INNOVATION AND IMITATION BARRIERS

Master Thesis – Innovation and Imitation Barriers
The relationship between resource orchestration, imitation barriers for different process innovation contexts.

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Management Summary

***Purpose* -** Companies and the economy in general thrive on innovations, either in the form of new products, new materials or new processes. The incentive for generating these innovations appears to be clear, because they are associated with increased profits for the developing companies. If competitors would be able to easily tap-in to some or all of these benefits created by an innovation, through imitation, the incentive for innovators to come up with innovations would be decreased or nullified. Process innovations and their imitations are generally more latent, and infringement of intellectual property rights is therefore harder to observe. It is therefore expected that companies who do develop process innovations, generate alternative barriers to imitation, in order to appropriate their investments. These alternative barriers to imitation tend to not be based on legislation, but originate as a result of a discrepancy in resource orchestration in both firms. This study therefore aims to explore the relationship between the creation of imitation barriers and the orchestration of resources in different process innovation contexts, with a specific focus on the development and diffusion trajectory of those innovations.

***Approach* -** This study is based on extensive literature research concerning the concepts of imitation barriers, resource orchestration and process innovation context. The developed theoretical framework was used to analyse a sample of ten cases in which a company developed and commercialised a process innovation. Data on these companies was generated by using an extensive questionnaire, developed by PwC, on resource orchestration during development and diffusion, involvement of stakeholders and factor mapping of success factors and barriers. In-case analysis per case and subsequent cross-case analysis of within group similarities coupled with inter-group differences was performed to unravel the relationship between the different concepts. Listing of subtle differences within case groups, clarified which relationships were exactly found and whether cases could possible by grouped based on other factors.

***Findings* -** The study shows that the relationship between resource orchestration, imitation barriers and process innovation context is nuanced and changes per individual case. Some relationships appear to hold for the whole sample. Firm characteristics always directly influence the orchestration of resources in a firm. Resource orchestration always directly influences the generated imitation barriers. Some imitation barriers in turn also influence subsequent resource orchestration, after they have been created. The relationship between the orchestration of resources and the generated imitation barriers can be mediated by both the characteristics of the innovation and the company's meso and macro contextual factors. Cross-case analysis shows that certain types of imitation barriers are clearly associated with particular types of innovations. The process innovation characteristics are established as a result of the orchestration of resources and most of the time also by factors from the company's meso and macro context. Finally, factors from the company's meso and macro context can also directly generate imitation barriers. This was particularly the case for willingness barriers.

***Value* -** This study contributes to existing theory on this topic in different ways. First, it contributes to a deeper understanding of how imitation barriers deter competitors from imitation in practice. Secondly, it sheds light on the largely disregarded cognitive and willingness barriers to imitation and how these are effected by resource orchestration. Third, it highlights the largely neglected situation for start-ups and SMEs in creating imitation barriers. Fourth, it comes up with the notion of configurations of imitation barriers. Empirical evidence in this study shows that certain innovation types are more compatible with certain reinforcing sets of imitation barriers. Finally, this study puts specific emphasis on the domain of process innovations, which according to literature benefit most from unconventional barriers to imitation.

***Next steps* -** Policymakers should consider the limitations and hindrances that especially small firms face when acquiring patents on their process innovations. Moreover, subsidy programmes should be made more accessible for companies lacking a patent. Managers developing process innovations should focus on their core competences and seek cooperation for everything else. This study shows that open innovation practices, in which either customers or suppliers participate in development, not only contribute to quality of the innovation, but also facilitate some of the key imitation barriers. Furthermore, analysis shows that imitation barriers are only seldom created randomly. Managers are therefore advised to come up with a clear strategy for the creation of imitation barriers, at the start of the development trajectory. As most resource orchestration actions simultaneously affect process development and imitation barrier creation, both strategies should be made to fit with each other. Ideally, imitation barriers are in place at the point of implementation or market entry of the process innovation. Finally, some types of process innovations are inherently more compatible with particular configurations of imitation barriers. Managers should identify opportunities for creating imitation barrier early on in the development process. This way a strong configuration of mutually supportive imitation barriers can be established, which potential imitators will find hard to overcome.

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1 Introduction

Companies and the economy in general thrive on innovations, either in the form of new products, new materials or new processes. The incentive for generating these innovations appears to be clear, because they are associated with increased profits for the developing companies, either through for instance costs reductions or revenue increases. If competitors would be able to easily tap-in to some or all of these benefits created by an innovation, through for instance imitation, the incentive for innovators to come up with innovations would be decreased or nullified. Through intellectual property law, governments have tried to "artificially" limit would be imitators in their imitative abilities, in order to incentivise innovative behaviour among companies and individuals. This limitation is called "artificial", because it is of a legal nature and not so much physical. The characteristics of this intellectual property law, cause it to be more effective for the protection of product and material innovations, and not so much for process innovations. Process innovations and their imitations are generally more latent and infringement of intellectual property rights is therefore harder to identify. The processes that companies conduct are often executed in a closed facility and are not open to publicity. It is therefore expected that companies who do develop process innovation, generate alternative barriers to imitation, in order to appropriate their investments. These alternative barriers to imitation tend to not be based on legislation, but originate as a result of a discrepancy in resource orchestration (or resource deployment) in both firms. ***This research is therefore concerned with the issue of how imitation barriers for process innovations are created as a result of resource orchestration, and if and how this relates to different process innovation contexts.***

1.1 Research scope

Literature on competitive advantage and profitability of companies in general can be distinguished by the strategic management school that they belong to. The resource based view, as a management school, explains how a company can achieve a sustainable competitive advantage through orchestration of its organisational resources. The idea that firms are fundamentally heterogeneous, based on their resources and capabilities, has been a underlying principle for strategic management for decades (Peteraf, 1993). The classic approach to strategy formulation, for instance, begins with stating the importance of organisational competencies and resources (Andrews, 1971). The resource-based view of the firm, initiated in the 1950s, started by explaining growth of the firm as a theory of internal growth (partially) through orchestration of available resources within the firm (Penrose, 1959).

This resource based view of the firm is an obvious approach to base this research on. The topic of this research is closely linked with this view of the firm, because which, if all, valuable process innovation a company is able to generate is highly dependent on the mix of resources that it is able to orchestrate. Schumpeter's idea of innovation, "new combinations" of for instance existing production methods, may be translated into the resource-based framework by considering the firm's "new combinations of resources" (Penrose, 1959) as a means of achieving the goal of sustained competitive advantage (Ghemawat, 1986). Confirmation of this link between innovation and the firm's resource position in previous literature is abundant. Barney (1986a), for instance, states that resources in terms of culture, generates innovativeness and flexibility in firms.

