NSI's* sub-systems' interplay, particularly the interrelation of the *corporate sub-system* and the *R&D sub-system*. It has influenced the industrial growth since the development of the first products during pioneering phase. At first the unprofessional industrial organization and the product's design as a recombined product facilitated personal relations and the trust-based circulation of different technical knowledge bases. Barriers for exchange were low, several employees had competitive sports backgrounds, and informal knowledge exchanges built the basis of formal partnerships, joint ventures and other cooperative relationships that led to a joint development of high-quality products. With prevailing mass production, new forms of knowledge exchange have emerged and actors, for example, have been formally and informally trained regarding the functionalities of new products and processes. Applied research institutes achieved technical improvements in related industries that may have been informally transferred to the EPAC industry, based on the recognition of improvements at

various trade fairs. Similarly, an increasing number of engineering graduates in Germany could have contributed to the informal transfer of scientific knowledge to the EPAC industry. The 'success-factor' has slightly decreased in importance over time, because a general technical knowledge base has been established and the intensive knowledge exchange is no longer as essential as it was in the beginning (Figure 12). Nevertheless, it has generally enabled and facilitated innovation throughout the whole development process.

IMITATION AND RECOMBINATION PRACTICES

> Our bicycle was copied by someone from Berlin. At the trade fair, he even lay down under our bike in order to measure the components. We placed the chain differently than usual and if you've seen that once, you can copy it (I 2.13).
>
> The bicycle has no shell. It's naked. You see all the technology. […] There is nothing like a car body, where you can hide your secrets (I 2.15).

The 'success-factor' *imitation and recombination practices* describes the products' existence as an intelligent rearrangement of already existing products (bicycles, batteries, electric motors). Through continuous adjustment of the development of Germany's traditional industries to the EPAC and intra-industrial imitation, German products have become internationally competitive.

Imitation and recombination practices can be seen in the influences of the *public sector sub-system* on the *corporate sub-system* and the *R&D sub-system* and in the interplay of these two sub-systems. Its influence has continuously increased during the industry's development (Figure 12). In the beginning, recombination was the necessary precondition for generating the new product. Based on the first recombination and the product's introduction to the market, continuous imitation practices became visible. Either actors immediately co-opted suitable technical solutions to apply them in their own constructions, or they seized the opportunity to collect new ideas and recombine them into own solutions. New ideas can be found at different trade fairs and have indirectly been supported by governmental funding of R&D in related industries. The more players entered the industry, the more opportunities existed to imitate or translate other ideas. In the later development stages, as EPACs have become technically more progressive, such ideas equally originate in *related and supporting industries* or the EPAC industry itself and shape today's innovative industry backgrounds.

'LOW' PRODUCT COMPLEXITY

> He told us: It would be wisest for your product to aim for crowd-funding, because people like the product and it's easily understandable (I 2.3).
>
> It's a product one can talk shop with colleagues and friends about (I 2.9).

The 'success-factor' *'low' product complexity* describes the fact that EPACs are easily understandable products. Most of the technology is visible and the mechanics are also easily understandable for laymen – especially compared to other engineering-related products – due to the German's general affinity for cycling. This stimulates demand, facilitates the acquisition of venture capital, and allows for the relatively easy transfer of knowledge.

This 'success-factor' can be identified in the interrelation of the *corporate sub-system*, the *public sector sub-system*, the *financial sub-system* and the *R&D sub-system*. It has never been one of the most important 'success-factors', but has nonetheless encouraged development. The increasing

national recognition of e-mobility, and similarly of EPACs, has stimulated the formation of businesses. It has eased the access to VC and private investments as technical laymen-investors have become aware of the potential future mobility type and have been able to easily understand the product's benefits and functionality. Due to the comparatively *'low' product-complexity*, start-ups have also been able to develop their products and acquire new knowledge by simply taking a look at other already marketable products and conducting product tests. Similarly, dealers with professional backgrounds in mechanics have easily understood the new products and have supported intra-industrial feedback and rapid technological developments. Accordingly, this 'success-factor' has influenced the industry's innovative background throughout all phases of development.

(IN-HOUSE) R&D IN TRADITIONAL INDUSTRIES

> There is one department whose only task is to create ideas and technical solutions that could be applied in any of our products. These engineers come up with new ideas for whatever. That's how we benefit from other industry-competencies in the EPAC section (I 2.10).
>
> They invested far more than €100 million. Obviously not everyone can do that. […] Brose in turn, as an automotive supplier knows the automotive market and the German market in general. Due to their processes, quality-systems, and financial background they could easily enter the market (I 2.18).

The 'success-factor' *(in-house) R&D in traditional industries* describes the influence of R&D within companies originating in traditional *related and supporting industries*. Technical progress is notably made by financially strong and traditional companies that have the capabilities to conduct in-house R&D which then radiates to the rest of the EPAC industry. It thus enables high-quality developments and guides the industry's technical orientation toward their fields of competence.

This is identifiable due to the relations between the *corporate sub-system* and the *R&D sub-system* and the influences of the *public sector sub-system* and the *financial sub-system* on both. The 'success-factor' became especially important when financially strong and research intensive companies such as *Bosch, Brose,* or *Continental* entered the industry during the beginning transition phase around 2008. Intra- and inter-industrial knowledge accumulation increased as a result of the EPAC industry's relations to such traditional *related and supporting industries* with strong, self-funded (in-house) R&D departments. In pursuit of technical improvements, large traditional companies have facilitated intra-firm feedbacks between different employees and departments, or increased their R&D capacity through strategic acquisition. Additionally, the large traditional industries receive more political and scientific attention and enjoy more access to public funds and scientific knowledge through cooperation with applied research institutes. The patenting activities reflect this (App. B, Table 13, e.g. Phase 3 EPAC-patents). *Bosch*, for example is strong in fine electronics, and *Schäffler* is a traditional supplier producing components and systems in engine, transmission, and chassis applications, as well as roll- and plain-bearing solutions for industrial applications. Due to the EPAC industry's imitation-characteristics and workforce with employment backgrounds in such traditional industries, this 'success-factor' has continuously stimulated knowledge diffusion toward the EPAC industry and its technological improvements.

SUMMARY AND IMPLICATION: AFFECTING 'SUCCESS-FACTORS'

This Sub-Chapter identifies and explains different 'success-factors' crucial for the successful industry development according to the findings of Lundvall's approach. The 'success-factors' are indirectly addressed by the interrelation of EPAC-related learning, knowledge generation, and R&D within the *NSI's corporate sub-system*, *public sector sub-system*, *financial sub-system* and *R&D sub-system*. As illustrated in Chapters 5.3.1 and 5.3.2, not all these interrelated factors are equally important in each phase of the development. In the beginning of the industrial formation, *informal horizontal and vertical knowledge accumulation* was most important for the *NSI's* EPAC-subsystem, enabling technical recombination and thus the initial construction of a suitable product. With time, not only recombination, but also imitation has become increasingly important as a core practice for product improvements. Widespread *imitation* has been aided by the product's comparatively '*low' complexity* and technological improvements introduced by companies that heavily invest in *(in-house) R&D*. Their developments have subsequently been adapted by EPAC producers. Along with the general acceptance of most important technologies and the establishment of a basic industrial knowledge base, the importance of the *informality of knowledge exchange* and the *product's 'low' complexity* has waned. Actors rely on known information. From a temporal view, these mutually dependent relations are visualized in Figure 12.

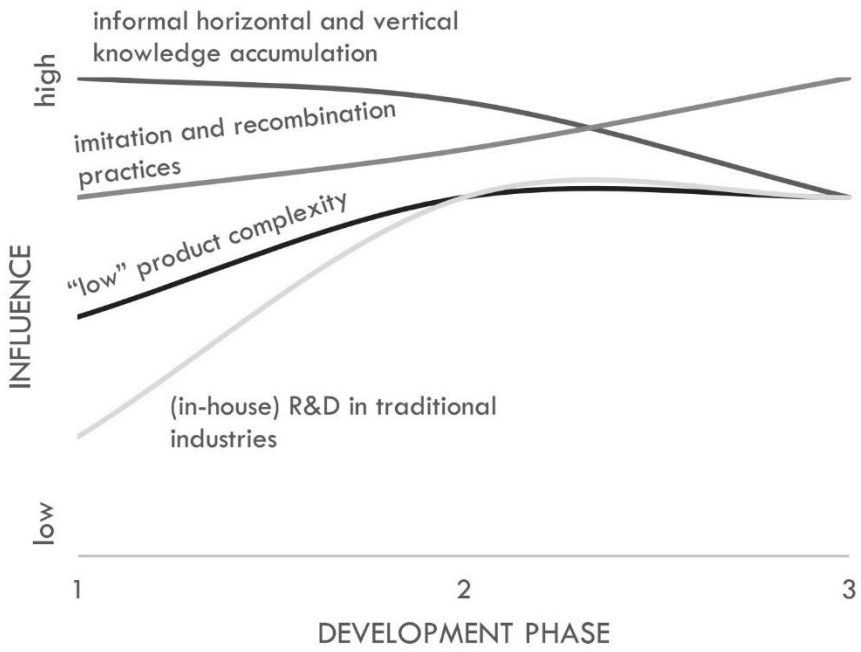


Figure 12: SUCCESS FACTORS DURING THE PHASES OF INDUSTRY DEVELOPMENT ACCORDING TO LUNDVALL'S FRAMEWORK
(source: author's elaboration)

THE FINDING'S VALIDITY

Compared to other studies that reveal industrial 'success-factors' based on the application of a *NSI*, the findings of this study are unique. Yeh and Chang (2003), for example, examine the Taiwanese machine tool industry and determine that the government, flexibility, prices in production, and close ties between users and producers are the most important 'success-factors'. Lo et al. (2013) identify the support of R&D facilities, the government's role, or the access of specific physical resources as

most influential in their investigation of the Taiwanese photovoltaic industry. Other industry studies that do not explicitly apply the *NSI* to investigate 'success-factors' (App. D) do, however, reveal several similar findings. Chu (1997) who investigates the Taiwanese bicycle industry, Chaudhary (2014), who researches on e-mobility in India, and Braguinsky (2015) who focuses on the cotton spinning industry in Japan, identify the quick accumulation of learning and the diffusion of (diverse) technical knowledge as important influences. This was facilitated by import-substitution (Chu 1997), investments in in-house R&D, and actively building knowledge linkages (Chaudhary 2014), as well as the "movement of individuals possessing relevant knowledge and experience" and a "diversity of knowledge sources and their unfettered competition" (Braguinsky 2015:3ff.). Other studies dealing with mobility industries similarly consider technical complexity and other technological influences important (Boschma and Wenting 2007, Altenburg et al. 2015). All these studies identify diverse similar or differing 'success-factors' important for an industry's successful development. As already explained in Chapter 5.2.2, the findings are explicitly related to the specific cases and cannot be generalized. Reflecting on the logical reasoning outlined in the conclusions of Chapter 5.2.3 as to why the identified influences should be emphasized as 'success-factors' in the EPAC context, however, demonstrates that these are reliable results of analysis.

All findings are finally summarized and related to the limitations and contributions generated by the application of Lundvall's *NSI* in Chapter 5.3.3.

5.3.3 Interim Conclusion and Reflection: Lundvall's Limitations and Contributions

Similar to the findings of Chapter 5.2, Lundvall's approach toward understanding national competitiveness helps retrace the EPAC industry's development in various respects and is limited in its contributions in other respects. To reflect the value of applying Lundvall's *NSI*, its most influential strengths and weaknesses are visualized in Table 8 and summarized in the empirical context below.

Table 8: IMPORTANT CONTRIBUTIONS AND LIMITATIONS OF THE *NSI* ON THE EMPIRICAL CONTEXT (source: author's elaboration)

	CONTRIBUTION	LIMITATION
empirical	reveals the role of innovation and structural-organizational aspects related thereto reveals the innovation-related background of industrial learning, R&D and knowledge-generation emphasizes the industrial relations that are connected to technological improvement and how they are shaped points to the influences of financial and *public sector* on the constitution of R&D and corporate relations	provides an incomplete picture, due to narrow focus on innovation-related aspects
conceptual	addresses the gaps of exclusively existing econometric analyses and of insufficient consideration of nations, institutions, knowledge and learning relatively extensive picture of innovation-related aspects	mostly considers only unilateral relations is far from a systemic viewpoint theoretical concept too vague for expedient empirical application theoretically argues with societal embeddedness of processes that enable innovative surroundings, but does not consider this for the 'applicable' concept no concrete conclusions possible very narrative character rather than scientific over-simplified reality, thus not every influence identifiable

Similar to the findings of Chapter 5.2, and as indicated in Table 8, the innovation-related industry development identifiable through Lundvall's terminology show that their structural-organizational backgrounds are important to understanding the industry's evolution (Ch. 5.3.1). Lundvall's contribution to answering the research question can be summarized as follows:

Only due to the interrelations and interaction between employees within or between firms does learning and knowledge accumulation become possible. This interaction was a necessary prerequisite for the industrial formation, because actors could informally learn from each other's competencies and develop suitable products. In combination with R&D financed by businesses, government, or VC and conducted in the industry or in related industries, imitation practices evolved to successfully drive the innovative capabilities of the industry. A broad industrial knowledge-base solidified. This knowledge-base, together with the product's relatively 'low' complexity encouraged the industrial participation of further start-ups, spin offs, and related companies that either developed new products based on recombination and adjustments or imitated already existing product innovations. The innovation-related background of development is crucial to the industry's successful development, as it enables the improvement of products on a high-quality basis, contributing the excellent reputation of German firms and subsequent demand of their products (Ch. 5.2).

These findings are supported by revealing further 'success-factors' important from Lundvall's viewpoint. *Informal horizontal and vertical knowledge accumulation, imitation and recombination practices, 'low' product complexity* and *(in-house) R&D in traditional industries,* have influenced

the industry's successful development until today. All these factors are related to an innovation-related industrial background. With the exception of '*low' product complexity*, all of these 'success-factors' indicate innovation-related industrial structures and forms of organization that are coupled to its successful development. Moreover, the *informal horizontal and vertical knowledge accumulation* hints to the existence of specific forms of coordination and potential intra-industrial regulation.

According to these findings, as expected from a theoretical framework and similar to the contributions of Porters approach, this approach contributes toward analyzing the EPAC industry's innovation-related backgrounds and structural-organizational and institutional-regulatory conditions. As called for, it additionally considers nations, partially institutions, knowledge, and learning to research industry development, and provides a relatively extensive picture of all innovation-related developments.

Nevertheless, and as indicated in Chapter 3.2 there are various conceptual issues limiting the applicability and explanatory range of the approach. For example, it unfortunately does not provide a systemic view on the innovation-related industry developments. It does not specifically address interconnections and feedbacks and only the researcher knows that each of the *NSI's* 'sub-systems' is important for the overarching picture. This is not systemic. Rather, and as already criticized by Edquist (2006:203), the *NSI* application provides more of a 'label' or a subsequent description of single aspects (e.g. Keck 1993, Umemura 2014, Edquist and Lundvall 1993, Gu and Lundvall 2006). This hampers the generation of a comprehensive picture of the developing EPAC industry.

The fact that the "system must be kept open and flexible" (Lundvall 1992b:10), makes its empirical application even more difficult. Despite the operationalization developed in Chapter 4.1, it is not clear what exactly deserves attention. No analytical procedure can be derived from Lundvall's theoretical introduction (1992) or the exemplary empirical applications (e.g. Edquist and Lundvall 1993, Gu and Lundvall 2006).

Additionally, because of Lundvall's very vague conception, all findings might only be a part of what else could have been identified in relation to the EPAC industry's innovative background. Although his *NSI's* definition is intuitive and cannot be contradicted, it is not differentiated enough to be narrowed down to very concrete findings. Despite a more cautious application of the framework and careful operationalization of potentially relevant data, findings partially remain unintegrated and unconcrete due to omissions in theoretical conception. Accordingly, the approach's most fundamental weakness is being too 'broad'. To partially counteract this weakness, the 'success-factors' mentioned above are disentangled from the description and separately identified and explained.

Due to the subsequent rather than systemic character of all potential blueprints, temporal dynamics and an evolutionary view cannot be captured in great depth. Because the reviewed publications present different points or periods in time which are then compared (e.g. Keck 1993, Umemura 2014, Edquist and Lundvall 1993, Gu and Lundvall 2006), the approach's application is less dynamic than expected from the theoretical discussion in Chapter 3.2. An effort was made to counter this through references to the different phases of development.

Like the *diamond*, and as discussed in Chapter 3, the approach also does not properly consider regulatory influences. Although it refers to the *public sector sub-system* and the *financial sub-system*, their regulatory influences are exclusively coupled to knowledge-related aspects and thus insufficiently considered.

Despite these very fundamental weaknesses, it must finally be stated this (very subjectively guided) application of the *NSI* nonetheless reveals several findings extending Porter's results. In order to address the empirical gap regarding the above mentioned coordinative and regulatory influences on the industry's development, Chapter 5.4 finally applies Hollingsworth's and Boyer's *SSP*-framework to conclude this thesis' empirical investigation.