One of the core premises of the RBV is that companies' resources are immobile and heterogeneous. Owning and deploying a certain bundle of resources allows a firm to achieve a competitive advantage (Penrose, 1959), for instance through a successfully commercialised process innovation. This competitive advantage translates into higher rent for the innovating company. However, to make this competitive advantage and rent generation sustainable, the resources have to fulfil certain criteria. Peteraf (1993) claims that there are four theoretical conditions which underlie competitive advantage, which all have to be fulfilled for the competitive advantage to be sustainable. These conditions are resource heterogeneity, ex post limits to competition, imperfect resource mobility and ex ante limits to competition. Other authors use slightly different terms to describe almost the same phenomena, for instance value, rareness, imitability and substitutability (Barney J. , 1991). Barney claims these concepts to be empirical indicators of the firm resources' potential to generate a sustainable competitive advantage. Without companies being different concerning their resource base, due to for instance rareness of resources in combination with inimitability, no sustained competitive advantage can be created (Barney J. , 1991).

Although these factors all are quite distinct from each other, they are also very much related (Peteraf, 1993). Arguably, of these four factors, ex post limitation to competition can be best influenced by companies themselves. It therefore would be the most interesting condition to study on a company level, within a management focused study like this particular research. The ex post limitations to competition in the resource based view consists of "imperfect imitability" (generated through ***imitation barriers*** and named by that term from here onwards) and “imperfect substitutability” (Peteraf, 1993). It is hard to draw a clear line between these two concepts, because for instance, would a slight alternation of a process still be an imitation or already a substitute. Substitutability is highly dependent on future technology developments which would make measurement of this concept very ambiguous and difficult. From a company perspective (which this research takes), it is easier to tell whether competition will be able to imitate their process, because this implies that they have to conduct at least somewhat the same steps. This is probably also why most attention within the resource based view has been given to imitation barriers (Peteraf, 1993). Following this reasoning, in this research ex post limitations to competition will be fully represented by imitation barriers.

This research will not focus on the other three conditions. In general, it is safe to assume that company resource endowment is heterogeneous and mobility of resources is limited. Thus, both heterogeneity and imperfect mobility of resources are assumed to be present. This assumption is backed by evidence from previous research, which states that it is reasonable to expect that in most industries there will be at least some degree of resource heterogeneity and immobility (Barney & Hoskisson, 1989).

The concept of ex ante limits to competition has received much criticism in literature, even within resource-based view literature (Dierickx & Cool, 1989) (Williamson, 1979). It is for instance argued that the most important resources or capabilities are in fact accumulated or build, not bought. Although Barney (1986b) claims that all required resources can be bought and sold on the market, this seems illogical and hard to believe. Williamson, for instance, stresses that the idiosyncratic nature of firm specific assets rules out their tradability on open markets. Furthermore, this concept is much more related with economic theory on factor markets than with management, and therefore is outside the scope of this study.

The focus on imitation barriers adds up to the other focus of this research on the development and diffusion trajectory of process innovations within companies, because the same resources or organisational capabilities that facilitate the creation of a unique process innovation, are also largely responsible for the (un)conscious creation of barriers to imitation. In fact, Hayes & Wheelwright (1984) clearly state that a piece of physical technology is by itself typically imitable. Especially when this technology is for sale, operation of the technology does not provide the innovator with sustained competitive advantage (Barney J. , 1991). It therefore does not make sense to analyse the technology itself. Rather, one should look at the resources, as deployed during the development process that led to the creation and implementation of the technology, that might form barriers to imitation. This research therefore specifically focuses on the imitation barriers that firms consciously and unconsciously create through the orchestration of resources during the development trajectory of process innovations in different contexts. The process innovation context in this case entails the innovation characteristics, firm characteristics and factors from the firm’s meso and macro environment. In particular, ***this research aims to explore the relationship between a firm’s resource orchestration, during process innovation development/diffusion, and the creation of different types of imitation barriers, for different process innovation contexts.***

Finally, as is described in previous literature (Rumelt, 1987), there is a clear link between future innovations and existing imitation barriers. As Rumelt (1987) phrased: “In many industries, after the first wave of innovation, competition is aimed at reductions in the size of isolating mechanism”. This means that imitators will try to develop new processes and products which undermine the resource position of the innovator. “These competitive moves, themselves innovative activity, all act to carry the industry from its early birth stages to maturity (1987)”. This proves that the imitation barriers are not only a valuable source of innovation protection, but also provide a stimulus for future innovation, and therefore are an interesting topic to the field of innovation management.

1.2 Theoretical relevance

Theoretical gaps

To arrange existing theories on imitation barriers, isolating mechanisms and all other synonyms that are used throughout literature to basically describe the same phenomenon, a closer look is taken at the process of imitation.

The imitation process entails three different steps (Jonsson & Regnér, 2009). In a logical order these are: first, the identification of what to imitate; second, the willingness to imitate; and third, the ability to do so. A potential imitator can be deterred from imitation at each step, by experiencing different barriers. Previous literature on this topic has mainly focused on barriers belonging to the last step of the process (Jonsson & Regnér, 2009). It is assumed by authors like Barney (1991), Diederickx and Cool (1989), Reed and DeFillippi (1990), Peteraf (1993) and Wernerfelt (1984) that firms always try to quickly imitate anything that seems profitable. However, in this study the counterargument of Jonsson and Regnér (2009), that first a company must be able to identify what it wants to imitate and be willing to do so, is pursued. Because "cognitive" and "willingness" barriers have been largely neglected by previous literature, these topics will receive specific attention in this research. This does not mean that "ability" barriers are not covered in this research, as these still make up the bulk of all imitation barriers and appear to be key.

Previous literature on imitation barriers does not seem to make a distinction between whether companies and managers consciously or unconsciously, through the orchestration of required resources for developing their process innovation, create imitation barriers. The current research setting seems especially suited for this angle on imperfect imitability, because the research to market trajectory of a recently commercialised process innovation provides an unambiguous (as far as possible) perspective on the resources that were deployed, and led to the creation of imitation barriers at the point of market entry. Even though companies might not have aimed to do so consciously, thorough description of the main activities during the development process, should enable the researcher to deducts the sources of imitation barriers and might even help to explain how they, in the particular setting, prevent competitors from imitation. This explanation of how imitation barriers exactly work in practice, is also identified as a gap in existing literature (Teece, Pisano, & Shuen, 1997). One of the research questions in this thesis, therefore is:

- ***How do different types of imitation barriers prevent competitors from imitating a process innovation, in practice?***

Contributions to theory

Based on the gaps in literature, put to light by this literature overview, the following foci are chosen to which the current research aims to make contributions:

- Barriers to the first and second step of the imitation process: "cognitive barriers" and "willingness barriers";

- Distinction between imitation barriers that are consciously build by managers and those that are the result of unconscious actions;

- Explain imitation barriers' functioning in practice by closely analysing the build-up and orchestration of resources, during the development trajectory of process innovations, that provide a source of imitation barriers.

Furthermore, although previous literature on the topic of imitation barriers is extensive, it has never really put specific emphasis on process innovation. By building extensive case studies, this research hopes to provide generalisation on the creation of barriers to imitation for process innovations. It is for instance highly likely that patents will not play such an important role in the protection of process innovation, for the simple reason that enforcement of such rights is harder when you cannot clearly see whether the competitor is infringing on your patent. In fact, Cadot and Lippman (1995) even explicitly state that: "When it comes to process innovations, patents are the least effective means of appropriation due to the direct leakage of information as well as the demonstration effect".

1.3 Practical relevance

The knowledge generated in this study, can be of value to both policy makers and managers/entrepreneurs. This thesis' focus on imitation barriers for process innovation in particular, might clarify whether current legislation provides enough incentive for innovation, and whether companies think that the appropriation of R&D efforts is sufficiently supported by for instance available patent law.

Furthermore, by analyzing which barriers to imitation were used by successful process innovators, this research aims to provide recommendations to companies on how to best protect their process innovation from competitive imitation. In this way helping to enable companies to better appropriate their R&D costs and make the achieved competitive advantage more sustainable.

1.4 Objective

Formulation of the research objective will be done using the format of (Creswell, 2006). This format supports the formulation of a research purpose for various qualitative research approaches. It is also a helpful tool for the researcher to think about the exact framing of the research question and is an opportunity to signal the reader the specific approach that will be used (Boeije, 2010).

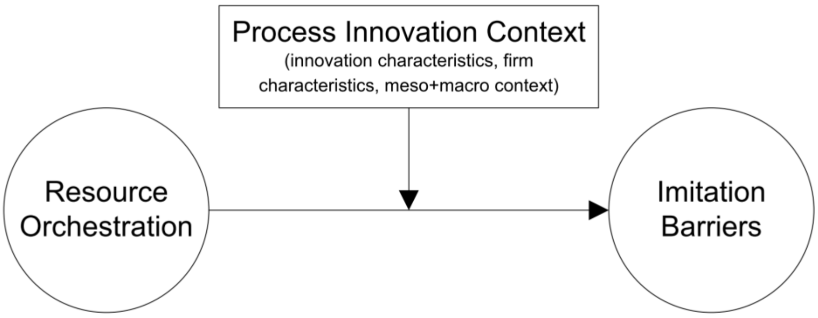
The objective of this multiple-case study analysis is to explore the relationship between the orchestrated resources during the research to market trajectory of process innovation and the imitation barriers that are created, in different process innovation contexts, in order to formulate recommendations for companies that want to more effectively protect their process innovations. At this stage in the research, "resources" are generally defined as all assets, capabilities, organisational processes, knowledge and firm attributes controlled by a firm. The "research to market trajectory" is defined as the sequence of actions with which a company develops and diffuses its innovation. "Imitation barriers" encompass all "cognitive", "willingness" and "ability" barriers that prevent competitors from imitating a process innovation. Finally, different "process innovation contexts" refers to the different innovation characteristics, firm characteristics and factors from the firm's meso and macro environment that apply to each individual case.

The knowledge gained in this research is used to form recommendation for companies wanting to develop process innovations, on how to build effective barriers to imitation by deploying certain resources during development and diffusion of a process innovation.

Conceptual model

This research explores the relationship between resource orchestration and the creation of different types of imitation barriers for different process innovation context. The nature of this research is explorative. We therefore do not establish clear hypothesis regarding the strength and direction of the relationship between the different concepts. We do, however, have a assumption regarding the direction of the relationship. It is assumed and theoretically proven that imitation barriers are dependent upon the firm's resource orchestration. Furthermore, it is assumed that process innovation context, embodied by the innovation characteristics, firm characteristics and factors from the firm's meso and macro environment, mediates the relationship between both concepts.

Figure 1: Conceptual model: Assumed relationships and directions



1.5 Research questions

Central question

To achieve the research objective the following central question needs to be answered:

- **What is the relationship between resource orchestration and the creation of different types of imitation barriers, for different process innovation contexts?**

Core Concepts

The core concepts, which will be further defined and operationalized in the literature review chapter, within this central question are:

- ***"process innovation context"***

In this research, *process innovation context* is a broad concept used to describe the ***characteristics of the innovation***, such as the type and degree of novelty, and the context in which the innovation was developed and commercialised, which encompasses the ***firm's characteristics*** and key factors from the ***meso and macro environment*** in which it operates.

❖ ***"resource orchestration"***

In this research, *resource orchestration* is defined as all resources and capabilities a firm possesses and deploys during the research to market trajectory for development and commercialisation of the process innovation under research.

❖ ***"imitation barriers"***

Imitation barriers encompass all cognitive, willingness and ability barriers that prevent or deter potential imitators from imitating the process innovation under research. In this research, we only look at imitation barriers that are created as a result of resource orchestration of the innovator company.

Research questions

The central question can be separated in the following research questions:

1) ***How are organisational resources orchestrated during the research to market trajectory of different types of process innovations contexts?***

2) ***Which imitation barriers can be identified based on the orchestrated resources per process innovation context?***

3) ***How do different types of imitation barriers prevent competitors from imitating a process innovation, in practice?***

4) ***What are the effects of differences in resource orchestration and process innovation context between cases, on the created imitation barriers?***

Based on literature and our assumptions, orchestration of resources during the development and diffusion of a process innovation, is largely responsible for the generation of imitation barriers that make the innovative advantage sustainable. Research question one therefore aims to capture all relevant orchestration activities in this respect, through detailed interviews with case respondents. Subsequently, we develop an imitation barrier framework based on literature and analyse the data on resource orchestration to identify the presence/absence of different types of imitation barriers. We take particular interest in how these theoretically described imitation barrier concepts, deter imitators in practice. During data collection we do not solely focus on resource orchestration, but also on the characteristics of the innovation, characteristics of the firm and key factors from the innovator's meso and macro environment. There is reason to assume that these factors might influence or mediate the relationship between resource orchestration and imitation barriers. By comparing different cases with diverging resource orchestration strategies and contexts, we aim to identify similarities and differences in the relationship between the three concepts. Answering all four research questions should provide sufficient knowledge to answer the central question of this study.