5.4 GERMANY'S *SOCIAL SYSTEM OF PRODUCTION* AND THE EPAC INDUSTRY'S SPECIFICS

Chapters 3, 5.2 and 5.3 all show the necessity of adding a third approach to the analysis of Porter's (1990) and Lundvall's (1992b) frameworks that emphasizes the idiosyncratic institutional, regulatory, and coordinative backgrounds of the EPAC industry's development. Thus, the *SSP* is applied to the industry in Chapter 5.4.1. As in the previous analyses, Chapter 5.4.2 again explores 'success-factors' identifiable in the application of the *SSP*.

5.4.1 Empirical Application of Hollingsworth's and Boyer's *SSP* Framework

Following the theoretical approach of Hollingsworth and Boyer (1997b) and the analytical structures of Hollingsworth (1997) and Moszyński (2015), this Sub-Chapter presents the German *SSP*[17] and descriptively analyzes its influences on the developing German EPAC industry. The national coordination modes of the *industrial relations system*, the s*ystem of training of workers and managers*, the *society's financial markets*, and the *structure of the state and its policies* are therefore analyzed, in consideration of *the internal structure of corporate firms*, *the relationships of firms*, *the conceptions of fairness and justice*, and *the society's idiosyncratic customs and traditions as well as norms, moral principles, rules, laws, and recipes for action*. To avoid a rambling narrative description, the single sections conclude with emphasizing their implications for the EPAC industry's successful development and thus for answering the research question.

FRAMING CONDITIONS

Ludwig Erhard (1957) and Alfred Müller-Armack (1981) argued that a combination of commonly accepted norms and values have created a moral basis for the German economic order. According to the two economists, these values include freedom, self-responsibility and solidarity, and "form the foundation for institutions that constitute the rules of the game for companies" in Germany (Moszyński 2015:17). In the EPAC industry (P1-3), intra-industrial solidarity is especially visible. Industrial actors, for example, meet on a regular and un-competitive basis (I 2.12), motivated by a characteristic and product-related attitude:

> If you take a closer look at the dealers, they are no typical merchants. They are craftsmen who deal with a product they like to work with. And I think it's the same thing within the whole industry (I 2.12).

[17] Due the national focus, Hollingsworth and Boyer (1997a) relate timely developments to large time spans rather than to only the last 22 years. Thus, the *SSP* is described without an explicit emphasis of single EPAC-development phases. If possible, however, timely references are made within the text.

This unifying attitude also shapes the configuration of moral principles and social values that influence the economic coordination of the EPAC industry's actors and thus the whole industrial structure and organization.

SOCIETY'S FINANCIAL MARKETS

In Germany, banks like *Deutsche Bank* or *Commerzbank* have long been more important in supplying capital to firms than equities and bond markets (Ch. 5.3.1, Hollingsworth 1997). German bank officers serve on the supervisory boards of hundreds of large German companies and as board chairmen in numerous firms. Additionally, banks exert influence on large companies through ownership of substantial proportions of voting rights on the enterprise shares. As a result, banks are able to engage in coordination of several German firms through asymmetric power constellations. They influence corporate strategic orientation with the outcome of increasing companies' profit orientation (ibid.). German companies have recently enjoyed growing independence from large banks due to political reforms strengthening the accessibility of VC (Ch.5.2.1 and 5.3.1), an increasing share of retained earnings, and the increasing influences of savings banks and regional banks (Hollingsworth 1997).

The EPAC industry has always been comparatively small and was initially characterized by an unprofessional organization (Ch. 5.2.1 and 5.3.1), so cross-shareholding and bank engagements have never been of significant relevance (P1-3). Large banks have rarely served as crucial capital providers, because most industrial companies are SMEs with personal house-bank relations (e.g. *Sparkasse* or *Volksbank*) or with so-called 'sustainable banks' (e.g. *GLS Bank*) (I 2.2, I 2.11, I 2.13). Only Germany's biggest EPAC producer by numbers, *Derby Cycle Holding GmbH*, and a few large producers of electrical components (e.g. *Continental AG*) have ever been publicly traded companies (P1-3, Ch. 5.2.1). *Continental* is one of the EPAC industry's listed big players (WKN: 543900 / ISIN: DE0005439004) and its supervisory board includes, amongst others, the chairman of the board of management of the *Norddeutsche Landesbank Girozentrale*, a regional rather than a large national bank. The accessibility of VC and other private funds has been of outsized importance for start-ups and developing SMEs (P2-3) within the EPAC industry (Ch. 5.2.1 and 5.3.1). Depending on the type of agreement on private funds (e.g. only VC, specific obligations, or active shareholding), companies have been to varying degrees independent in their strategic orientation or influenced by some kind of private hierarchy strengthening the dependency on capital providers (I 2.3, I 2.16, I 2.17).

Accordingly, there has not been a single ideal mode of financial coordination within the EPAC industry. In relation to the size, product type, and strategic orientation, varying financing constellations have emerged associated with varying degrees of regulatory influence. Thus, unlike in other industries (Hollingsworth 1997), and due to the prevalence of SMEs in the industry, strong bank-influences and regulations are not present.

INDUSTRIAL RELATIONS 'SYSTEM'

Generally, German firms perform well in traditional industries and have been successful in applying the latest microelectronic technology to the production of traditional products and to new production processes (Hollingsworth 1997), of which the EPAC is an excellent example.

Hollingsworth (1997) argues that it is the specific type of the German *industrial relations system* which is conducive to the rapid diffusion of the latest technology to the production of more

traditional but high-quality goods. He maintains that essential to the German *SSP's industrial relations system* is the firms' embeddedness in a highly developed civil society, shaped by strong centralized employer and business associations as well as trade unions and work councils[18]. Unions are responsible for collective bargaining and participation in corporate boardrooms, while elected work councils participate in organizing working conditions inside firms and ensuring that employment protection laws are obeyed by management. This minimizes conflicts between labor and management and enables an enhanced flexible production within firms. It not only plays an important role in shaping distributional issues but also influences the quality and international competitiveness of German products (ibid.). The influence of works councils, trade unions, and employer or business associations increases in conjunction with companies' sizes.

Due to the EPAC industry's SME structure (Ch. 5.2), work councils are relevant only for the largest EPAC part suppliers (e.g. P2-3 *Bosch*, *Brose*, *Continental*, or *BMZ Karlstein GmbH*), and indirectly support their competitive positioning. Based on internal hierarchies as described by Hollingsworth and Boyer (1997b), only the automotive supplier *Brose* negatively stands out in the news for its non-compliance with court decisions on employment protection and respectful internal interaction (e.g. Bayrischer Rundfunk 2015) (P3). Excluding EPAC part producers, *Derby Cycle Holdings GmbH* is the only German EPAC producer large enough to set up a work council (P1-3). Similarly, labor within the industry has rarely been unionized. If so, it has been organized within the *IG Metall*, which is responsible for employees from technical trades and electrical engineering, among others. Since much industrial interaction has been shaped by social values, personal relations, and trust (Ch. 5.2-5.3), unionization has not been as important as in other industries. Instead, superordinate industry representation is important for the EPAC industry (P1-3). This role is held by the German bicycle industry association (*ZIV*), which traditionally represented the conventional bicycle industry's interests. In 2007, it integrated EPACs into its portfolio. With over 80 manufacturing members, today it represents the domestic producers of more than 80% of all conventional and electric bicycles manufactured within the country (ZIV 2016b). Even though more than 120 domestic EPAC brands and 40 domestic EPAC component brands supply the German market (App. A, Fig. 22-23, Tab. 10-11), most of them have market shares of less than 0,1% (I 2.11). Thus, the *ZIV* is commonly regarded as representative of the industry's interests – also for non-members of the association (I 2.2, I 2.3, I 2.4, I 2.8, I 2.11). Especially during the early stages of industrial professionalization (P2), the *ZIV* managed to bring national competitors together to discuss business environments, trends, market forces, and future development (I 2.12). Different committees work, for example, on EPAC regulations for the national and European level or on the establishment of charging standards (I 2.2, I 2.4, I 2.6). The results are presented at different spatial and political levels. On the European level the *ZIV's* interests are bundled in the overarching European association *CONEBI*, which represents 14 EU countries. In addition to the *ZIV*, several other associations organize the industry. The *vsf.* represents the interests of around 300 German EPAC dealers and is engaged in retaining high-quality products. The trade guild association for bicycle mechanics (*BIV*), in turn, is responsible for craft-related VET and influences the occupational profile of the bicycle mechanic. The independently established association *ExtraEnergy e.V.* (Ch. 5.3), in turn, aims to sensitize citizens for e-mobility in general and LEVs in particular. It performs educational work rather than immediate coordination functions (Manthey 2010),

[18] The German Trade Union Federation (DGB), founded in 1950, consists of 8 industrial unions with a total of 6.095.512 members today (DGB 2016). Employers, in turn, are organized in the Confederation of German Employers' Associations (BDA), a federation of 50 sectorial employer associations and 14 *Länder* associations (BDA 2016).

indirectly influencing product qualities by conducting quality tests and forcing producers to enhance their products (Ch. 1 and 5.3).

As observed, all associational work coordinates and regulates the EPAC industry's internal structuring from different angles, supports an increasingly professional organization, and offers an excellent example of how closely the research question's sub-aspects are related to each other.

Compared to countries such as Japan or the U.S., Germany generally demonstrates that diversified quality forms of production work best in environments that facilitate collective behavior (Hollingsworth 1997). German industry is characterized by vertical disintegration, so the most common types of inter-firm organizations are networks linking various actors together, subcontracting and cooperative contracting, joint ventures, and strategic alliances (ibid.). This quality of the German *SSP* is reflected in the evolving EPAC industry (P1-3), which is structured by trust-based communities, networks, joint ventures, and other forms of cooperation (Ch. 5.2-5.3). Community coordination for example, has strongly influenced the EPAC industry's organization. Actors know each other (P1-3) from annual meetings (e.g. trade fairs), working groups, or former professional relations (I 2.7, I 2.9). Based on trust and independently of concrete cooperation (P1-3), they talk about suppliers, problems, or even their personal lives (I 2.8, I 2.16).

> We are just friends and know each other. […] We don't realize concrete projects together but we talk every now and then and exchange our experiences with suppliers. This openness might be noteworthy, since we recommend our suppliers to one another when we've had good experiences (I 2.16).

Taking all interview partners as an example, the density of such community-based interaction and exchanges is related to the companies' size, the professional attitude of internal organization (P1-3, Ch. 5.2-5.3) and the framing values previously introduced. Smaller and more open organizational structures correlate with more intensive personal interaction. Even in the case of recognizing previously jointly discussed developments in competitors' products, some industrial players would initially presume unintentional behavior or a misunderstanding rather than exploitation (I 2.8). Similar to the work of associations, communities also result in some joint lobbying (P2-3). For example, a so called 'EPAC-Festival' took place in Dortmund, in the densely populated Ruhr Area, in April 2016.

> We noticed that EPACs are underrepresented regarding solutions for topics such as CO_2-reduction, mobility in cities or traffic problems in general. […] Thus we thought, we should popularize this topic for potential customers. […] So we united and organized this festival, where the whole industry was represented. That means, not only *Bosch* was there, but also *Alber* and *Go Swiss Drive*, etc. […]. From *Cube* to *Stevens*, all EPAC producers presented their concepts and we provided between 500 and 1000 EPACs for test rides (I 2.4).

Such overarching and established communities further influence the industrial organization, according to Hollingsworth and Boyer (1997b), because they simplify and facilitate professional cooperation, networking and other alliances (P1-3). For example,

> just now, one asked for help. In his first e-mail he asked: 'I'd just like to know how you grew so fast and which steps to take.' […] So we had an intense personal talk. He then took one of our bikes and is now going to combine it with his own ideas (I 2.13).

Resulting development partnerships, joint ventures, and other forms of cooperation (Ch. 5.2-5.3) occur horizontally or along the value chain. They channel technical product or process development and thus coordinate and indirectly regulate the EPAC's technical orientation and quality (I 2.2, I 2.6, I 2.10, I 2.11). The core moral principle framing economic interaction within the industry is

of trust-based and collaborative character (P1-3). It is shaped by the moral obligation of sharing technical knowledge and problems with collaboration partners, as well as by a deep sense of justice (I 2.5, I 2.8, I 2.11). Grounded in these social and moral values, the typical German characteristic of producing high quality products is reflected in various EPAC production strategies as well (Ch. 5.2.1), because producers feel obligated to provide customers with safe and stable products.

These observations indicate that the industry's internal structure and organization is largely shaped by collective forms of coordination, rather than self-interest action motives. In keeping with these values, cooperation is simplified, enabling joint lobbying and problem-solving. These circumstances facilitate technological improvements and lead to success.

Between industrial players, however, hierarchies, markets, and self-interest action in general have also influenced the industry's development in some respect. When the industry began to grow faster, the considerate behavior described above met actors with diverging moral action motives, social values, and senses of justice (P3, Ch.5.3.1). Some players have aimed to maximize utility at the expense of development cooperation and other alliances. For example,

> back then we voluntarily collaborated regarding the purchase of standard components. Every distributor was responsible for certain components which got us better profit margins. The sales regions were spatially divided, but then somebody started also selling in Baden-Württemberg. It became a mess and the cooperation ended soon after (I 2.11)[19].

Self-related action motives also appear in hierarchies on an inter-firm level (P.2-3). Several large companies hold strong (e.g. *Bosch*) or even monopoly (e.g. *Shimano*) market positions (Ch. 5.2-5.3) and constitute inter-firm hierarchies. Their high-quality products are in demand and force competitors toward small niches or even to stop production (I 2.11, I 2.20). Market forces affect the industrial structure's constitution as well. The demand for high quality products 'made in Germany' has both encouraged qualitative competition within the existing market[20] (Ch. 5.2, Hollingsworth and Boyer 1997b), and triggered an increasing participation of new companies (P2-3), further influencing the EPAC industry's coordination.

> More and more electronics groups are joining, even though they had no relation to bicycles. But they sense that the sector is growing rapidly and they want their piece of the pie (I 2.5).

Accordingly, self-interest action motives influence and regulate the EPAC industry's development and exert economic pressure on participating companies. They are not, however, the guiding or dominant motives of industrial coordination. Among producers, established industrial actors engaged in small companies rather feel the need for even more networking and partnerships to counteract instabilities and insecurities and to stabilize their position (I 2.8, I 2.11) in the face of these rapid changes. Thus, the industry is still strongly shaped by cooperation and thereby successful.

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[19] Generally, intra-industrial sanctioning of such behavior is possible only in case of clear patent infringements or when deciding with which industrial players to interact. Such decisions are based on the exchange of information in personal relationships and communities (I 2.11, I 2.16).

[20] The high-quality products have been in high demand (App. B) in Europe. Germany, the Netherlands, Austria and France have been the largest sales markets for the German products (internal ZIV data 2016).

'SYSTEM' OF TRAINING OF WORKERS AND MANAGERS

Resulting from the strong associational and unionized structure in Germany, labor has enjoyed high job security since the 1950s. Codetermination policies encouraged domestic firms to invest in the long-term training of their labor force. The German Works Constitution Acts of 1952, 1972 and 1976 resulted in a high-wage, engineering and high-skill intensive system with diversified and high-quality procedures (Hollingsworth 1997). When management realized it could not easily dismiss workers in the event of economic adversity, it had an incentive to engage in the investment in employees with skills high and broad enough to adjust to complex and rapidly changing technologies and unstable markets. Grounded on these investments by domestic firms in training their workforce, a relatively high degree of trust is typical in labor-management relations in Germany today (ibid.). The employees and employers within the EPAC industry benefit from these general national standards, as they apply equally to all national workers. Skill investments within the EPAC industry occur in the form of informal inter-firm training along the value chain (P3, Ch. 5.2-5.3). It has become common for motor-component producers such as *Continental, Bosch, Brose, Heinzmann, Shimano, Alber,* etc., to offer trainings for their dealers and EPAC-producing customers (I 2.4, I 2.10). They also provide tools as well as support during error analyses (I 2.20). Generally, however, a high skill-intensity is only required (P1-3) for product and process-related R&D (I 2.15), which is why even more intense VET is not a major focus for further developing the industry.

In addition to domestic investments in skills, a dual education structure has evolved in Germany and as a result, domestic firms have developed one of the world's most skilled labor forces (Hollingsworth 1997). Due to this education structure, German intra-firm hierarchies are comparatively low, because workers are involved in both conceptualizing and executing projects (ibid.). The educational structure within the EPAC industry, however, is not related to the dual system. Conventional bicycle manufacturers train bicycle mechanics, while manufacturers of motor and battery components employ engineers with university training. A joint education of both subjects, specifically related to EPACs, exists neither as a university course of study, nor as dual or enterprise-based training (I 2.3, I 2.8, I 2.19). Instead, incongruities abound:

> We sent our apprentice to his examination for his master craftsman certificate and he came back without any knowledge about EPACs. The chamber of crafts does not pass on this knowledge so far. In an examination you have to disassemble and assemble a 7-gear-hub. You don't do that anymore. If there's something broken, you send it to Shimano. But to repair an electric motor or to solder a broken cable, that is what is important today and that is something every qualified bicycle mechanic should be able to do (I 2.8).