1.6 Research Setting

Parts of this research will be conducted within a research project executed by PwC on behalf of the European Commission (from here onwards EC). PwC is a global professional service provider. The company specialises in assurance, tax advisory, financial advisory, actuarial sciences and advisory. One of the core competencies of PwC Advisory in the Netherlands is to conduct studies on behalf of, and formulate policy recommendations for, government bodies. Data collection for this thesis will be conducted within one of those studies. The study investigates the key activities that were conducted and barriers that were experienced during the research to market trajectory of recently commercialised innovations.

2 Literature review

2.1 Introduction

This literature review will focus on definition and operationalisation of the core concepts mentioned in the central questions of this study. A clear definition and operationalisation of the core concepts is key for subsequent analysis of data. The three core concepts that are central in this review are: imitation barriers; resource orchestration; and process innovation context. The literature review will result in a theoretical framework, which will form the basis for data analysis.

2.2 Approach

The literature review is conducted using many of the most influential articles within the resource-based view, to get a good overview of well-known authors and theoretical perspectives used. These articles were acquired using forward and backward referencing. Searches were done by specific authors and titles, because conducting an inclusive literature search on research based theory would be too comprehensive. Furthermore, test with keyword searches like “imitation” and “barrier” did not result in the influential articles that were referred to by influential authors. The approach of referencing was therefore used. The literature database that was used for acquiring this literature search was Web of Science. In case Web of Science did not provide the required article, Google Scholar was used.

Based on this collection of articles and their content, found through backward and forward referencing, the researcher decided to do an additional literature search for the two steps of the imitation process that have been largely disregarded by resource-based view literature. These two steps concern the willingness to imitate and the cognition of what to imitate. Although recent publications indicated that not much had been written on these topics, the researcher wanted to include any useful articles that were available. The keywords used for literature search are listed in table three, including the amount of hits per search and number of relevant articles.

Keywords were based on the research questions, the initial literature study and keywords mentioned in review articles on the topic, like Peteraf (1993), and publications she refers to. The keywords for the literature search had to be balanced between inclusiveness and excessive results. More or broad search terms would have made the literature review more inclusive, but because of time limitations, too many results would not be manageable.

The literature search in this research therefore only relied on keyword searches in combination with Boolean operators. The volume of publications on these two topics was limited. An inclusive approach was therefore possible. Searches by specifics, authors and titles were not conducted, because this is not really suitable for an inclusive literature review (Fink, 2004). The Web of Science database does not offer a thesaurus search function.

Asterisks were used to include variations of words like “imitation” and “cognition”, which might be missed out by lemmatisation, a search tool that was activated during the search process. The literature search was not confined to a certain time span, because during the initial literature review, its showed that “older” articles have been influential within the topic.

To identify relevant articles and focus on the most influential articles, the following criteria are used to briefly assess every found article:

- The publication is written in English or Dutch;
- Research field of the publication is Management, Business or Economics;
- The publication is either a review or article;
- The publication is unbiased/neutral;
- The content of the publication is relevant for the topic;
- The publication is available to the researcher.

The first three criteria were easily accessed by applying the database’s refinement functions. The third and fourth criteria are accessed by briefly analysing the article’s title, abstract and source. The last criteria of availability is self-evident.

Table 1: Overview of keywords in Web of Science

Keywords	Number of hits	Number of relevant articles	Number of articles available
cogniti* + barrier* + imitat*	1	1	1
cogniti* + resource* + imitat*	3	1	0
cogniti* + resource* + barrier*	4	1	1
identif* + resource* + barrier	96	2	2
identif* + resource* + barrier	37	10	9
willingness + barrier + imitat*	2	2	2
willingness + resource+ imitat*	2	1	1
willingness + resource + barrier	7	1	1
willing* + imitat*	15	3	2

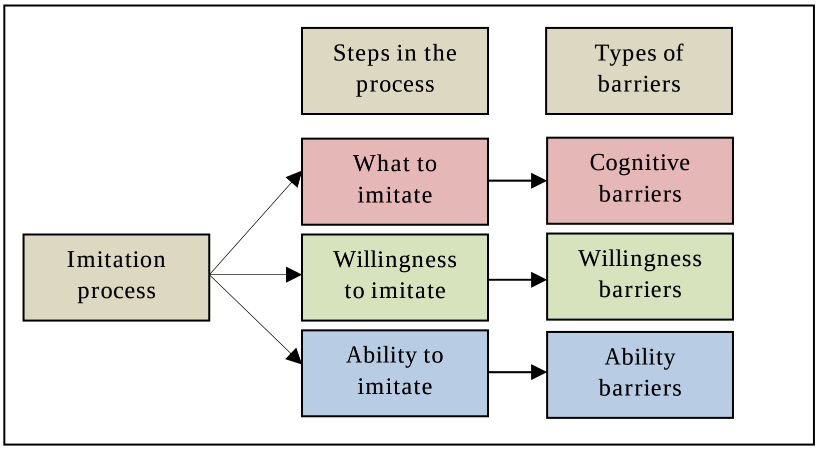
For the analysis of resource deployment during the development and commercialisation of the process innovations, we shift our focus slightly from the resource based view to the resource orchestration and dynamic capabilities perspectives. These perspective are more modern than the resource based view and have made enhancements to traditional RBV assumptions and suggestions to make them more empirically valid (Sirmon, Hitt, Ireland, & Gilbert, Resource Orchestration to Create Competitive Advantage: Breadth, Depth and Life Cycle Effects, 2011). In short, these perspectives put more emphasis on how resources are deployed by conscious managers.

This approach fits the current research design well, because during data collection emphasise is put on managers' perceptions and intensions concerning the orchestration of resources were (due to the manner of data collection). Furthermore, the model is robust enough to deal with a variety of firms, as is the case in this research, because it is extended to adjust for firm specific characteristics like scope, level of hierarchy and stage of maturity. It is expected that these factors influence the manner in which companies deploy their organisational resources.

2.3 Imitation barriers

The factors used to structure imitation barrier literature are the three steps in the imitation process. The most important theoretical contributions to imitation barriers are categorised along these steps and will be used during the data collection and analysis phase to operationalise the different concepts. The dividing lines between the three different steps are not as clear for all barriers. Where applicable, this overlap will be indicated. The basic structure is displayed in figure two.