VET adjustments are, however, part of the National Cycling Plan (Ch. 5.3), where the BMVBS declared an intention (P3) to "consult with the federal states and organizations representing employers and employees to determine whether, and if so to what extent, the training of cycle mechanics needs to be adapted. This will involve including aspects of two-wheeled electric mobility in the corresponding training regulation" (BMVBS 2012:49). This again, stresses the important position of the domestic associations. Otherwise, the EPAC industry indirectly benefits from dual education in other industries, since such provide EPAC producers with a skilled workforce. Additionally, employees within EPAC-producing companies work together closely and share their individual and partially tacit knowledge based on personal trust relations (Ch. 5.3) and social values. This encourages low hierarchies similar to those resulting from dual education structures. According to Hollingsworth (1997), the German system of dual training has led to a strong emphasis on product quality. It increases opportunities for long-term close cooperation between assemblers

and suppliers in quality control and product R&D, which is likely reflected in the EPAC industry (P1-3). Thus, it indirectly influences the industrial structure and supports the cooperative internal (innovation-related) organization.

STRUCTURE OF STATE AND ITS POLICIES

In Hollingsworth's and Boyer's (1997b) terminology, Germany's democratic federal government policy aims to regulate, sanction or strengthen the links among the coordinated elements introduced above through indirect forms of intervention. The national social policy supports and encourages compromise between capital and labor in order to finance social peace. It advocates stability, social security, and social justice (Kocka 2006). Furthermore, the federal government provides public goods such as the dual education system, R&D funds, or specific policies (Ch. 5.3, Hollingsworth and Boyer 1997b, Moszyński 2015) relevant to the processes of the production of goods and services (Hoffmann 2003). As indicated (Ch. 5.2-5.3), both education and R&D funds affect the EPAC industry indirectly (P1-3). Public policies engineered by at least one of four federal departments (BMVBS, BMVI, BMUB, BMWI) responsible for e-mobility topics are limited to isolated cases (P1-3, Ch. 5.2-5.3). On the *Länder*-level, development plans comparable to the federal ones, like the *Masterplan Bicycling 2025* (Berlin) or the *RadSTRATEGIE* (Baden-Württemberg), consider EPACs' infrastructural needs (e.g. charging stations) and thus might indirectly stimulate an increasing national product-demand. Additionally, the German federal government has developed forms of protection to limit foreign competition, and *Länder*-owned banks are engaged in providing VC or financing start-ups (Ch. 5.3).

Germany's national idiosyncratic laws and technical directives specifically regulate the directions of technical development, quality, and production standards in different industries (Hollingsworth 1997). The EPAC industry has been coordinated by regulations of the *Straßenverkehrsordnung* (StVO), and directives for batteries (2006/66/EG), electromagnetic compatibility (2004/108/EG), approval for two-or three-wheeled motor vehicles (2002/24/EG) or machineries (2006/42/EG), as well as the dangerous goods regulation (DGR), the European agreement concerning the international carriage of dangerous goods by road (ADR), the worldwide agreement on technical instructions for the safe transport of dangerous goods by air (ICAO TI), and further European and German norms (ADFC 2016). These regulations apply varyingly depending on the EPAC's classification as either a bicycle (25km/h EPAC) or a light moped (45km/h EPAC) (Jaeger 2011, Glossary). Testing institutes such as the *Zedler Institute* ensure the compliance with all legal provisions.

The federal government and the *Länder* have shaped the industry's development through regulation in the form of standards and technical norms, as well as through infrastructural developments. This has influenced the degree of product-innovativeness and the organization of production structures, shaping the extent and constitution of industrial cooperation and accordingly, the industry development as a whole.

SUMMARY AND IMPLICATION: MERGING THE STRANDS OF THE 'SYSTEM'

This industry description, concluding the analytical frame developed in Chapter 3, complements former insights and answers the research question with findings identifiable through the *SSP's* particular viewpoint. It reveals institutional and regulatory-coordinative influences, as well as

structural-organizational peculiarities. This further supports the application of the *SSP* as a complement to the *diamond* and *NSI*.

As visualized in a simplified form in Figure 13, the description indicates that particularly framing social values and collective 'institutional arrangements' have shaped the *society's financial markets*, the *industrial relations system*, the *system of training of workers and managers*, as well as the *structure of the state and its policies*. Mostly horizontal regulation characterizes the innovative capabilities and organizational structures and leads to the industry's successful development.

Based on the *SSP's* view, it appears that the presence and measures of industry-oriented associations are significant for the industry's successful development. They have conducted lobbying for the product, strengthened its political standing (e.g. regarding educational standards), addressed legal quandaries and raised awareness among domestic citizens. Against the background of national management and educational characteristics, the product's high production-quality and the industry's small size have led to the formation of explicitly collective behavior and obligational modes of coordination. The strengths in collective networking, community-ism and cooperation, predicated on social justice and moral obligations, have decisively contributed to successful industry development because they have led to the joint production of highly demanded high-quality products. The self-interest horizontal market coordination has nonetheless also influenced the national industrial success, because the rapidly changing and pressuring market dynamics have strengthened collaboration between SMEs and supported the diffusion of new ideas. These *SSP's* influences have finally been accompanied by both the federal government's regulations regarding legal product requirements and the specific financing of several development attempts. In sum, the industry could develop successfully as a result of embeddedness in the "German diversified quality system of production" (Hollingsworth 1997:284).

This reflects that the industry has not only developed successfully, due to structural-organizational or innovation-related characteristics, but also due to institutional forms of industrial coordination. Again, this final industry description emphasizes the interconnectedness of structural-organizational, innovative, and institutional-regulatory backgrounds.

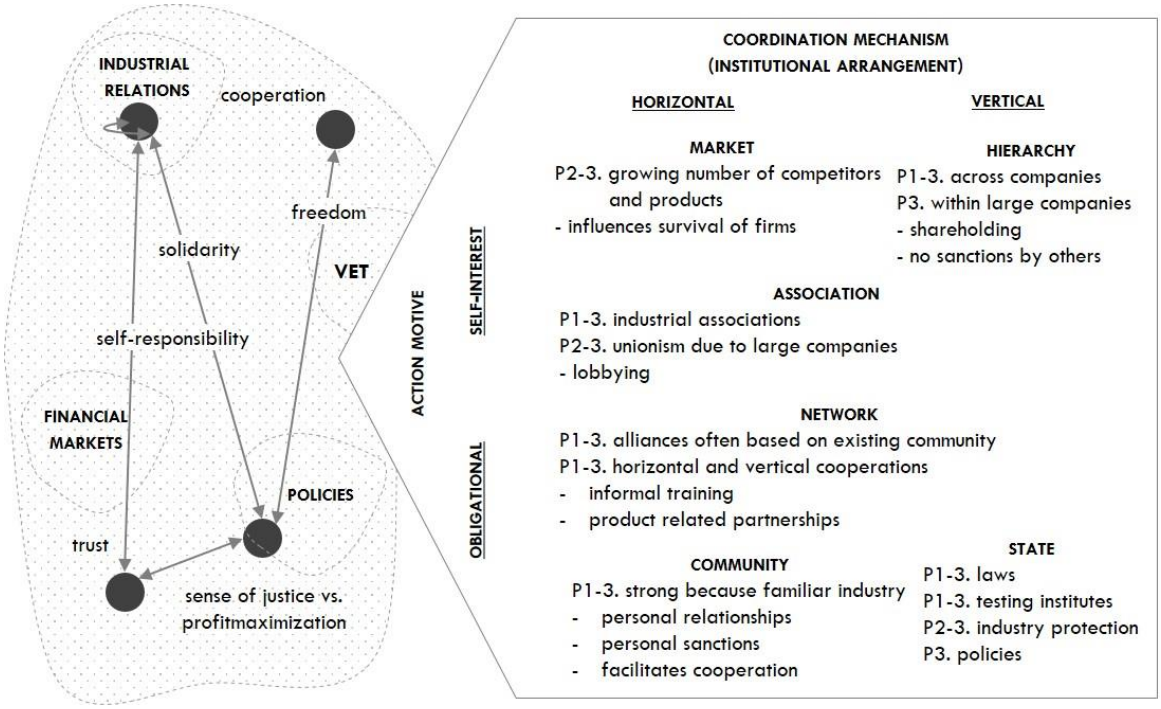

Figure 13: SKETCH – GERMANY'S *SSP*, INFLUENCING THE EVOLVING EPAC INDUSTRY
(source: author's elaboration)

THE FINDING'S VALIDITY

Briefly evaluating these results in relation to other studies in order to validate the findings is nearly impossible, as the framework has been previously discussed almost exclusively in theoretical contexts (Ch. 3.3, 4.1). Hollingsworth (1997) describes a similarly labeled *diversified quality system of mass production* characterized by close industrial relations regarding sub-contracting, the presence of joint problem solving, and minimally influential state regulation, as well as a unionized and associational structure and long-term job security for labor. All of these elements are observable in this study of the EPAC industry. His description of a poorly developed VC market, close dependencies of leading banks, and strong mutual stockholding between companies, while present in Germany in general, is not observable in the EPAC industry due to its small size and unique constitution. A contrasting *social system of flexible production*, in turn, is characterized by a highly regulatory state, weakly developed associations and unions, and difficulties engaging in collective behavior. Markets and hierarchies are the dominant institutional arrangements, and relationships along the value chain are characterized by opportunistic behavior (ibid.). This description of a *social system of flexible production* exhibits virtually no similarities with this study's description of the EPAC industry. The strong similarities between this study's findings and the related *diversified quality system of mass production* indicate a valid application of the framework, and are consistent with Hollingsworth's and Boyer's (1997b) central conceptual ideas.

In a further step toward understanding the influences fostering the EPAC industry's successful development, the following Sub-Chapter analyzes the concrete 'success-factors' revealed by the applied *SSP*.

5.4.2 Exploring Influential 'Success-Factors' Derived from the *SSP's* Application

The *SSP's* application extends the understanding of the EPAC industry's successful development to aspects of regulation, coordination, and national social idiosyncrasies. These shape the constitution of innovation-related processes and several structural-organizational peculiarities. Accordingly, a closer look at this description reveals five additional influences as particularly important for the industry's successful development. Directly addressed by Hollingsworth and Boyer (1997b) and Hollingsworth (1997), these are: *Social values*, *industry associations*, *communities and low hierarchies*, the *product's qualities* and *market dynamics*. In the following sections, these are illustrated by two representative quotes and explained regarding their importance in development, theoretical anchoring, and phase-relevance.

SOCIAL VALUES

> Bicycle-people aren't rational. They're idealists (I 2.7).
>
> I refuse requests from large bike dealers who have many stores, because I don't want them to compete against the smaller dealers I cooperate with and who have their stores in striking distance (I 2.8).

The 'success-factor' *social values* describes the influence of idiosyncratic social principles on the constitution and dynamics of the EPAC industry's development. Due to the small industry's size and its characteristically trust-based knowledge exchanges, social values are particularly important action motives that stimulate the industrial and strategic orientation.

The 'success-factor' *social values* can be observed in Hollingsworth's and Boyer's emphasis on the society's moral principles, norms, rules, and idiosyncratic social framing conditions in connection to the *industrial relations system* and the *system of training of workers and managers*. Underlying all social interactions, these important values have been constant over time and have built the foundations for an economic order (Figure 14). Due to the initially unprofessional organization and the companies' embeddedness in the civil society, low-hierarchies and trust- and value-based interrelations between firms developed based on values such as freedom, self-responsibility, and solidarity. Professional interactions between SMEs are also founded on personal senses for justice and idealistic agreements. Relations between labor and management are characteristically trusting, and personal and informal helpfulness and the exchange of sensitive information are a common practice, partially reflected in informal VET arrangements, resulting from the moral obligation to exchange accumulated technical knowledge. These social values underlie inter-firm and intra-firm relationships and have thus partially replaced the need for unionism. Not least, underlying social values are reflected in stable national work conditions, which support workers' identification with their employers and could positively influence the production of high quality goods. Accordingly, social values prove to be another important 'success-factor' underlying the industry development.

INDUSTRY ASSOCIATIONS

> I think in the automobile industry you cannot bring the leading managers of Mercedes, VW and Fiat together on a regular basis in order to talk about the market (I 2.12).
>
> Actors like Hannes Neupert and ExtraEnergy, who ensure that people do test drives are immensely important. Because everybody who tests comes back with a smile (I 2.18).

The industry's development is also influenced by the support of *industry associations*, which have been stimulating growth by lobbying and guiding technical developments toward equal utilization standards (e.g. use of same charging plugs), among other activities.

The importance of this 'success-factor' becomes visible by analyzing the coordination modes within the *industrial relations system* and the influences of the *system of training of workers and managers* as well as of the *structure of the state and its policies*. Along with the EPACs generally increasing recognition in society, *industry associations* have become more influential (Figure 14). Initially, only the independent association *ExtraEnergy e.V.* facilitated test-drives, conducted product tests, and aimed to increase the popularity of EPACs in society. In this pioneering period, *ExtraEnergy e.V.* supported technical improvements and the generation of demand. From 2007 onwards, when related companies increasingly joined the industry, the *ZIV* has engaged in collecting statistical data and lobbying political representatives. The engagement of associational players resulted in further educational achievements, regulatory standards, and infrastructural adjustments. Thus, industry associations have supported technical improvements and hence the circulation of new knowledge, the establishment of product norms and standards concomitant with quality assurance, and the product's political and societal anchoring, all indicators of this 'success-factor's' influence on the industry's successful development.

COMMUNITY AND LOW HIERARCHY

> It's a very small world. And it's very *hemdsärmelig* (I 2.10).
>
> The competitive thinking is, compared to other industries, somewhat more laid-back. It is the entrepreneurial ambition to have its benefits though, but […] all pull together and collectively enjoy being successful (I 2.12).

Strong *communities and low hierarchies* are a characteristic of the comparatively small industry and facilitate solidarity, trust, and the informal exchange of information amongst participating companies. This in turn results in collective behavior and formal cooperation.

The influential 'success-factor' *community and low hierarchy* can be revealed by analyzing the interrelations of the *society's financial markets* and the *industrial relations system*. In the initial development stage, it was most influential in developing and jointly establishing a high-quality product (Figure 14). The initial strength of community-ism can be traced to the semi-professional organization, the underlying social values, and the number and structure of participating companies. Trust has framed personal relations based on a deep sense of justice. This has resulted in strong communities, informal communication and formal alliances. This formation has been strengthened by the absence of cross-shareholding and thus the absence of foreign intervention into internal firm-decisions. However, simultaneously to the product's increasing sales and the increasing participation of large companies, community-ism has been partially replaced by market-based competition. Nevertheless, and in keeping with Hollingsworth (1997), diversified quality forms of production work best when collective behavior is detectable, which is why this 'success-factor' decisively influences the industry's development.

PRODUCT'S QUALITY

> Maybe this German workmanship is simply important (I 2.14).
>
> In Asia, they don't get it if you say: 'I pay $0.30 more per EPAC, because I want to use stainless steel spokes in production' (I 2.18).

The developing German EPAC industry is internationally recognized for producing goods with high *product qualities.* This stimulates demand and the establishment of new firms, and potentially results in increasing innovativeness. The 'success-factor' *product's quality* thus indirectly stimulates the successful industry development.

The influence of the *product's quality* is apparent in the interplay of social values and the engineering tradition in Germany, identifiable through the relations between the framing conditions, the *system of training of workers and managers*, and the *industrial relations system*. Its relevance has increased simultaneously with growing demand (Figure 14), as an increasing number of potential customers has begun to compare different products. Since product quality has, among others, been one important purchase criterion, high-quality producing firms 'clustered' in Germany (Ch. 5.2.1) have gained a strong reputation and thus a competitive advantage. Additionally, the national investments in a high-skill environment and the education system contribute to ensuring national product qualities. According to Hollingsworth (1997), such high quality is, furthermore, best ensured in environments with collective behavior, so that especially the EPAC industry provides a suitable organizational structure for anchoring high-quality production.

MARKET DYNAMICS

> A lot of firms try to enter the market with new ideas. At the same time, lots leave. As long as the growth remains that rapid, there will always be new participants (I 2.11).
>
> In the EPAC-segment, Germany has the largest market worldwide (I 2.20).

For various reasons, *market dynamics* are an influential 'success-factor' for the EPAC industry's development. They reflect customers' demands and enable producers to adjust their products accordingly. Also, they reflect the producer's ability to develop mass suitable products. The rapidly growing sales markets attract new producers and eliminate others that cannot keep up with the development (e.g. in pace or quality). Additionally, *market dynamics* enable producers to calculate which countries to produce for and hence, which adaptions might be required. This stimulates continuous development.

This regulating 'success-factor' is revealed by the interplay of the *industrial relations system* and the *structure of the state and its policies*. As national and international sales markets grow, the 'success-factor' gains influence in coordinating the industrial structure (Figure 14). During the pioneering phase, the sales market was relatively small. Industrial participation thus was not motivated by immediate profit expectations. Following *Bosch's* marketing campaign after the transition phase, however, demand and supply increased rapidly. Due in no small part to market dynamics and low entry and exit barriers, most diverse companies and start-ups have tried establishing and adjusting their products and product ideas in response to market feedback. The number of participating companies has reinforced each other and apart from the product's attractiveness, only technical norms and political regulations have restricted market access and success. Today, the German market offers the largest potential for firms to establish, because together with the Netherlands, it is the world's largest sales market for EPACs. The size of the German sales market has constantly radiated toward the remaining European countries, where

German products now enjoy a strong reputation and, as in the Netherlands, are increasingly in demand. Thus, *market dynamics* have influenced the EPAC industry's development, structure, innovative behavior, and regulation.

SUMMARY AND IMPLICATION: AFFECTING 'SUCCESS-FACTORS'

To summarize, this Sub-Chapter identifies and explains different factors crucial for the successful industry development from the *SSP's* viewpoint. The factors are directly addressed within the approach and reflected by interdependent linkages between the *SSP's* inner systems. Similar to the other approaches' 'success-factors', not all have been equally important in each phase of the development. Figure 14 visualizes the mutually dependent interplay of the success factors in relation to the temporal evolution. In the beginning of the industrial formation, *communities* and idiosyncratic *social values* were highly important in regulating and structuring the industrial formation. The influences of *associations* and the *product's quality* slowly increased and reinforced along with the formation of an industry and its beginning demand and societal recognition. In the final phase, the influence of *market dynamics* has grown. It has coordinated the survival and innovativeness of firms as an institution, partially opposing communities and industrial solidarity.

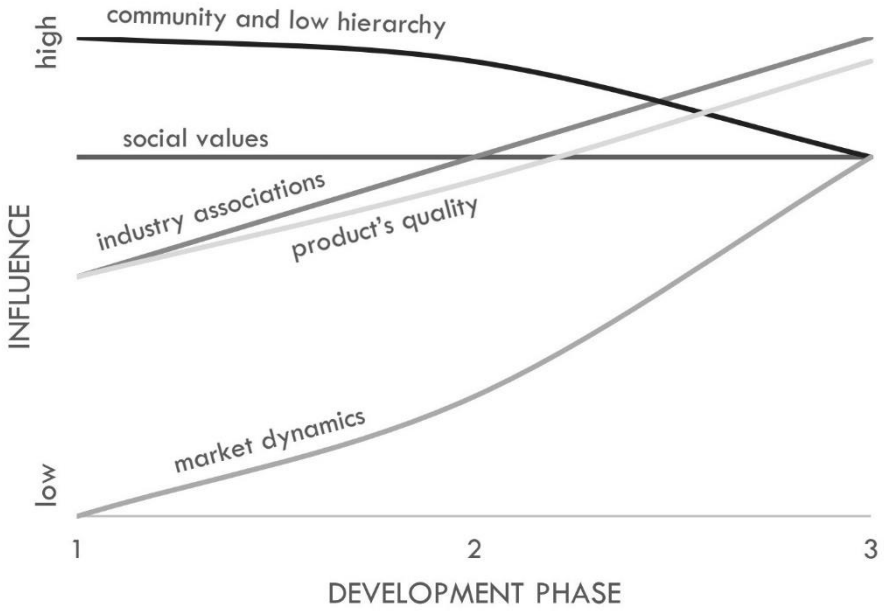

Figure 14: SUCCESS FACTORS DURING THE PHASES OF INDUSTRY DEVELOPMENT ACCORDING TO HOLLINGSWORTH'S AND BOYER'S FRAMEWORK
(source: author's elaboration)

THE FINDING'S VALIDITY

In comparison, without further specification, other studies on the successful development of national industries argue that 'institutional arrangements' influence the successful constitution of industrial structures (Chu and Li 1996) or that institutional contexts are generally supportive to industry development (Saxonhouse and Wright 2010). Yan and Hu (2008), who investigate the development of Taiwan's bicycle industry, find that industrial actors, similar to this study's case, developed a close network weaving together part suppliers and assemblers. Unlike this study,

however, many of the studies reviewed in Chapter 2 and Appendix D identify the federal governments as a substituting positive and regulatory 'success-factor' (e.g. Yan and Hu 2008 or Zaho et al. 2013). The role of *industry associations, low hierarchies* or of specific *social values* are not identified as powerful 'success-factors' in other studies. Once more, this reflects how diverse research results are and reiterates that the specific findings of this study cannot be generalized.

Finally, these findings can be related to the *SSP's* particularly case-related limitations and contributions in the following Sub-Chapter.

5.4.3 Interim Conclusion and Reflection: Hollingsworth's and Boyer's Limitations and Contributions

In addition to the findings of Chapters 5.2 and 5.3, the *SSP* toward identifying the institutional mechanisms by which economic activity is coordinated supports understanding the EPAC industry's development in various respects. Nevertheless, its contributions are limited in other respects. Thus, the value of finally applying this framework for understanding the EPAC industry and its most influential strengths and weaknesses are visualized and reflected in Table 9 and the following sections.

Table 9: IMPORTANT CONTRIBUTIONS AND LIMITATIONS OF THE *SSP* ON THE EMPIRICAL CONTEXT (source: author's elaboration)

	CONTRIBUTION	LIMITATION
empirical	reveals institutional-regulatory aspects, influencing the structural-organizational and innovation-related ones	originally, no explicit relation to industries, which makes empirical application more difficult
	provides a detailed and extensive picture of the industry's overarching socio-national framing conditions	representation of timely influences not explicitly possible due to the industry's short time span of development
	perfectly emphasizes the importance of associations, communities, social values and the market	
	allows integration of local or regional specifics into the national approach	
conceptual	addresses the gaps of selective and econometric analyses, and of omitting socio-institutional influences on national industry development	very narrative character rather than scientific
	in adjusted form, the theoretical conception is easily transferrable to the empirical case	simplified reality, thus not every influence identifiable
		missing definition of what is meant by 'institution' impedes empirical analysis
		not a systemic view

Applying the *SSP* to the empirical case expands the answer to the research question in various respects. As indicated in Table 9, the characteristics of industry development, identifiable by Hollingsworth's and Boyer's terminology show that the structural-organizational and innovation-related developments are shaped by specific regulatory-institutional arrangements (Ch. 5.4.1). These coordinate the industry's players' economic interaction, which is embedded in a highly developed civil society. The arrangements' interplay provides an EPAC-specific environment for

successful industry development. Due to the industry's comparatively small size and the open-minded character of interacting players, communities and cooperative alliances rather than private hierarchies were of major importance in the coordination of the industry's economic activity. The coordination has been influenced by market pressures, moral principles of interaction, solidarity, and further collective social values which formed the cooperative industrial structure.

Accordingly, the most influential 'success-factors' identifiable by the *SSP* (Ch. 5.4.2) are *social values*, *industry associations*, *communities and low hierarchies* and *market dynamics*. However, the *product's qualities*, which result from the cooperative and non-hierarchical behavior, can also be regarded as unique to the industry.

Based on these findings, similar to Porter's and Lundvall's frameworks, and as expected from a theoretical viewpoint, the application of the *SSP* complements understanding the EPAC industry's development. It extends the previous findings by emphasizing the role of national institutional-regulatory conditions. Thereby it widens the simply industry-specific view to the whole national setting and responds to the call to consider national and institutional aspects. But the approach does not frame only the national setting, it also allows the identification of regulatory influences, resulting from other spatial scales such as the *Länder* specific policies.

Similar to the other two approaches and as already discussed in Chapter 3, however, the *SSP* is only of minor systemic character. It empirically proves that as in Lundvall's *NSI*, specific aspects (modes of coordination and interrelated influences) are analyzed without being a "full-fledged system" (Hollingsworth and Boyer 1997b:2). Unlike the application of the *NSI*, this is not as significant for empirical application because: (1) Hollingsworth (1997) provides at least three exemplary empirical analyses of nations that clarify the framework on an empirical basis. (2) The systemic character is not a central conceptual focus as in the *NSI* concept. The *SSP* is instead interested in the coordination of different but interrelated settings. While the term 'system' is used for labeling the coherence of these interrelations, it is not applied conceptually throughout the approach. Thus, in contrast to the *NSI* analysis, this does not inhibit the empirical analysis, as it is clear that there is no ultimate systemic claim.

The application of this framework nonetheless faces several unexpected difficulties. Temporal developments, for example, cannot be traced as well as theoretically expected. This is grounded in the fact that the EPAC industry's development is analyzed in a comparatively short time span. The *SSPs*, however, is originally designed for the analysis of economies that established over decades and centuries.

Another limitation discernible in Chapter 3 is the uncertainty about what exactly is considered an institution within the *SSP*. Even though the empirical analysis (Ch. 5.4.1) follows the theoretical and empirical guidelines, it is not clear which aspects should be labeled institutional. This limits empirical institution-related conclusions. When equating the term with the modes of coordination or regulation, as indicated by Hollingsworth and Boyer (1997b), this becomes much clearer.

As already indicated in Chapter 3, however, several of these weaknesses are not as significant since they are mitigated by the application of the other two approaches. Of course, each approach has its particular omissions, but as subsequent complements they provide a comprehensive macroeconomic picture of the industrial formation and successful development. This is finally summarized and reflected in Chapter 5.5.

5.5 INTERIM CONCLUSION AND REFLECTION: EMPIRICAL FINDINGS AND THE COMPLEMENTARY FRAMEWORKS' ANALYTICAL VALUE

To answer the research question, this Sub-Chapter aggregates the findings of the guiding frameworks' applications. It emphasizes the different constellations and interdependencies of 'success-factors' during the development phases and considers the development's structural-organizational, innovative, and institutional-regulatory characteristics. A brief reflection on this thesis' research shows how the chosen frameworks empirically suit a complementary analysis.

SUMMARY OF ALL EMPIRICAL FINDINGS

P1 – Pioneering. The development of the German EPAC industry dates back to the year 1994, when its legal framework was established. A first pioneering development phase can be defined from 1994 to 2007, characterized by the joint interaction of SMEs originating in different industries. Employing varying strategies and due to sophisticated customers, which were initially dealers and athlete-employees, the first firms began industrial production. This was possible because they informally exchanged technological knowledge all along the value chain. A strong industrial community formed, grounded upon similar social values, trust, and the embeddedness in a social environment sensitized to 'green' means of transport. Firms jointly conducted R&D financed by accessible VC and the business sector itself. Products improved due to the firms' collaborative behavior and first associational support.

Accordingly, the industrial structure and organization was most characteristically shaped by inter-firm relations of SMEs originating in different industries. Institutional-regulatory backgrounds were characterized by collaboration, and informal knowledge exchanges were innovation-related peculiarities. Thus, the *distinct structure of related and supporting industries*, *'green' mobility anchored in daily life*, the *SME-structure and industry's size*, *informal horizontal and vertical knowledge accumulation* as well as the developing *community and low hierarchies* and the existing *social values* are the most important 'success-factors' during this pioneering phase. Jointly, these laid the foundation of further development.

P2 – Transition & Professionalization. Around 2008, the developing industry entered a professionalization phase. Slowly, start-ups, spin-offs, and large firms originating in related industries began engaging in the EPAC industry. The R&D opportunities of financially stronger players spawned technical advances, and some new players engaged in scientific R&D collaborations. SMEs benefited from the major players' knowledge and expertise regarding technology and production processes. Imitation and recombination practices grew increasingly important for SME's technological improvements. This sometimes stood in contrast to the trust-based and cooperative behavior, which was generally characterized by low hierarchies and collective coordination. In addition to the first associational influences, the *ZIV* recognized EPACs as a viable industrial good in 2007, and thus began expanding its engagements toward the new product and lobbying on the industry's behalf. As the product developed, end-customers became more sophisticated and their willingness to pay increased.

Accordingly, the structural-organizational characteristics of this phase are grounded in the increasing participation and interconnectedness of industrial players. Innovation-related peculiarities are shaped by the R&D capabilities of new participants and the sophistication of customers. Continuous collaboration, partial anti-trust strategies, and increasing associational influences characterize the institutional-regulatory backgrounds of this development phase. Thus,

'*green' mobility anchored in daily life, informal horizontal and vertical knowledge accumulation, imitation and recombination practices* as well as *social values* and *community and low hierarchy* proved to be the most influential 'success-factors' in the transition phase. The ability to conduct *(in-house) R&D in traditional related industries* and the role of *industry associations* and *professionalization dynamics* increased. In short, this second development phase was characterized by the transition from initial joint experimentation to the establishment of a professional industry.

P3 – Mass Production. The industry's transition led to a phase of mass production, beginning around 2011 and, heralded by the market penetration of one large related enterprise – *Bosch.* The enterprise financed a strong marketing campaign and established the mid-motor's leading market position. Following this example, other large players, for example *Brose* or *Continental*, have utilized their R&D capabilities to join the industry. Foreign companies have relocated some production to Germany, large traditional firms have registered further captive spin-offs, and students from engineering-related fields have formed new start-ups. These start-ups have been increasingly financed by private and public VC, easily secured due to promising industrial growth figures and readily understandable product concepts. While accessible VC has enabled R&D within SMEs, it has also supported an increasing supply of replicated and imitated products, counteracting trust-based relationships. Both have encouraged market participation from a growing number of firms, increasing pressure on firms' competitiveness. This has expanded the supply of diverse high-quality products and enlarged the product portfolio available to end-customers. While on the firms' side of the market this pressure has led to exits, it has also strengthened cooperative industry coordination in an effort to remain jointly competitive. Specialized technological expertise, for example, has been circulated cooperatively by self-organized informal VET. Associations have increasingly engaged in implementing VET adjustments and improvements, advising the BMVBS in accordance with the National Cycling Plan. Furthermore, they have established regulatory standards and successfully lobbied for the adoption of technology directives by the state. As a result, from these processes, German products have earned a strong reputation for being of high quality and representing German workmanship.

Accordingly, this phase's structural-organizational development background is most dominantly shaped by continuous and unfettered growth and the influences of professionally organized players that guide the industry's development. This is mutually affected by the institutional-regulatory influences of an increasingly competitive market. At the same time, competitiveness is opposed by even closer collaboration. From a regulatory view, the continuous expansion of associational work impacts the industry's development. The professional R&D capabilities of major players, extended imitation practices, and informal VET shape the innovative background and likewise the structural peculiarities of the mass production development phase. Thus, the *product's quality, market dynamics,* the role of *industry associations, social values, communities and low hierarchies* as well as *imitation and recombination practices, sophisticated customers,* the *product's low complexity, professionalization dynamics, trust in established enterprises,* and *'green' mobility anchored in daily life* proved to be the most influential 'success-factors' during the third development phase. In sum, it has been a phase of rapid growth which has not yet ended. Interview statements indicate that it is expected to continue for several years before reaching a point of saturation of industrial development (I 2.7, I 2.11, I 2.20).

These interrelated developments led to the EPAC industry's dominant position in Germany today. Unlike the case studies reviewed (Ch. 2), this summary indicates that structural-organizational, innovative, and institutional-regulatory aspects of industry development are closely related to each other and equally important to consider when conducting a comprehensive industry analysis.

Because of such diverging findings and in order to contextualize the empirical finding's value for industrial research, they are briefly reflected in the following section.

CRITICAL REFLECTION

It is essential to recognize that the qualitative validity points to diverse national, industrial, and contextual peculiarities. Thus, the specific development identified cannot be generalized, nor can it be translated to other contexts.

As indicated in Chapter 4, it must be stated that this research is framed by subjective thoughts and relies largely on interview statements. Other interview partners or researchers might have come to slightly different descriptions and conclusions, or might have identified different 'success-factors'. For example, as in other studies (App. D), one might also label the 'access to VC' as an independent 'success-factor' which has influenced the industry. In this study, VC is instead broadly considered as a modifying influence on, or result, of other 'success-factors' (e.g. the '*low' product complexity*). It is not considered as an independent 'success-factor' in its own right, but its important influences are still visible. Due to the detailed descriptions and the close interrelations of all developments revealed, it is assumed that other potential 'success-factors' are at least indirectly addressed.

In respect to the research results, it is also important to consider that the analytical focus lies on industrial success. Thus, potentially negative influences are not analyzed. Various aspects, however, might also negatively influence the industry's development. To name only a few: The 'conservative' dealer structure, is (apart from its benefits) also regarded as a "cultural boundary" (I 2.7). The highly dynamic market bears the risk of making standardization attempts impossible, because actors try to set their own personal standards (I 2.13). Greater access to financial resources for R&D in foreign countries could trigger enhancements of foreign products (I 2.15) and thus negatively influence development in Germany.