Figure 2: Overview of the imitation process and types of barriers



It is important to note here that this research only focuses on resource based imitation barriers. Literature on for instance competitive blind spots (Zajac & Bazerman, 1991), deriving inimitability from a competitor's managerial deficiencies like overconfidence, non-rationality or limited perspective and frame to the problem, are not included in the scope of this literature review. Other factors like opportunism or bounded rationality among managers of potential imitators (Conner & Prahalad, 1996), are also disregarded. All these sources of inimitability are dependent upon the competitors' skills and capabilities and not the innovator's deployed resources and capabilities. To conclude, focus will be on articles originating from the resource based view, because these mainly treat imitability from the innovator's resource perspective. The acquired data collection only facilitates an analysis from the "innovator's resource perspective" of inimitability.

2.2.1 Cognitive barriers

Previous literature on this subtopic is concise. Especially Amit and Schoemaker (1993) have been influential in this field. They suggest that differences in cognitive structures and beliefs may lead to variations in how for instance managers identify different resources and capabilities. This in turn, has effect on the time it takes a company to imitate. Apart from internal organisational processes and cognitive biases of managers, the institutional context of firms also matters (Jonsson & Regnér, 2009).

Amit and Schoemaker (1993) suggest that a firm's resources and capabilities generate rents, partially due to the inimitability that they generate. Managers have difficulty identifying, developing and deploying the required resources and capabilities for imitating an innovation due to: uncertainty, complexity and inter-organisational conflict. These three sources for cognitive barriers to imitation will be clarified below. It is evident that there is an obvious overlap with concepts from ability barrier literature, like causal ambiguity.

Uncertainty regarding the future

In theory, the initial firm's resource and capability endowments form the only source of variety regarding managers' behaviour. In practice, however, managers face significant uncertainty and ambiguity regarding the future, originating from new proprietary technologies, economic and political trends, competitive actions, changes in societal values, and corresponding shifts in consumer preferences. Uncertainty and ambiguity make it likely that managers hold different expectations regarding key variables like demand growth, price levels, costs, and consumer preferences (Amit & Schoemaker, 1993). Moreover, their judgements and choices are likely to display individual degrees of aversion to risk and ambiguity (Kahneman & Tversky, 1979; Einhorn & Hogarth, 1986) .

Consequently, an example of a common flaw among managers is that they are too focused on past competitors and pay too much attention to recent occurrences. This phenomena is known as the recency effect which is closely linked to the more widely spread concept of the availability heuristic (Kahneman & Tversky, 1979).

Complexity and interplay of resource and capability issues

Because resource and capability issues often exceed managers' cognitive abilities, they must be extensively simplified (Russo & Schoemaker, 1989). Simplification of complex resource and capability issues often results in cognitive biases. Examples of simplified framing can be considered the isolation of different future scenarios or relative expression of outcomes (Amit & Schoemaker, 1993).

This complexity of resource and capability issues, according to Peng, Schroeder, and Shah (2008), is created because an organisational capability is build on a bundle of interrelated organisational routines. Potential imitators therefore cannot observe the complete bundle and the complex interplay between the routines underlying it. In combination with the tacit nature of the individual routines and path dependency in creating them, observability of what to imitate is severely hindered.

Kahneman & Tversky (1979) suggest examples of how simplified framing can lead to inadequate decisions. In particular, simplified framing may lead to exclusion of important future scenarios, competitors or new technologies; incorrectly determine the reference point relative to which resources and capabilities are measured (e.g., "Chrysler comparing its quality control capability to GM's rather than to Japan's Honda" (Kahneman & Tversky, 1979)); and inappropriately specify the criterion or unit of measure used to evaluate resources and capabilities (e.g., evaluating quality in terms of defective parts per thousand vs. the number and nature of consumer complaints).

Mintzberg and Waters (1983), among others, also make a link to path dependency or the role of the firm's unconscious past. They suggest that a firm's realised resource and capability strategy is a combination of both rational or intentional choices, and implicit and more tacit forces within organisations.

To conclude, managerial decisions concerning resource and capability deployment are affected by a wide range of cognitive biases created due to the handling of both uncertainty and complexity. This, consequently, generates imitation barriers and organisational rents for firms using this occurrence to their advantage (Amit & Schoemaker, 1993).

Intra-organisational conflict

Intra-organisational conflict is another key challenge encountered by managers making resource and capability decisions. Any change in the existing bundle of resources and capabilities within a firm, might be advantageous for some employees and disadvantageous for others. Issues like the agency problem, cooperation, trust and competence must all be accounted for when making decisions regarding a firm's resources and capabilities (Amit & Schoemaker, 1993).

A key point here is that organisations are complex social entities with their own inertia and constraints. Managers cannot make resource and capabilities decisions solely based on the prospective rents that each option would result in. Organisational participants, like employees, have to be accounted for. This for instance poses problems of nestedness; "for example, strategic business unit level choices impact divisional as well as corporate capabilities and vice versa" (Amit & Schoemaker, 1993). It cannot be assumed that organisations have solved their principal-agent problems and only need to focus on the market for resources and capabilities and simply acquire the ones they need.

Complementarities between resources or business processes in valuation

Authors adopting a behavioural strategy approach identify the difficulty of recognising particular resources and capabilities that underlie a firm's competitive advantage (Denrell, Fang, & Winter, 2003). They suggest that the difficulty of recognising the value of a particular resource or capability is associated with the lack of certain complementary resources or business processes in a potential imitator's firm. A certain resource would then only be evaluated as valuable if the way in which existing resources or processes are used, would change significantly. "Only if all of these changes occurred simultaneously would the value of such a resource be discovered" (Denrell, Fang, & Winter, 2003).

Long time lags

Authors from dynamic capabilities literature (Ambrosini & Bowman, 2009), argue that long time lags between the deliberate decision to deploy certain resources or capabilities and the subsequent resource stock outcomes clearly hinder identification among competitors, but also innovators. These long time lags appear to be one of many conditions for (increased) causal ambiguity, with regard to cognitive imitability.

Secrecy

Maintaining secrecy about resource and capability development and deployment is considered to be an important cognitive barrier to imitation (Cohen, Nelson, & Walsh, 2000). Imitators could try to overcome this cognitive barrier, for example, by increasing their absorptive capacity through allocating close to an innovator or by hiring away the innovator's employees. The strength of this barrier depends on how much information flows from the innovator to the potential imitator. In general, information flows are bad for the innovators because the resulting decrease in complexity for the follower reduces sustainability. Innovators can actively maintain secrecy through the signing of non-disclosure agreements with all involved parties.

Causal ambiguity

Causal ambiguity is mentioned both as a cognitive barrier and ability barrier to imitation. Causal ambiguity**,** is a concept that is in effect when competitors aiming to imitate an innovators resources, have difficulty seeing the link between an innovator's unique resources and the competitive advantage that it creates. They therefore do not see which resources or capabilities need to be imitated in order to duplicate the competitive advantage of the innovator.