A comprehensive analysis could be realized only by the complementation of different theoretical approaches (Ch. 2). Thus, on the one hand, the chosen frameworks differ regarding their objects of investigation. To take just one example, the *diamond* points to the EPAC industry's specialized *factor creation*, whereas the *NSI* highlights the *intra-industrial R&D organization*. The *SSP*, in turn emphasizes the *role of training and education*. On the other hand, the frameworks also differ regarding their particular viewpoints on the same objects. Governmental influences, for example, are considered in each framework. However, they are only of minor importance for the *diamond*, where they influence its four attributes. In the *NSI*, the government is considered important only in relation to innovation- and technology policies on a national level. The *SSP* in turn allows the consideration of diverse governmental and state intervention on differing spatial and organizational scales. As complements, the chosen combination of approaches thus empirically proved to lead to a more complete and contextual portrayal of the EPAC industry than a single approach could have (see summary above, compare also Ch. 5.2.3, 5.3.3 and 5.4.3).

It empirically proves that Porter's *diamond* particularly emphasizes the industry's structural-organizational specifics, whereas Lundvall's *NSI* highlights an innovation-related context of the development, including structural-organizational and institutional-regulatory backgrounds related thereto. The *SSP*, in turn, emphasizes the institutional-regulatory backgrounds of development and their influences on structure and organization of the industry. Accordingly, due to their specific terminology, the approaches independently provide answers to parts of the research question, which can finally be merged on a shared empirical level (see summary above).

Porter's approach was the easiest to apply empirically, because it explicitly focuses on an industrial setting. This concrete industry focus also allows the most detailed and interrelated empirical description. Lundvall's *NSI* is easiest to follow from a theoretical view, but proved to be the most difficult to empirically apply. His thoughts are plausible and succinct, but remain theoretical and abstract. The *SSP* seemed very complex and somewhat impossible to implement at first. This is already apparent in the definition of what a *SSP* should be. Based on Hollingsworth's (1997) exemplary application of the framework in the cases of Japan, Germany, and the U.S., however, his theoretical thoughts could be translated to the EPAC case-study.

Due to the frameworks' predefined structures, historical and dynamic patterns could not be emphasized as well as theoretically expected. The frameworks are structured according to thematic blocks rather than temporal developments and as a result are not very dynamic. Despite being less evolutionary, however, this structure allowed an orderly analysis.

Several of the 'success-factors' identified based on one of the three approaches could have also been presented in the context of another of the three approaches. In such cases, the author chose to present the 'success-factor' in the context of the framework offering the most clarity and detail. For example, the *diamond's* empirical application points to the production of high-quality EPACs. The quality of industrial goods is more explicitly emphasized as a result of the particular *SSP*, however, which is why it is identified as 'success-factor' in the context of the *SSP*.

Finally, it must be stated that despite seeking to identify the independently specific structural-organizational, innovative, and institutional-regulatory backgrounds of development, all these backgrounds are somehow of structural impact, shaping the industry's development. In retrospect, the research-question might thus seem unnecessarily differentiated. However, the initial differentiation was necessary to achieve a dense description that considers the diverse facets of the industry's development.

In short, the empirical summary and the critical reflections highlight and confirm the value of applying three complementing theoretical frameworks when investigating the German EPAC industry. Together they re-trace the industry's development in great detail, consider the research question's many facets, and identify significant 'success-factors'. On both a theoretical and empirical level, the findings complement each other and show how diverse industrial regulation, coordination, institutions, innovation, structures and organizations are interrelated. To better understand the EPAC's industry development in Germany, this is briefly interpreted on a meta-level in Chapter 6.

6 BRIEF META-LEVEL INTERPRETATION: STRUCTURING UNDERSTANDING OF THE EMPIRICAL FINDINGS

A review of the aggregated empirical findings (Ch. 5.5) supports understanding how the German EPAC industry developed until today. It indicates how different 'success-factors' have influenced each other during different phases, jointly causing positive feedbacks triggering further development. To take one final step further toward understanding the industry's development, this Chapter briefly interprets the empirical findings on an overarching meta-level. It discusses interrelations between different spatial and organizational scales and focuses on the functionalities of the different 'success-factors'. This deepens understanding of the industry's development and

structures the empirical findings, resulting in a superordinate picture of how the industry could develop successfully until today.

SCALES

Interpreting the industry's successful development on a meta-level, it can be stated that it is coupled to the 'success-factors'' effective radiation of their particular influences toward different spatial and organizational scales during all phases.

Spatial. The 'success-factors' directly function on a particular spatial scale and indirectly influence and radiate toward others. The regionally organized firm complex of *Bosch*, with its professionalism-, quality-, trust- and marketing-based leading position (Ch. 5.2 and 5.4), for example, influences the local strategies and organization (Ch. 5.2-5.3) of other producers (e.g. imitation of processes) and likewise stimulates supra-local networking of other companies that aim to maintain their market-positions (Ch. 5.4). In another example, the national dynamics in the sales market (Ch. 5.4) both increase the industry's international visibility and influence local strategic orientation (Ch. 5.2).

Organizational. Each 'success-factor' also affects the supra-organizational industry-level on the one hand, and individual industrial firms themselves on the other. Influences either directly affect a specific firm and by radiation indirectly affect the entire industry, or vice versa. The leading position of specific firms, for example, leads to a common recognition of the whole industry and thus positively influences other industrial players (Ch. 5.2-5.4). The distinct structure of related industries (Ch. 5.2), in turn, indirectly influences single firms, for example, by circulating new knowledge within the industry (Ch. 5.3).

These feedbacks positively underlie all developments summarized in Chapter 5.5, and likewise influence the interrelation of the 'success-factors'. Moreover, each 'success-factor' can be classified regarding its functionality. Differentiating the 'success-factors' on this higher level of abstraction further contributes to structuring the results, and deepens the understanding of which kinds of influences have shaped the industry's development in which ways. Such differentiation is introduced in the following section.

TYPES

Without any concrete substantiation, the language of the three frameworks implemented in this thesis indirectly point to the different ways in which particular 'success-factors' might function during the process of industry development. Porter (1990:132ff.), for example, relates the *diamond*'s attributes to terms such as "simulate," "make larger," "pull," "encourage," "spawn," and the like. Lundvall (1992b:8ff.) relates terms such as "attracting," "support," "influence the rate and direction," or "the enabling role" to the *NSI*, whereas Hollingsworth and Boyer (1997b:5ff.), frequently refer to "coordination" and related terms. Similarly, the empirical findings of this study point to different ways in which the 'success-factors' function during the development. These can be classified into four functional types of 'success-factors':

Structuring. This type labels 'success-factors' that have structuring influence on the industry's development. It equally describes all 'success-factors', even though each 'success-factor' functions slightly differently. As described in Chapter 5, each 'success-factor' specifically shapes the industry during the different phases of development, and thereby fulfills a structuring and ordering function.

For example, the *distinct national structure of related and supporting industries* structures the industry's organization (Ch. 5.2), while s*ocial values* or *informal horizontal and vertical knowledge accumulation,* in turn, structure the way industrial actors interact (Ch. 5.3-5.4). In their structuring function, all 'success-factors' contribute to reducing the risk of a negative, chaotic perception of the industry and a potentially resulting negative reputation.

Enabling. This functional type labels 'success-factors' that served as initiating preconditions for establishing the industry with its growth potentials. Within this study, these are the *distinct national structure of related and supporting industries*, *SME-structure and industry's size* (Ch. 5.2), *informal horizontal and vertical knowledge accumulation, (in-house) R&D in traditional industries* (Ch. 5.3), and *community and low hierarchy* (Ch. 5.4). Based on the existence of expertise in related industries and their R&D, actors engaged in informal horizontal and vertical knowledge accumulation and developed a trust-based community, possible due to the SME-structure and the industry's size. These intertwined preconditioning factors allowed actors to produce the first products. Thus, these 'success-factors' enabled industrial establishment.

Guiding. This functional type classifies 'success-factors' that have impacted the direction in which the EPAC industry further developed. These are the *distinct national structure of related and supporting industries*, *sophisticated customers*, *trust in established enterprises, professionalization dynamics* (Ch. 5.2), *imitation and recombination practices, (in-house) R&D in traditional industries* (Ch. 5.3), *industry associations,* and *market dynamics* (Ch. 5.4). The *distinct national structure of related and supporting industries,* for example, not only enabled the initial industrial formation, but also guides the direction in which the industry develops today. Due to greater financial power and their abilities to continuously conduct R&D, actors originating in related industries have lead the way for new technological improvements until today. This guiding influence grew with industrial professionalization and the spread of imitation and recombination practices. Meanwhile customers' trust in the products supplied by established enterprises further strengthened their guiding position. Sophisticated customers and market dynamics guide the industry's development in a similar manner. Special emphasis on customers' needs, as well as high market demand specify the directions of future development. Thus, these 'success-factors' have a guiding influence on the development path's direction.

Facilitating. Such 'success-factors', while they have positively influenced the industry's development, have neither been concrete 'enablers', nor have they guided the directions of development. Rather they have simplified or stimulated the development. In this study, these are *'green' mobility anchored in daily life* (Ch. 5.2), *'low' product complexity* (Ch. 5.3), *social values,* and the *product's quality* (Ch. 5.4). The '*low' product complexity*, for example, eased understanding of the product and thus access to VC. *Social values* had positive influences on cooperative behavior and thus facilitated the formation of a strong community. The *mobility type's anchoring in daily life*, in turn, has stimulated domestic demand and thus facilitated the development as well. Accordingly, this type can simply be regarded as functioning supportive.

On a superordinate level, the successful development of the EPAC industry can thus be summarized as visualized in Figure 15. It highlights the most influential 'success-factors' of each development phase in relation to their frameworks of origin, their functional types, and the affecting positive feedbacks located on the framing organizational and spatial scales.

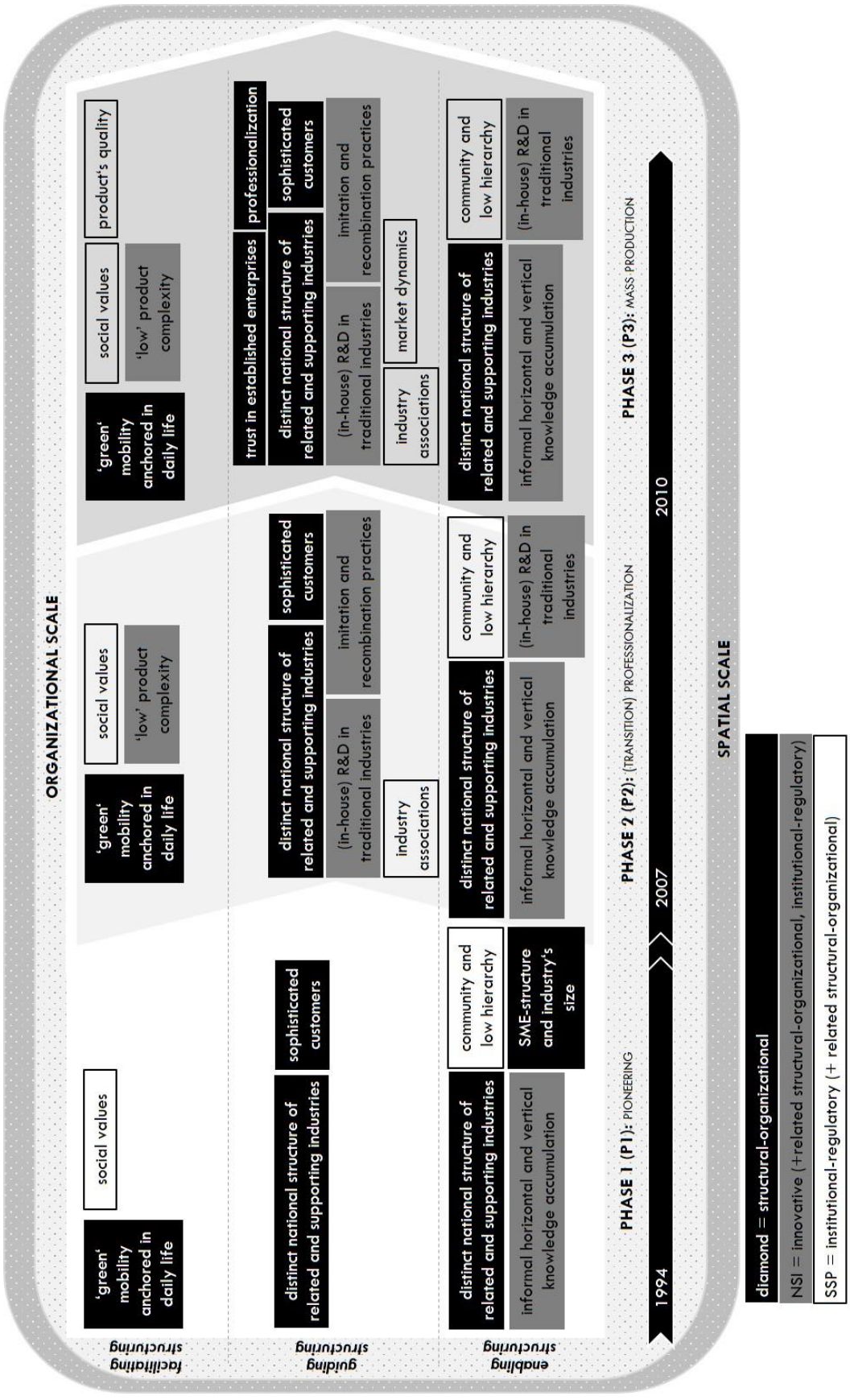

Figure 15: FUNCTION OF THE MOST INFLUENTIAL 'SUCCESS-FACTORS' OVER TIME
(source: author's elaboration)

The interpretation of this Chapter visualized in Figure 15 illustrates rough main implications for enhancing a meta-level understanding of the developing German EPAC industry:

Over time, the different 'success-factors' have influenced the industry's development and affected the industry on various organizational and spatial scales. Related to the findings of Chapters 5.2.2, 5.3.2, and 5.4.2, the interpretation reveals that all 'success-factors' had a structuring influence on the industry's development. Inherently, enabling 'success-factors', and to some extent facilitating 'success-factors', have influenced the industry since the initial phase of the development. Interdependently affecting each other, these conditions allowed the industry to form. In the formative phase, there were no development goals toward with the industry could be directed, so guiding influences were less influential. While enabling 'success-factors' remained important and the influence of facilitating 'success-factors' slightly increased over time, particularly guiding influences have dominated the later stages of development. These are currently influential, as they have offered the industrial players strategic ideas for future development.

This very brief meta-level interpretation is validated in the following section.

THE INTERPRETATION'S VALIDITY

The empirical investigations reviewed in Chapter 2 do not address the radiation of entanglements and influences in relation to different spatial or organizational scales and therefore offer no direct comparisons.

In relation to this interpretation's core focus, however, particularly Pangborn (2012) provides strikingly similar findings. The author's investigation (2012:ii f.) of influences on growth within a farming industry classifies factors that "were necessary for growth, […] caused growth, […] [and] had a positive influence on growth." Other case studies apart from Pangborn's (2012) did not try to classify the investigated 'success-factors'. Guiding 'success-factors' might nonetheless be identifiable in Chaudhary's study of e-mobility in India (2014). He argues that the product and technological awareness of end-customers has increased, shaping customers' demands accordingly. As a result, customers are guiding future strands of development, a phenomenon similarly observable in the German EPAC industry. Also Gelijns and Rosenberg (1999), who investigate a national industry for diagnostic devices, argue that it might be important to distinguish between the conditions and factors determining initial success and those determining eventual commercial success. This indirectly indicates differing functions of such conditions and factors. Without being explicit about how 'success-factors' might function in the context of national industries for synthetic dye, Murmann and Homburg (2001:200) argue that the legal environment "can act as a barrier or facilitator of entry into the industry and hence influence industry dynamics in a fundamental way". Such examples indirectly underscore the chosen classification's suitability in the research context of successful industry development, which is reflected upon in the following section.

REFLECTION

When briefly reflecting on this interpretation, four main aspects are important:

(1) It must be considered that the entirety of this interpretation is the result of the post hoc rationalization of all the different 'success-factors' and processes previously investigated. It is thus subjective in nature and contains only general categories. These broad generalizations do, however,

support understanding the way in which particular 'success-factors' have fostered the EPAC industry's successful development.

(2) Since this interpretation provides only broad classifications, some 'success-factors' fit into more than one category. However, this is not contradictory. The *distinct national structure of related and supporting industries*, for example, must be classified as an enabling type, because only through the joint development of actors originating in different industries could a mass suitable industrial good be developed. At the same time, this 'success-factor' must also be classified as a guiding type, because the EPACs' technological improvements are commonly inspired by developments, taking place in such *related and supporting industries*, and as such guide the directions of technological advancements.

(3) Related to the three frameworks applied in Chapter 5, it can be stated that each framework leads to a homogenous identification of enabling, guiding, and facilitating 'success-factors' important for the industry's development (Fig. 15). Accordingly, the three frameworks not only complement each other and lead to interrelated empirical results, they also share similarities regarding their functional output and confirm each other's findings.

(4) Even though this Chapter attempted to further structure the empirical findings in order to enhance understanding of the industry's development. While it also attempted to provide a final superordinate picture of successful development, the findings of this thesis are complex, diverse, and closely interrelated. It is thus hardly possible to provide a simple overarching picture of the empirical results, as elaborated in the concluding remarks of the following Chapter 7.

7 CONCLUSION

Despite the fact that the single components of an EPAC are globally produced, a rapidly growing industry for EPACs has established in Germany. Addressing this counterintuitive fact and the dearth of empirical knowledge on the topic, this master's thesis has studied how the German EPAC industry developed, and in what way identifiable 'success-factors' fostered this development. In order to provide an extensive picture of the development, it further asked for the industry's specific structural-organizational, innovative, and institutional-regulatory development backgrounds. In answering such questions, this thesis is theoretically situated within the research discipline of industrial geography, which lacks a single one-size-fits-all theoretical approach to empirically investigate all these facets of the development.

Thus, the research design consisted of an unconventional multi-theoretical single-case study. To generate empirical insights, and to contribute to the scientific discussion on how national industry development is most suitably investigated, this study subsequently employed the theoretical language of three frameworks: The *diamond* (Porter 1990), the *NSI* (Lundvall 1992b), and the *SSP* (Hollingsworth and Boyer 1997b). Fed with qualitative and quantitative data, each framework allowed the identification of particular development characteristics and 'success-factors' influencing the German EPAC industry.

The *diamond* (Porter 1990), chosen as an analytical starting point, emphasized the developing industrial structure and internal organization, and its interrelations with other industries and demanding customers. The *distinct national structure of related and supporting industries*, as well as *sophisticated customers*, the *SME-structure and industry's size*, as well as *'green' mobility*

anchored in daily life, *trust in established enterprises*, and *professionalization dynamics* could be identified as influential 'success-factors' by Porter's terminology.

The influences of technology-related learning, knowledge generation, and innovation, as well as their structure-forming effects, could be emphasized by the *NSI's* application (Lundvall 1992b). Based on this application, *informal horizontal and vertical knowledge accumulation*, *imitation and recombination practices*, *'low' product complexity*, and *(in-house) R&D in traditional industries* were identified as additional 'success-factors' affecting the EPAC industry's development.

The *SSP* associated the evolving EPAC industry with nation specific regulation structures and institutions. Describing the industry's development with a focus on its modes of coordination indicated that *social values*, *industry associations*, *communities and low hierarchies*, the *product's qualities*, and *market dynamics* have impacted the success of the industry's development as well.

Jointly, the different frameworks' insights provided an extensive and highly interwoven industrial picture, and pointed to reinforcing sets of 'success-factors' that have differently influenced the phases of development since 1994. In short, the initial pioneering development phase (P1) was characterized by non-hierarchical, informal cooperation and knowledge exchange between actors originating in other industries. In the transition and professionalization phase (P2), R&D opportunities increased as the first 'big players' entered the industry, bringing their in-house R&D departments with them and inspiring collaborations between companies. Associations expanded their engagement, and high-quality demanding end-customers stimulated further technical improvements. In this growing landscape of industrial players and diversified demands, attempts at imitation, copying, and replication developed alongside the remaining collaborative characteristics. It led to the industry's development (P3, since 2011) toward mass production and attracted even more players. Further innovation, the diversification of the industrial product portfolio, and diverging moral principles increased competitive pressure on the market that remains today. These growth and diversification trends, as well as the increasing participation of more diverse actors, are expected to continue further until the market is saturated and the final distribution of market shares is reached in several years (P4?).

To structure the empirical findings and to understand the way in which the affiliated 'success-factors' have fostered the development, the results were briefly interpreted on a meta-level. It showed that the 'success-factors' fulfill different functions and purposes, and affect varying spatial and organizational scales. All factors structured, and additionally enabled, guided, or facilitated the development toward today's standing. Enabling 'success-factors' served as the basis of industrial formation, whereas guiding 'success-factors' influenced the directions of development. Facilitating 'success-factors' simply stimulated the development. While enabling 'success-factors' remained constantly important throughout the industry's development, the influence of guiding and facilitating 'success-factors' increased over time.

These multi-theoretically generated findings have contributed to structuring and deepening knowledge about the German EPAC industry in particular. They provided insights into an increasingly important German industrial and political mobility field, which is still growing and changing, and identified its backgrounds and forces of success.

More generally this thesis has contributed to research on successful national industry development in social sciences. Resulting from theoretical omissions in the advancement of industry research, this study met the demand for more comprehensive and rigorous investigations (e.g. Nelson 1994, Hudson 2004). As pointed out above, it therefore utilized the analytical terminology of different concepts dealing with the same overarching topic. Thereby, the specific limitations and

contributions of the chosen approaches to research on national industry development – at least for this case – could be investigated in comparison to each other, so that this study also contributed to reflecting upon the empirical and explanatory value of the three theoretical frameworks. To achieve this comprehensive investigation, the demand for considering nations, institutions, and regulatory conditions, as well as aspects of knowledge and learning (e.g. MacKinnon et al. 2002) was met in the empirical analysis. Its findings empirically reflect the actual value of such theoretically demanded, more extensive considerations. Also, this thesis took historical developments into account (Malerba et al. 1999, Boschma and Frenken 2003). By explaining the EPAC's historical origins, as well as considering different phases of industry development throughout the description, evolutionary changes of the industrial structure became visible. Finally, this study also contributed to more qualitative research on industry development, as called by scholars such as Martin (1999), or Murmann (2003).

Despite the various contributions, however, it would be interesting to conduct further research. Cross-country comparisons, for example, might provide additional insights into which developmental backgrounds and 'success-factors' were especially characteristic for the national setting. This might further point to general indications of Germany's peculiarities as a successful industry location. Further research could also attempt to analyze potentially hampering influences on the developing EPAC industry and contrast these with the results of this study in order to gain an even more differentiated picture. Due to the scope of this study, it was only possible to roughly identify the most important 'success-factors', functionalities, and affecting scales based on the three macroeconomic frameworks. Each 'success-factor', however, could have been analyzed in more detail and also in relation to micro-economic influences. For example, the role of *Bosch* and its influence on establishing the mid-motor as a *dominant design* leads to a thinning of the market and impedes the establishment of other designs (Nelson 1995, Abernathy and Utterback 1978). Accordingly, applying more narrow theoretical approaches, such as *dominant designs*, for explaining the successful industry development and its influential 'success-factors', might eventually extend the findings to include more details.

Notwithstanding such further potential for research, it can finally be stated that this study has unraveled the complex empirical phenomenon of the developing EPAC industry in a first step, and that it has empirically applied an unconventional but fruitful theoretical research approach.

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APPENDICES

APPENDIX A: EPACS

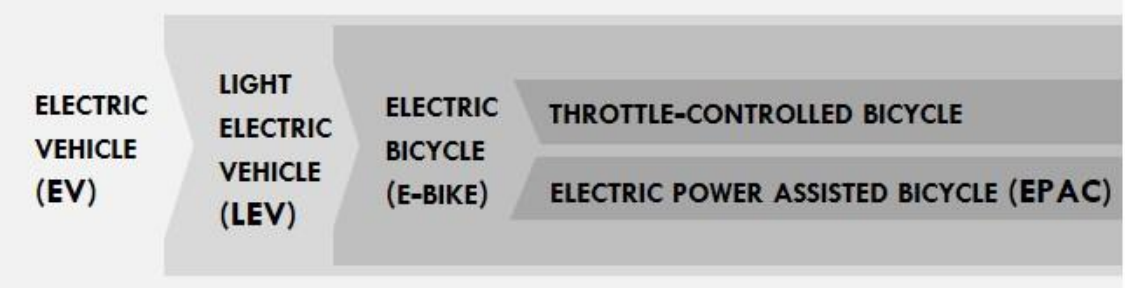

Figure 16: OVERVIEW AND CLASSIFICATION OF THE EPAC
(source: author's elaboration)

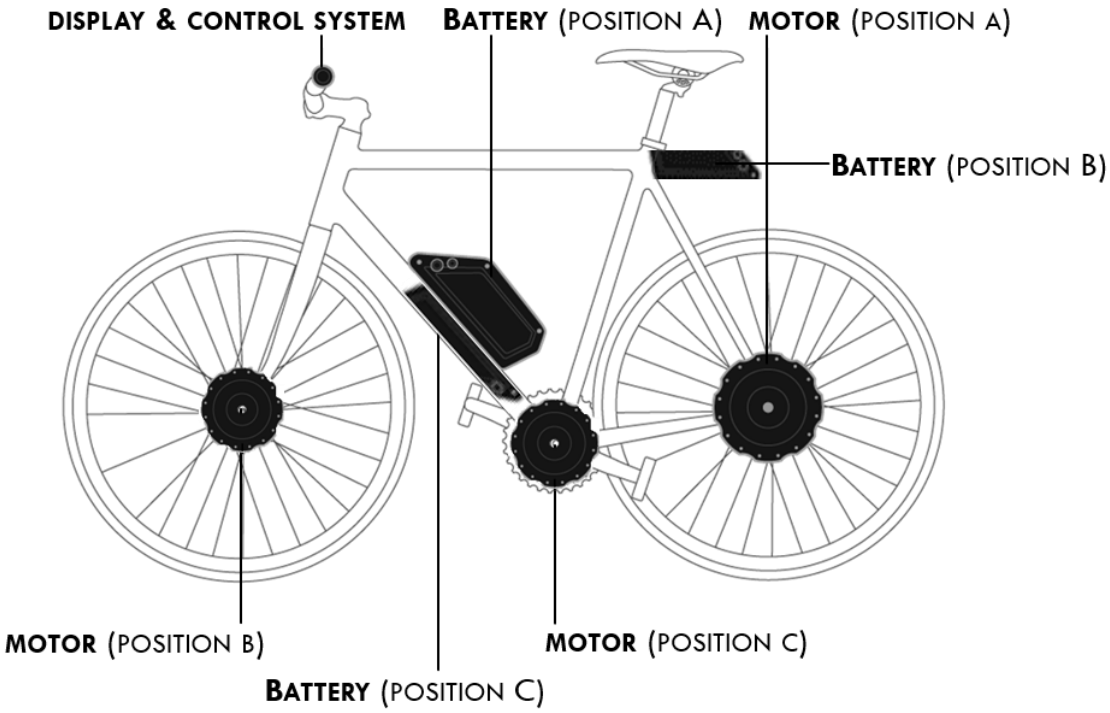

Figure 17: SKETCH OF AN EPAC
(source: author's elaboration based on a bicycle sketch of www.maxonbikedrive.com)

Figure 18: COBOC – ONE SOHO
(source: http://www.coboc.biz/wp-content/uploads/2016/03/2.2-Soho-Fullscreen.jpg)

Figure 19: SWISS FLYER – C8
(source: https://www.swissflyer.de/bilder-e-bike/FLYER-C10-Damen-weiss-Produkt-720x540.jpg)

Figure 20: STROMER – ST1
(source: http://www.emotion-technologies.de/e-bike-marken/stromer/st1/)

Figure 21: CONWAY – E-RIDER
(source: http://www.e-rider-shop.de/images/pics/E-Ride1200.jpg)

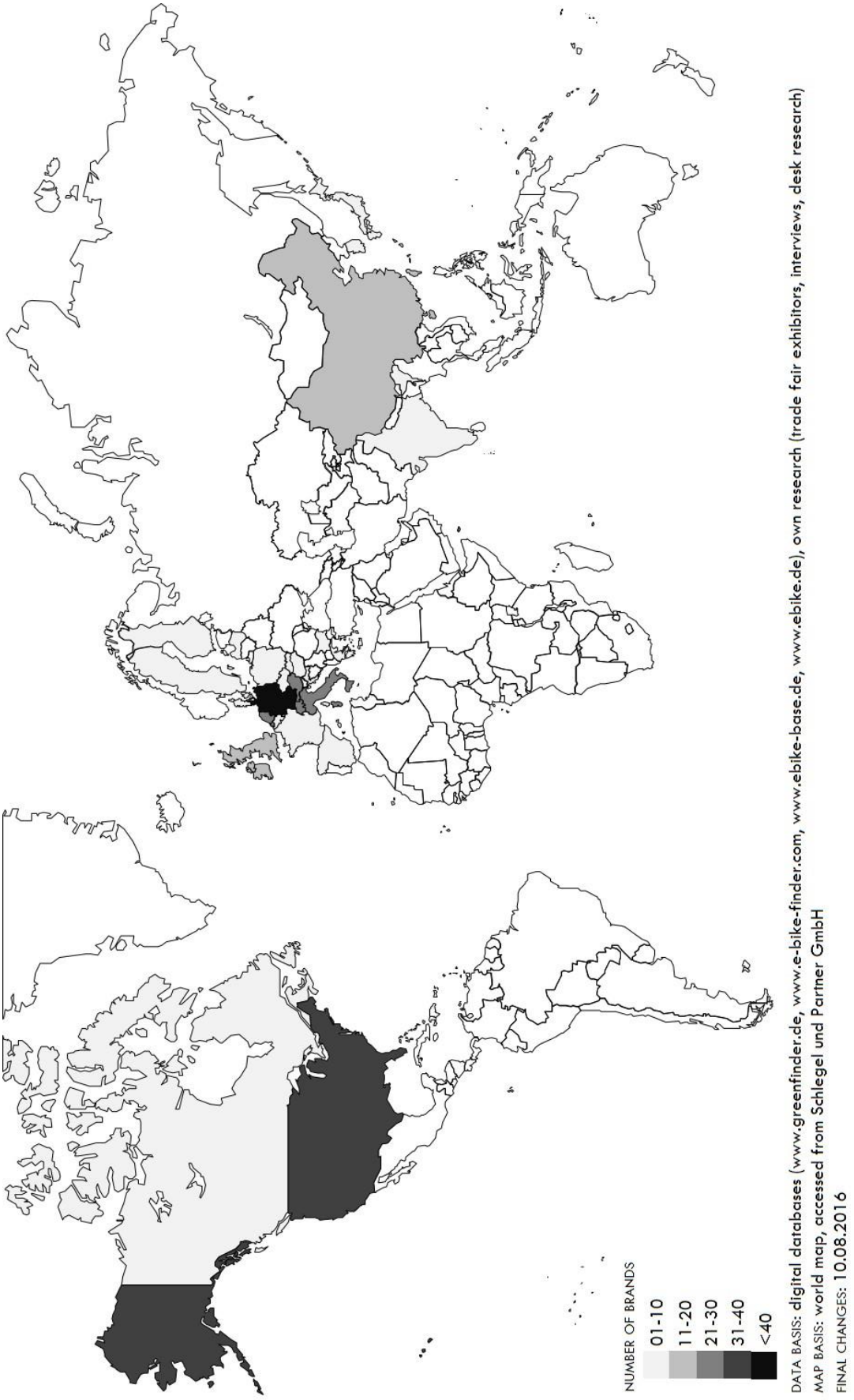

Figure 22: EPAC BRANDS SOLD IN GERMANY (BY COUNTRY OF BRAND-ORIGIN)
(source: author's elaboration)

Table 10: EPAC BRANDS SOLD IN GERMANY (BY COUNTRY OF BRAND-ORIGIN)
(source: author's elaboration)