This barrier to imitation has some overlap with other cognitive barriers like complexity and time lags. These latter two can be seen as factors contributing to the degree of causal ambiguity. Other authors claim to have found additional underlying factors within an innovator firm that would increase causal ambiguity as a cognitive barrier to imitation. González-Álvarez & Munoz-Doyague (2006), for instance, claim that existence of a participative or motivated workforce should bar competitors from identifying the competencies of the firm, because this would increase the degree of causal ambiguity perceived by rivals. This is, however, not empirically supported in their study.

2.2.2 Willingness barriers

Barriers concerning the willingness to imitate, are even more neglected by previous literature (Jonsson & Regnér, 2009). Jonsson and Regnér (2009) can be considered to be the pioneers in this sub domain of imitation barriers and identify institutionalised professional norms on product appropriateness as barriers to imitation.

Institutionalised norms

In specific, product categories that are considered less professionally appropriate by industry are imitated with significantly longer time lags. Furthermore, normative institutionalisation has a significant effect on the willingness to imitate socially complex competences. The study highlights that inimitability differs across industries, depending on how heavily invested firms are in the industry's core competencies. Some firms might be able to make use of the institutionalised setting in a particular industry by exploiting the differential normative barriers to imitation this creates (Jonsson & Regnér, 2009). Managers with insights into social complex norms that other competitors cannot apply as easily and quickly, might be able to so.

Johsson and Regnér mainly base their conclusion on institutional theory, where the role of institutionalised norms of appropriate actions has been the central topic of research for a long period. Other authors from this field have addressed institutional constraints on economic action (Ingram & Silverman, 2002) and the benefits of complying with institutional pressures (Deephouse, 1999) (Oliver, 1997), as the origins of unwillingness to imitate.

Although authors within the resource based view might not have given this phase of imitation much attention, industrial economists have. They elaborate on moves that make imitation unrewarding even if it is technically feasible. In game-theoretic models, for instance, innovator firms make costly investments, which alter their own future incentives, to make retaliation threats publically known and in this way make imitators unwilling to imitate (Rivkin, 2000).

Institutional barriers from the political and cultural context

Similar to aforementioned institutionalised norms, other authors suggest institutional isolating mechanisms as firm level factors that influence the chances of optimal resource use and acquisition (Oliver, 1997). These mechanisms are defined as low levels of political or cultural support for certain resource decisions within firms. Institutional isolating mechanisms, according to this author, are barriers to imitation that result from a firm's unwillingness to imitate or acquire certain resources that are incompatible with the firm's cultural or political context. They therefore affect a firm's willingness to imitate.

Environmental stability

Willingness to imitate is higher when the innovator and imitator's environment are stable. "Stability implicitly builds in an advantage for imitative behaviour" (Hehenkamp & Kaarboe, 2008). Assuming that an imitator will always lag behind the innovator to a significant degree, a stable environment would assure the imitator's success when imitating an innovator's conduct, some period after the innovator displayed a certain degree of success with that conduct. In a significantly changing environment, an imitator might be constantly missing the successful fit between conduct and environment, because the environment already changed while the innovator's conduct was copied.

Availability and price of IPR licenses

It is expected that if the technology of the innovator is licensed against a reasonable price, imitators will be less willing to imitate. Clearly, what is perceived as reasonable depends on a variety of factors. Whether the potential imitator is capable of engaging in imitative R&D, offers it a significantly better bargaining position. Other factors like an imitator's willingness to pay for innovation and whether they consider licensing as an alternative to in-house research, are hard to assess from the innovator's perspective (Gans & Stern, 2000). In general, however, availability of licenses to potential imitators, lowers their willingness to imitate.

2.2.3 Ability barriers

Literature on so called ability barriers is quite extensive and many authors state different names and concepts to describe the same phenomena or closely related ones. To get a clear overview, the different concepts and terms are grouped in a framework of nine concept categories. Although this grouping is quite subjective, based on the researcher's interpretation and chosen level of abstraction, argumentation for each choice is given in the following paragraphs.

Barney (1991) already partially did what is intended in this literature review, which is creating an overview of the different barriers by grouping examples mentioned in literature. We therefore take the three categories that he constructed and extent these with the work of other authors to come to a inclusive framework of all ability barriers to imitation. We will then take a closer look to the definition of each concept and how to operationalise them. The various types of imitation barriers, mentioned by the different authors, are elevated to a more abstract level, to be able to group and compare them. The more specific concept features mentioned by authors are used to operationalise each category.

According to Barney (1991) resources of companies can be inimitable for a combination of three reasons: the ability for a firm to obtain a certain resource is dependent upon its *unique historical conditions*. The link between the resources and the competitive advantage that they create is *causally ambiguous*. Or, finally, the resource generating the competitive advantage is *socially complex*.

Path dependency

The concept of *unique historical conditions*, or ***path dependency***, as it will be called in this research, is a proven concept in literature, even supported by strategy researchers from other schools (Ansoff, 1965) (Learned, Christensen, Andrews, & Guth, 1969). It basically claims that the ability for firms to acquire and exploit certain resources depends on their place in time and space. Once this particular time or period in history passes, it will become very hard for other firms, that do not have space/time dependent resource, to obtain them (Barney, 1991).

Dierickx and Cool (1989) take a particularly interesting perspective on limitations to imitation. In their view, how imitable an asset is depends upon the nature of the process by which it was accumulated. The direct link to the research to market trajectory for a process innovation, and the capabilities that are developed during this process, are self-evident here. The authors also emphasise that especially resources and capabilities that cannot be bought on strategic factor markets, are highly inimitable through the following factors: *time compression diseconomies*, *asset mass efficiencies*, *interconnectedness of assets stocks*, *asset erosion* and *causal ambiguity*. The authors seem to put a lot of emphasis on ***path dependency***, as both time compression diseconomies and asset mass efficiencies can be assigned to this concept, that emphasises that “history matters”. Asset erosion, or punitive post entry behaviour is out of the scope of this research as it focuses more on post development actions. Both **causal ambiguity** and (asset) **resource interrelatedness** are identified as key concepts, and will be described later-on in this chapter, incorporating this article’s input.

Path dependency, although apparently closely related to many other concepts, like for instance “distinct organisational capabilities” in the form of organisational learning, in this research is thus defined as all phenomena associated with *irreversible investments*, *time compression diseconomies* and *asset mass efficiencies*.