AUSTRIA – 25
Bauer's E-Bike, Biketronic, Capo, Eego, Ego, EH Line, Elektrobiker, Enorm EBike, Genesis, Greenbike, Hofer, Hrinkow, Kraftstoff, KSR, KTM, Nakita, Ortler, Powerbike, Puch, Quest., Schachner, Simplon, Steinbach, Vivax Assist, YOOM
BELGIUM – 6
BEONE BIKES, Bike43, Granville, Krigori, Norta, Swyff
BULGARIA – 1
DRAG
CANADA – 3
Daymak, OHM, Solex
CHINA – 15
ACHIEVER, ACTIVE CYCLES, Cemoto, Cycleman, E-Bann, KOMDA, Kunshan Sevenone, Longwise, Qoros, Rakxe, San Eagle, Seeyes, TXED, Yuebo
CROATIA – 2
Greyp, Visiobike
CZECH REPUBLIC – 5
AGOGS, APACHE, BikeFun International, Crussis, Leader Fox
DENMARK – 6
Biomega, Butchers & Bicycles, HERSKIND + HERSKIND, PF Mobility, Promovec, WINTHER
FINNLAND – 1
Helkama
FRANCE – 8
Cyclopolitain, Hilltecks Bike, Lapierre, Matra Sports, Mobiky, Moustache, SEV Electric Vehicles, XXCYCLES
GERMANY – 127
3Element, 3G Bikes, Accell (Winora, Haibike, Staiger, Sinus, Batavus, Green's, Ghost), ACTIONBIKES, ACXA, ADDITIVE, Ansmann (STAIL), AT ZWEIRAD (Velo de Ville), ATLANTA, AUTARK, AVE, Bachtenkirch, BAYK, BBF, Bike, Bergamont, Bernds, bike 2 care, bike group eV (Sabotage), Bikeasy, BMW, Böttcher, Campus, Carver, Checker Pig, CHEETAH, Coboc, Corratec, Cucuma, Cycle Union (Prophete, Kreidler, Rabeneick, ebike Manufaktur), Derby Cycle (Focus, Kalkhoff, Raleigh, Univega, Rixe), Diamant, Drössger, Dynamic, E!legal, eflow Europe, Electrolyte, Elmoto, E-LOM, Enviado, Epple, Erhard Mott (Vitali), Etropolis, EXTERNUM, eZee (eZeebike), FALTER, Feldmeier, Fischer, FREYGEIST, FXX Cycles, Girgin Design (e-Goist), Gobax (silent-E), go-e, Grosskreutz & Ridder (Velano, Estelle), Grünberg, Grünrad, Gudereit, Hadi Teherani, Hammer, Hapex, Hase Bikes, Hawk Bikes, Herkelmann, Hermann Hartje (Contoura, Hartje, Victoria, Conway, Tern, Radio, I:SY, Prince, Excelsier, moxon), HNF+Heisenberg, HP Velotechnik, ID Worx, Kettler, Kingbird, Klever, KMX KARTS, LEHMKUHL, Leisger, Leviatec, Liebe-Bikes, Lightride, M1 Sporttmechanik, Maxcycles, MAXX, Merkapur, Mifa (Cyco, FunLiner, Germatec, Grace, McKenize, MIFA, Steppenwolf, Zündapp), Morrison, Movena, MSA (Trenoli), Müsing, Nutzrad-Studio (Libelle), Opelit, Pantherwerke (Göricke, Panther), PATRIA, Pedalpower, Pending System (CUBE), PfauTecPfiff, PG-Bugatti Bikes, Porsche, Radkutsche, Radon, Radrezept (Flitzbike), Remsdale, Riese & Müller, ROSE, Rotwild, Ruder-Rad, Rumstromer, R-Wind, Schauf, Senglar, SFM-Bikes (Saxonette), Silverback, Smart, Speedliner, Stassen, Steinerdesign, Stevens Bikes, Storck, Tout Terrain, Tretwerk, UmaZooma, Urban-e, Utopia velo, Veelo, Veleon, Vermont, Wulfhorst, Wurm, XYZ CARGO, ZEG (Bulls, zemo, Pegasus, Hercules), Zemo
GREECE – 1
Ideal Bikes
HUNGARY – 2
Gepida, Goccia
INDIA – 1
Hero Eco (A2B, F4W)
ITALY – 25
ADRIATICA, BIANCH, Carraro, Carter, Coppi, Denver, DI BLASI, Ekletta, EUSEBI, Fiat, Idurox, ITALWIN, Klaxon, Lampociclo, Leaos, Lombardo, MASCIAGHI, Neox, OLYMPIA, Pininfarina, Tazzari Zero, Velorapida, Volksrad, Wayel, Whistle
JAPAN – 1
Fuji
KOREA – 3
ALTON, Hiddenpower, Mando Footloose
LATVIA – 1
Blue Shock Bike
NETHERLANDS – 27

APOLLO, AZOR, Babboe, Bakfiets, Basil, Batavus, BESV, BIKKEL, CORTINA, DRACAT, Dutch ID, Ebikez, Fylla, GAASTRA, Gazelle, Johnny Loco, KOGA, MEIJS, Multicycle, Protanium, Qwic, Sparta, Spiked, Trefecta, Trikke, Urban Arrow, Vanmoof
POLAND – 1
Creme
SLOVAKIA – 1
Dienatronic
SPAIN – 7
Bebike, BH Bikes (Emotion), Bultaco, Megamo, MONTY, OREBA, Oxygen
SWEDEN – 1
EcoRide
SWITZERLAND – 29
Boo Bicycles, Cannondale, Cresta, Dia-Velo, Dolphin, ELBY, Flyer, Flying Cranes, HILITE, IBEX, Jaal, Kristall, La Ciclera, MTB Cycletech, Price Bikes, Rikscha Taxi Schweiz AG, Saxonette, Scott, Simpel, Stöckli, Stromer, TDS, Thömus, Trek, Villiger, Watt`s, Wheeler, YouMo
TAIWAN – 11
AKOKO, ARIX, Ballistic, Centurion, Darfon, DKN Cycle, GIANT, Merida, Ming Cycle, Optimist, Zephyr
UNITED KINGDOM – 12
AS FOLDING BIKES, Batribike, Bearprint, Curtis Bikes, Cyclamatic, CYCLES MAXIMUS, Gocycle, Maxpro, Pedicabs, Momentum Electric, Pedego, Raleigh, Volt
UNITED STATES – 34
Breezer, Dahon, Electra, Electric Motorsport, Energie Cycles, EVELO, Faraday, FELT bicycles, Fifield E-Bikes, GenZe, Gi Bikes, Herobike, Hi-Power Cycles, ICON, IZIP, Juiced Riders, Karmic, Maxwell Motorbikes, Motiv, Outrider USA, Polaris, Prodecotech, Propella, Riide, Segway, Specialized, Stealth, Terra Trike, Trek, UBC, Velomini, Vintage Electric, Xtracycle, Yuba

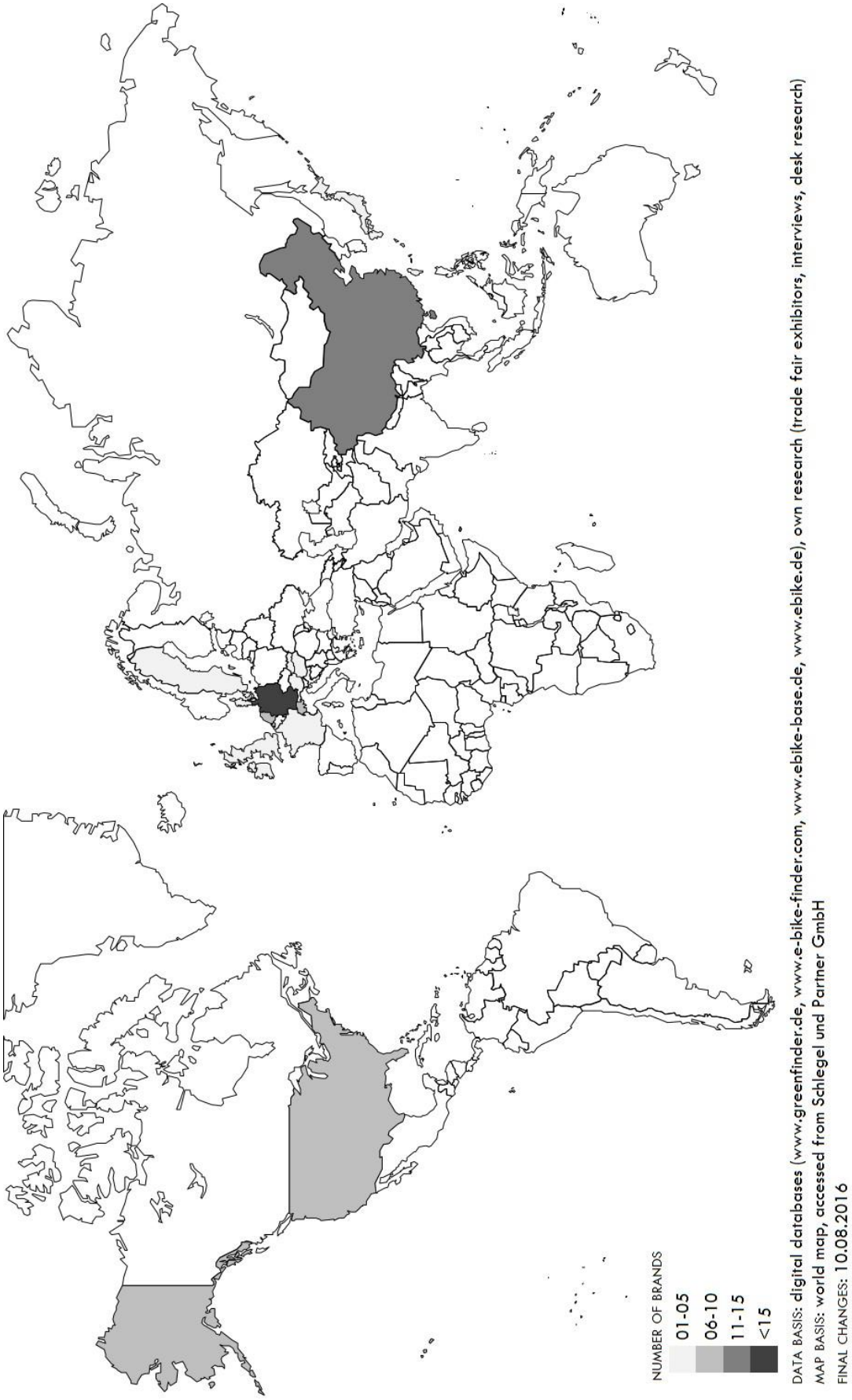

Figure 23: EPAC COMPONENT BRANDS SOLD IN GERMANY (BY COUNTRY OF BRAND-ORIGIN)
(source: author's elaboration)

Table 11: EPAC COMPONENT BRANDS SOLD IN GERMANY (BY COUNTRY OF BRAND-ORIGIN)
(source: author's elaboration)

AUSTRIA – 4
EGO Kits, MPF, Schachner, vivax assist
CHINA – 13
Ananda, Bafang (8fun, CST, Groove), Dapu, Keyde, MXUS, Pengte, Phylion, RESSEL, Sempu, Shengyi, TranzX, Xing Feng Moter (ASC), Xiongda
DENMARK – 1
Promovec
FRANCE – 1
Solex
GERMANY – 40
AEG, Alber (E-Motion, Neodrives), Ansmann, Badass eBikes, Binova, BionX (devinci, Ride+), Bosch, brose, Bulls (Green Mover), compact power motors, ContiTech, Das-Kit, Daum Electronic, Derby Cycle (Impulse, EVO, Xion), evinci (pike), eZee, Fendt, go-e, Grace (Ultra Engine), Grünberg, Haberstock, Hawk Bikes (E-System Hawk), Heinzmann, Klever (Biactron), M1 Sporttmechanik, Marquardt, MESA Systemtechnik GmbH, Nitro Motors, Panther (Panterra, E-Silento), Prophete (e-novation, TRI), Driving Innovations (Relo), Remsdale, Senglar, SFM, Smart.E, TQ-Systems (cleanmobile, Pin), Urban-e, Utopia (Silent, Van Raam), Victoria (E-Silento), Wippermann jr. GmbH
HUNGARY – 1
Gepida (GPDS)
INDIA – 7
A2B (Ultra Motor), Falco, Golden Motor, CeB Motor (Ekletta), Compagnia Ducale, Neox, ZeHus
JAPAN – 5
Dapush, Panasonic, Shimano (STePS), SR Suntour, Yamaha
NETHERLANDS – 6
Accell Group (Winora-Mionic, Koga-ION), Crystalyte, Gazelle (Innergy), ID-BIKE, Protanium, QWIC
SLOVAKIA – 1
Dienatronic (EMH)
SWEDEN – 2
Eco Ride, Höganäs
SWITZERLAND – 7
Evantage, GO SwissDrive, Kristall (Easy Drive), Maxon Motor, SONCEBOZ, Stromer (Syno Drive), Sunstar
TAIWAN – 4
Darfon Electronics Crop. (BESV), Giant (SyncDrive, Sanyo), GreenTrans, TDCM
UNITED KINGDOM – 2
AlienOcean, Gocycle
UNITED STATES – 6
Carter, Currie Tech (eflow), ETM, EVELO, SRAM, SSD

APPENDIX B: DATA

Table 12: GERMANY'S SALES, PRODUCTION, IMPORTS AND EXPORTS (2007 – 2015)*
(source: ZIV 2013, ZIV 2016a, 2016b, CONEBI 2016, internal ZIV-data)

	2007	2008	2009	2010	2011	2012	2013	2014	2015
					Sales (GER)				
B+E	4600000	4350000	4050000	4010000	4100000	3950000	3800000	4100000	4350000
E	70000	110000	150000	200000	330000	380000	410000	480000	535000
B	4530000	4240000	3900000	3810000	3770000	3570000	3390000	3620000	3815000
	2007	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
					Production (GER)				
B+E	2400000	2418000	2248000	2229000	2288000	2211000	2160000	2140000	2190000
E	30000	50000	100000	130000	214000	264000	280000	254000	310000
B	2370000	2368000	2148000	2099000	2074000	1947000	1880000	1886000	1880000
	2007	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
					Imports (GER)* **				
B+E	2920000	2990000	2720000	2710000	2910000	2940000	2870000	2780000	3280000
E	40000	70000	80000	132000	185000	210000	199000	230000	370000
B	2880000	2920000	2640000	2578000	2725000	2730000	2671000	2550000	2910000
	2007	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
					Exports (GER)				
B+E	670000	970000	1080000	1020000	1100000	1180000	1280000	1190000	1160000
E	0	10000	30000	50000	70000	84000	98000	102000	140000
B	670000	960000	1050000	970000	1030000	1096000	1182000	1088000	1020000

B ▸ bicycle
E ▸ e-bike (German label) // EPAC (EU label)
* Associations and federal ministry's started the collection of statistical data on EPACs in 2007; earlier data was not available due to too little
production and sales numbers
** note: imports also include all bicycles produced aborad by German companies

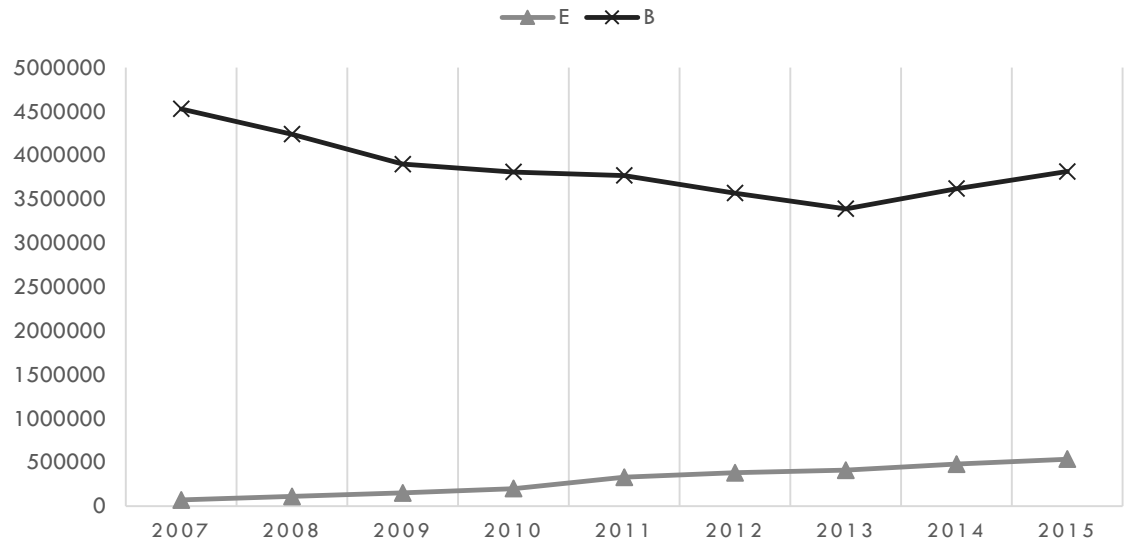

Figure 24: SALES OF BICYCLES AND EPAC'S IN GERMANY (2007-2015)
(source: author's elaboration based on Table 12)

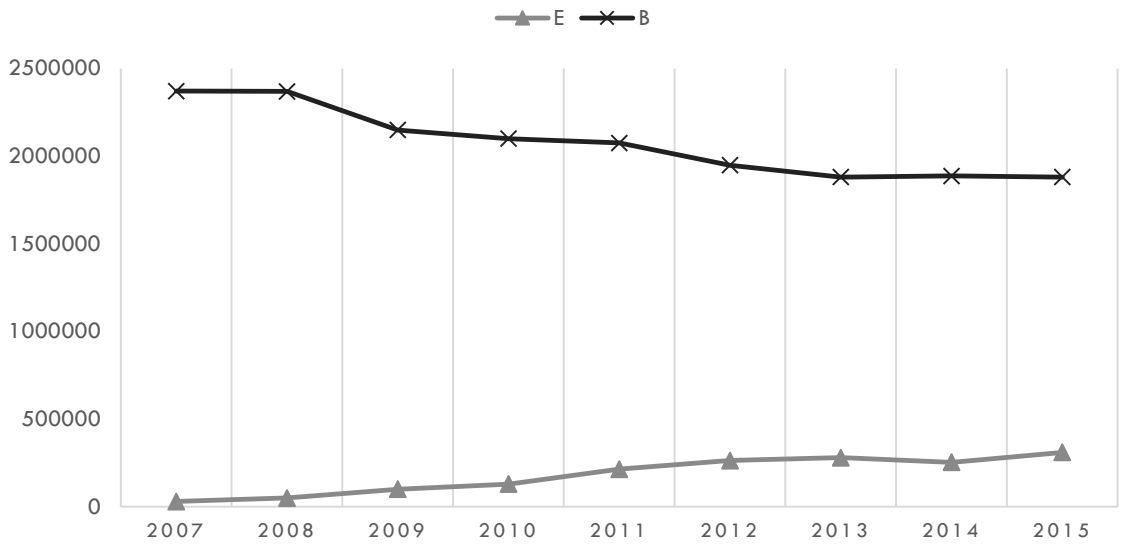

Figure 25: PRODUCTION OF BICYCLES AND EPACS IN GERMANY (2007-2015)
(source: author's elaboration based on Table 12)