Irreversibility of investments does not need any further clarification. Time compression diseconomies can be best explained by an empirically supported phenomena in R&D. The presence of time compression diseconomies implies that maintaining a certain rate of R&D spending over a particular period of time produces a larger quantity of R&D know-how, than maintaining twice this rate of R&D spending over half that period. It basically implies that the time factor cannot be compensated by extra money, personnel or other resources (Dierickx & Cool, 1989).

Asset mass efficiencies refer to the notion that adding increments to an existing asset stock is easier when a company already possesses high levels of that stock. For example, firms with certain R&D expertise, can more easily generate additional knowledge in that field. Simply said, success breeds success.

Finally, experience economies are also included under this concept, because they mainly encompass irreversible investment over time, and not so much learning based on capability (Ghemawat, 1986). Although path dependency can also be linked with the organisation’s capability to learn, as this is very much embedded in the firm’s history, the concept will be kept narrow to maintain workability.

Causal ambiguity

Peteraf (1993) provides a fairly complete overview of the most important contributions to the field of ability imitation barriers up to the 90s, including Rumelt, Dierickx & Cool and Ghemawat. Rumelt coined the term “isolating mechanisms”, to refer to a phenomen0n which protects individual firms from imitation and preserves their rent streams. This author wrote multiple articles on this concept and therefore developed several types.

Besides *intellectual property rights*, the most basic and explicit form of imitation barriers (which will be discussed later-on in this chapter), he distinguishes various quasi-rights like *time lags*, *information asymmetries* and *frictions* which deter or prevents imitation (Rumelt, 1984). His most important contribution, however, is the concept of *causal ambiguity* (Lippman & Rumelt, 1982).

Causal ambiguity, is a concept that is in effect when competitors aiming to imitate an innovators resources, have difficulty seeing the link between an innovator's unique resources and the competitive advantage that it creates. It basically says that the link between the resources deployed by a firm in order to develop a process innovation and the actual process innovation itself, or the competitive advantage derived from it, is not understood or understood only very imperfectly. Causal ambiguity clearly inhibits the cognitive phase of imitation, but is also mentioned throughout literature that is more focused on ability barriers (Rumelt, 1984) (Dierickx & Cool, 1989). It is therefore adopted as an important, separate category of imitation barriers.

Although Lippman and Rumelt (1982) state that causal ambiguity can only be a source of inimitability if both innovator and imitator are faced with the same level of causal ambiguity, in this research we extent concept of causal ambiguity to also include cases in which the link between resources and process innovation is only causally ambiguous for the imitator, and not for the innovator. The reasoning behind this decision is that, although imitators might overcome this barrier by hiring away key knowledge workers from the innovator, in the short run it still poses a barrier to imitation. A short term barrier to imitation in combination with a particular innovation context, like a closing window of opportunity, can prove sufficient to deter imitation permanently. This implies that significant forms of information asymmetries are also grouped under this concept.

We also distinguish our definition of causal ambiguity with that of for instance Diericks and Cool (1989) based on it deterministic nature. The mentioned authors claim that causal ambiguity is created by the stochastic nature of the resource accumulation process. In this research, causal ambiguity can also be deterministically created by innovator firms. This evidently follows from the reasoning mentioned in the previous paragraph.

Information impactedness, as defined earlier, and secrecy as a tool of acquiring this state, are both also categorised under causal ambiguity in this research. Information impactedness, through secrecy, can be seen as a deterministic manner of generating causal ambiguity. The concept of *information impactedness* (Rumelt, 1987) entails the degree in which innovators can prevent potential imitators from obtaining the knowledge needed to copy the innovation. Secrecy, as a tool of doing this, is clearly easier when the innovation for instance is not sold on the market. Both concepts, *causal ambiguity* and information impactedness, are linked, but do not exactly encompass the same thing. The latter is seen as a manner of consciously using the first.

Social complexity

Social complexity is in effect when the competitive advantage of an innovator is based on resources that are the result of complex social phenomena, and it is beyond the ability of imitators to systematically manage and influence them. Barney (1991) claims that many firm resources may be based on socially complex phenomena, like a firm's culture or relationships with customers and suppliers. This does not mean that imitators cannot see how the competitive advantage of the innovator is related to these social phenomena, but they just lack the social engineering skills to, in the short term, for instance copy another firm's culture (Barney J. , 1986a). Social complexity is therefore adopted in this research as a key category of imitation barriers.

It is also possible that a competitor does have access to the physical technology, but still cannot imitate the competitive advantage derived from it because it lacks the socially complex resources needed to successfully exploit the technology. Finally, it is important to make a distinction with causal ambiguity here, because both concept are interlinked. Social complexity of resources can provide a source of causal ambiguity. The degree in which social complexity prevents the identification of how certain resources led to the development of a process innovation is attributed to causal ambiguity.

Resource interrelatedness

Resource interrelatedness, although closely related to both causal ambiguity and social complexity, is identified as a separate category. Many authors identify this concepts as a source of inimitability. Resource interrelatedness is different from both causal ambiguity and social complexity in that it specifically refers to the complexity of orchestrating tightly interrelated resources. If causal ambiguity would prevent a company from unravelling the recipe of an innovation, resource interrelatedness would prevent it from, with the recipe in hand, acquiring the delicate balance between the different ingredients. Whereas social complexity is more oriented on the difficulty of engineering a socially complex resource, resource interrelatedness has more to do with engineering the balance between different resources.

An example of this comes from economies of scope, which are also included in this category. Increases in existing resource stock might depend not just on the level of that stock (as mentioned at path dependencies), but also on the level of other stocks. For example, to the extent that new product and process developments find their origin in customer requests or suggestions, it may be harder to develop technological know-how for firms who do not have an extensive service and feedback network with its customer base. Thus, the complexity of building resource stock is related to the low initial level of another stock which is its complementary (Dierickx & Cool, 1989).

Distinct managerial capabilities

One of the earliest articles on the resource based view of the firm (Penrose, 1959) already made substantial contributions to our knowledge on the more traditional, ability oriented, "isolating mechanisms" or imitation barriers. According to Kor and Mahoney (2004), in contradiction to Rugman and Verbeke (2002), her findings contribute to at least five areas: "*Path dependencies in resource development*; *firm-specific knowledge possessed by managers; shared team-specific experience of managers; entrepreneurial vision of managers; and the firm's idiosyncratic capacity to learn and to diversify*. The first element is synonymous to *path dependency*. The second, third and fourth element will be grouped under a new concept called *distinct managerial capabilities*. ***Distinct managerial capabilities,*** refer to the unique skills and capabilities of an managerial individual, within the innovator firm, essential to the development and commercialisation of the innovation. The last factor, a firm's idiosyncratic capacity to learn and diversify, is rephrased as a separate concept named *distinct organisational capabilities*.