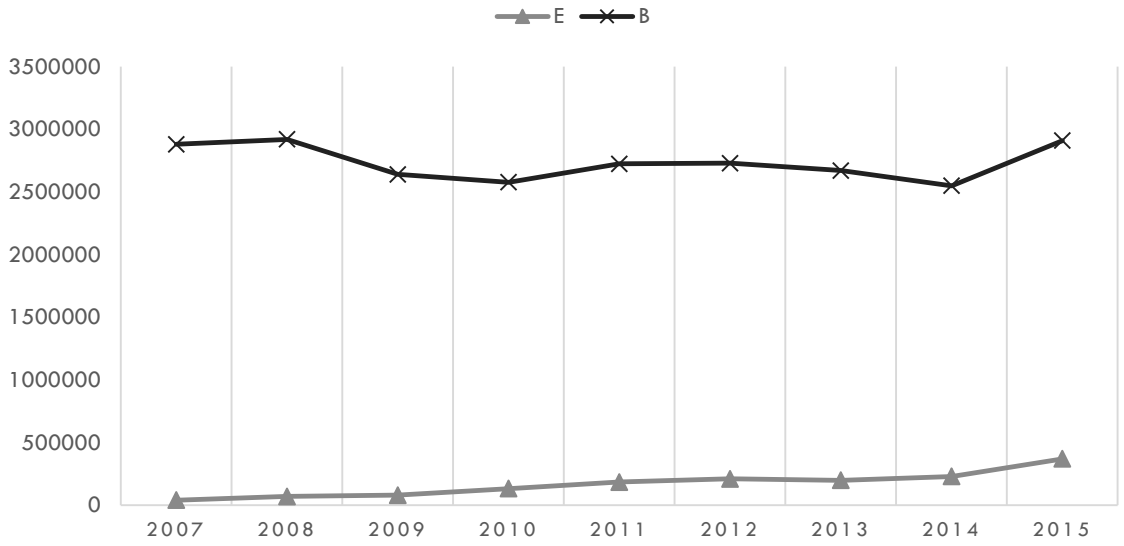

Figure 26: IMPORTS OF BICYCLES AND EPACS TO GERMANY (2007-2015)
(source: author's elaboration based on Table 12)

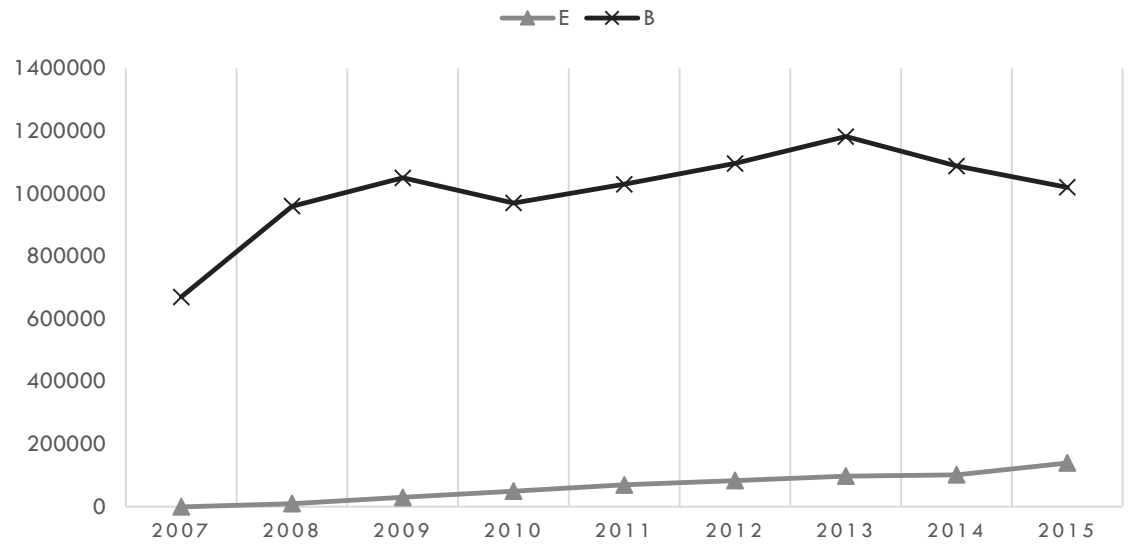

Figure 27: EXPORTS OF BICYCLES AND EPACS FROM GERMANY (2007-2015)
(source: author's elaboration based on Table 12)

Table 13: PATENTS REGISTERED IN GERMANY ACCORDING TO DPMA "FULL-TEXT SEARCH" – TERMs "ELEKTROFAHRRAD" (= electric bicycle) AND "PEDELEC" (= EPAC)
(source: author's elaboration based on DPMA 2016a, DPMA 2016b)[21]

ELECTRIC BICYCLES	PHASE 1	PHASE 2	PHASE 3
TOTAL PATENTS	**51**	**93**	**418**
GERMAN	26	76	327
FOREIGN	25	17	91
TOP 3 LISTED COMPANIES	*Sanyo* I 4 I JP	*Bosch* I 25 I DE	*Bosch* I 160 I DE
	Buchner I 3 I DE	*Schäffler* I 9 I DE	*Ford* I 20 I US
	Thöne I 3 I DE	*Clean Mobile* I 4 I DE	*Ovalo* I 17 I DE
TOP 3 LISTED COUNTRIES	26 I DE	76 I DE	327 I DE
	10 I TW	6 I TW	30 I US
	7 I JP	3 I CN	21 I JP
EPCAS	**PHASE 1**	**PHASE 2**	**PHASE 3**
TOTAL PATENTS	**8**	**58**	**309**
GERMAN	7	53	261
FOREIGN	1	5	48
TOP 3 LISTED COMPANIES	*Schäffler* I 4 I DE	*Schäffler* I 22 I DE	*Bosch* I 74 I DE
	-	*Scott* I 3 I CH	*Schäffler* I 30 I DE
	-	*Bosch* I 3 I DE	*Marquardt* I 15 I DE
TOP 3 LISTED COUNTRIES	7 I DE	53 I DE	261 I DE
	1 I AT	3 I CH	12 I AT
	-	1 I MY	11 I US

[21] Information on the areas in which patents were registered (e.g. batteries, frames, motors, etc.) were not accessible.

Table 14: MAIN GUIDING INTERVIEW QUESTIONS
(source: author's elaboration)

INDUSTRY DEVELOPMENT AND GERMANY AS A LOCATION

- How would you describe the development of the (German) EPAC industry from its beginning until today? Which were some milestones (products and processes)? How does it differ from foreign EPAC industries? Examples. (II, EI)
- How would you describe the recipes for success? What challenges have existed? Examples. (II, EI)
- Which companies have been the leading companies and important industrial actors? Which have been the most interesting and exciting companies? Why? (II, EI)
- Are there any supporting characteristics regarding the 'location Germany' (other industries, education, economic conditions)? Which? Why? Examples. (II, EI)

FIRM DEVELOPMENT AND INNOVATION

- Please describe the historical development of your enterprise (foundation, products, location, internal structure, and organization). (II, EI)
- Who are your competitors? (II)
- With which companies (from which industries) do you cooperate? Why? How? Experiences? Examples. (II)
- What relations do you have to other industries? Why? Examples. (II)
- In which situations do you interact with colleagues, competitors, and partners? (II)
- How does spatial proximity to your partners, competitors, and related industries influence your work? (II)
- How do you leam of new technologies or developmental tendencies? How do you utilize them? Examples. (II)
- If the partner is a producer: describe a typical production cycle. Take one exemplary marketable product: how did research and product or processdevelopment proceed? (II)
- How many resrouces do you spend on R&D and innovation related activities (expenditures, personnel, patents)? (II)
- In case of technical questions or problems, whom do you ask for help? Why? Examples. (II)
- How do customers and demand influence your work? (II)
- What advantages does Germany offer for being innovative? (II, EI)

INSTITUTIONAL, COORDINATIVE AND REGULATORY ENVIRONMENT

- How have politics and the state influenced the industry? (II, EI)
- Which councils, associations, unions or other alliances are influencial? (II, EI)
- Are there any norms or rules you follow? (II)
- What happens if a partner does not meet your expectations or behaves uncooperatively? (II)

* these are only guiding questions. More specific and detailed questions followed single answers during the interview. Not each question was asked in each interview. Questions have roughly been distinguished according to the type of interview partner (Table 5). II = "intra-industry: main interview partner"; EI = "extra-industry: additional interview partner".

INTERVIEW NOTES, AND TRANSCRIPTS

CD

Note: For the research's transparency, a CD was attached to the two officially submitted, and graded copies of this thesis. The CDs included .pdf-files of the transcripts and/or notes of the conducted interviews. All .pdf-files were labeled according to the abbreviations of Table 6.

To ensure the anonymity of interview partners, no transcribed data circulated in publically or was passed to other third parties.

APPENDIX C: ANALYSIS

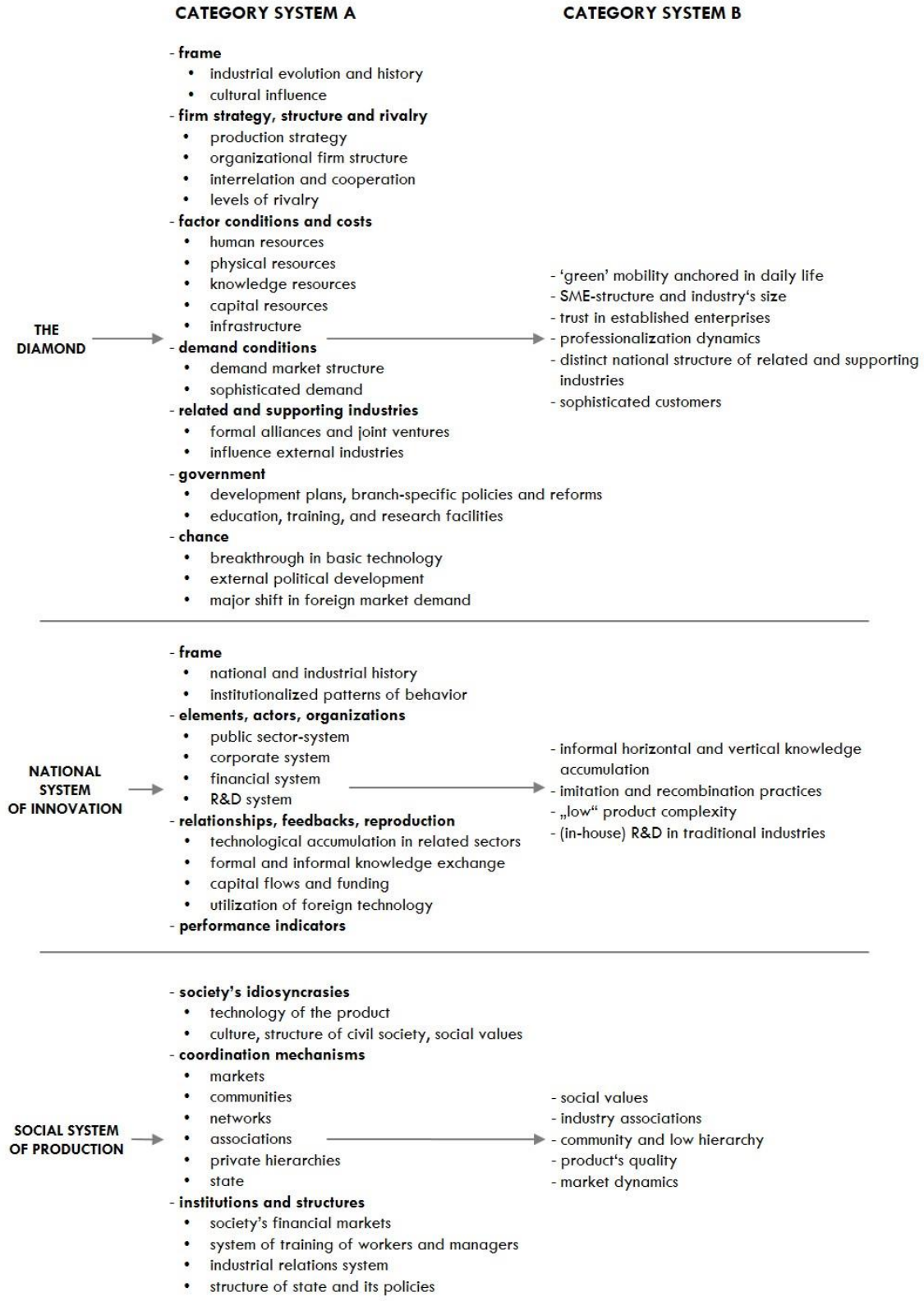

Figure 28: STRUCTURE OF CODED CATEGORIES
(source: author's elaboration)

APPENDIX D: SYNOPSIS

Table 15: SYNOPSIS – EMPIRICAL STUDIES EXPLICITLY FOCUSING ON SUCCESSFUL INDUSTRY DEVELOPMENT OF NATIONS
(source: author's elaboration)

AUTHOR	THEORETICAL APPROACH	INDUSTRY	COUNTRY	EXPLICIT DATA-COLLECTION APPROACH	REASONS FOR INDUSTRIAL GROWTH (✓) = SIMILARITY WITH GERMAN EPAC INDUSTRY
LARSEN AND NILSSON (1984)	xxx	bicycles	Denmark	xxx	national regulations; external effects; demand (✓)
CHU AND LI (1996)	vertical integration	bicycles	Taiwan; South Korea	xxx	state intervention; institutional surrounding (✓)
CHU (1997)	xxx	bicycles	Taiwan	xxx	quick accumulated learning (✓); political environment; globalization of production
MURMANN AND HOMBURG (2001)	evolutionary economics	synthetic dye	Britain; Germany; France; United States; Switzerland	construction of comprehensive database, including qualitative and quantitative primary and secondary data	legal environment; availability of skills (✓); economies of scale and scope; positive feedback mechanisms between enterprises and national institutions (✓); existing infrastructure (✓); technological dynamics (✓)
KLEPPER (2002)	theory of the firm	automobile	United States	qualitative and quantitative secondary: catalogues, case studies, statistical data	ties to related industries (✓)
YEH AND CHANG (2003)	national innovation systems	machine tool	Taiwan	xxx	government; flexibility; prices; ties between users and producers (✓)
BOSCHMA AND WENTING (2007)	evolutionary economic geography	automobile	Britain	construction of comprehensive database, including qualitative and quantitative primary and secondary data	spinoff-dynamics (✓); agglomeration economics; time of industry entry; related industries (✓); pre-entry techno-economic background (✓)
YAN AND HU (2008)	strategic entrepreneurship	bicycle	Taiwan	xxx	collaboration and networking (✓); abundance of enterprises (✓); production skills (✓); government; international ties (✓)
SAXONHOUSE AND WRIGHT (2010)	endogenous technological change	cotton spinning	Britain	xxx	historical contexts (✓); institutional contexts (✓)
AHN AND YORK (2011)	resource-based theories; institution-based theories	biotechnology	Malaysia	qualitative primary and secondary: interviews, case analyses; quantitative primary: survey	access to funding (✓); talent; government
PANGBORN (2012)	*diamond*; industry development; innovation	dairy	New Zealand	qualitative primary and secondary: interviews, desk research; quantitative primary and secondary: survey, desk research	natural resources; infrastructure (✓); property rights; government; basic economic conditions (✓)
LO ET AL. (2013)	national innovation system	photovoltaic	Taiwan	qualitative primary and secondary: interviews, desk research; quantitative primary and secondary: survey, desk research	technological capabilities (✓); government; access to resources; support of R&D facilities
WEERATHAMRONGSAK AND WONGSURAWAT (2013)	competitiveness; competitive advantages; *diamond*	rubber	Thailand	qualitative primary: in-depth interviews	sizes of plantation areas; high amounts of producible volumes
ZHAO ET AL. (2013)	development paths	photovoltaic	China	qualitative and quantitative secondary: literature review, statistical data, regulation and policy studies, law review	technological capabilities (✓); government; access to resources; support of R&D facilities
CHAUDHARY (2014)	xxx	e-mobility	India	qualitative primary: interviews; quantitative secondary: statistical data	private sector enterprises (✓); *demand conditions* (✓); *factor conditions* (✓); policies; R&D across sub-technologies (✓); building of knowledge linkages(✓); cheap skills; societal awareness for environmentally-friendly means of transport (✓)
RUAN ET AL. (2014)	disruptive innovation	e-bikes	China	qualitative secondary: archival research; qualitative primary: semi-structured interviews	government
ALTENBURG ET AL. (2015)	technological development paths	e-mobility	France; China; Germany; India	qualitative primary and secondary: interviews, desk research	technological capabilities (✓); *demand conditions* (✓); political priorities; economic governance (✓)
BRAGUINSKY (2015)	knowledge diffusion on nanoeconomic level; industry life cycles	cotton spinning	Japan	xxx	diffusion of technological knowledge (✓); access to human capital (✓); diversity of knowledge (✓); unfettered competition (✓); government