Rivkin (2000) states that the complexity of a company's strategy can prevent other firms from imitating that strategy, even if the "recipe" for this approach is publically known and imitation of separate components is not technically impossible. Although the author clearly states that this particular type of imitation barrier is completely different than those examples mentioned in resource-based view literature, the source for its imitability is not unfamiliar. Inimitability of a strategy is generated by the strong interactions among the decisions made to formulate the strategy. Strong interrelatedness or interaction, as described earlier, is also mentioned by resource-based view authors as a source of inimitability. They only apply the concept to resources, while Rivkin applies it to strategies. Although, arguably not directly within the scope of the resource-based view, this concept of strategy complexity (strong interaction among decisions in the strategy) will be included in this study's scope, because a specific development strategy for a process, can also result in the inimitability of the resulting process innovation. This type of imitation barrier has significant overlap with the ***distinct managerial capabilities*** concept as mentioned by Penrose (1959), assuming that managers and their skills and capabilities are the dominant antecedents for strategy development. Rivkin's reasoning is largely in line with what Porter (1996) says about generic strategies. We assume that general business strategies can only be considered as a supportive factor for the resources deployed in the research to market trajectory. We therefore do not threat them here as a separate concept and assume that they are sufficiently covered by the concept of distinct managerial capabilities.

Distinct organisational capabilities

Aforementioned **distinct organisational capabilities**, basically refer to a firm's unique ability to develop and transform its organisational resources and capabilities depending on the environmental requirements imposed on them. These dynamic capabilities, which often entail some sort of organisational learning and is also referred to as the firm's idiosyncratic capacity to learn and diversify or *producer learning*, can prove a barrier to imitation (Teece, Pisano, & Shuen, 1997). This basically means that the firm masters resource orchestration (as explained in the next paragraph) so well, that it's results have become inimitable.

It is hard to define this concept, as literature on this topic is extensive enough to devote another thesis to. It is also to be expected that any organisation capable of developing a new process innovation, possesses some form of organisational learning, either through adaptive learning, assumption sharing or development of the knowledge base (zu Knyphausen-Aufseß, 2012). The manner in which a firm's has learned about the innovation during development will become evident during data collection and based on this we will assess whether this has been exceptional.

Preferential market access

Wernerfelt (1984), as one of the more influential authors in the field of RBV, recognises resource position barriers. He defines this concept, as being partially analogues to entry barriers, but clearly states that the resource position barrier also contains the mechanism to make an advantage over another resource holder defensible. This concept can be seen as a synonym to imitation barriers. Wernerfelt stresses the importance of a resource's uniqueness for the business strategy. He argues that inimitability is derived mainly from the company's *first mover advantages* in acquiring a unique resource. In this research we define this concept a bit more specifically, by splitting it into two groups named *preferential market access* and *pre-emptive actions*.

Preferential market access, is largely associated with the diffusion of the innovation and refers to all advantageous accessibility options a firm might have to its customer market. Factors that contribute to this dimension are *communication good effects*, *buyer evaluation cost*, *advertising & channel crowding*, *product complementarities and buyer switching costs* (Rumelt, 1987).

Communication goods effects are synonymous for network externalities and refer to the phenomena that a certain product's value increases, once the number of users increases (e.g. mobile phones). If *buyer evaluation cost* are high, customers tend to rely on opinion leaders to make their purchase decision. This implies that the best product does not always get the best evaluation by customers. *Advertising and channel crowding* refers to the cost of creating customer awareness. Early entrants into a market often face less crowded advertising and distribution channels, whereas laggards often face saturated channels. This asymmetry allows the early entrant to build customer awareness less expensively than later entrants (Rumelt, 1987). Finally, *buyer switching costs*, concerning for instance the compatibility of the new process innovation, might not be so evidently connected with the research to market trajectory of innovations. Decisions during this process, however, highly effect compatibility, and thus market access and diffusion of the innovation.

Pre-emptive actions

According to Rumelt (1987), the isolating mechanisms that protect innovations from imitation normally appear as first-mover advantages. They are all basically the result of *asymmetries* in either *information* or *costs*. The terms mentioned by Rumelt are *response lags*, *economies of scale*, *producer learning* and *buyer switching cost*. *Response lags*, described as the time it takes competitors to recognise, evaluate and formulate a response, are considered to be more of a result of the imitation barriers and not an actual cause. This factor is therefore disregarded. *Economies of scale,* although unlikely to already be in effect at the point of market entry for a process innovation, are categorised under the newly formed concept of *pre-emptive actions*, which will apply to for instance pre-emption of scarce inputs, market positions or production capacity. *Producer learning* was already framed under the earlier coined term of the firm's *distinct organisational capabilities*. *Reputation,* as a source of inimitability is disregarded in this research, because its direct connection to the research to market trajectory is absent. Other terms mentioned by Rumelt (1987) were already mentioned in previous paragraphs.

Ghemawat (1986) takes more of a firm orientation and uses several case studies to prove the existence of different barriers to imitation. According to this author, inimitable competitive advantages are derived from: *size in the target market*, *superior access to resources* or *customers* and *restrictions on competitors' options*. Benefits of size are divided in three types of "economies", scale, experience and scope economies, which were already assigned to respectively *pre-emptive actions, path dependencies* and *resource interrelatedness*.

Access advantages are based on so called *investment asymmetries*, which means that the imitator would suffer a penalty if he would try to imitate the innovator. Access advantages are divided along three dimensions, markets, inputs and markets. Access to inputs and know-how, can be assigned to the, now slightly broadened, concept of *pre-emptive actions*. Access to markets, sharing a lot of overlap with the terms coined by Rumelt (1987), is already included under the earlier formulated *preferential market access* concept.

Finally, restriction on competitors' options are partially (pre-emptive actions are included) out of the scope of this research, as these factors are more competitor oriented than innovator oriented (data collection does not facilitate this). As mentioned earlier, response lag is considered to be more of a result of imitation barriers, than a cause. Other sources of inimitability mentioned by Ghemawat, can be assigned to *path dependency* and *intellectual property rights*, but these manifestations were already mentioned by other authors.

Pre-emptive actions, thus refer to an innovator's actions with regard to the acquisition of either know-how, inputs or market positions before competitors, which disables or complicates a competitor in acquiring the same. Although the link with time and thus path dependency is evident, the emphasis with pre-emptive actions lies on exclusive nature of the competitive advantage and not so much on the notion of time. Pre-emptive actions include pre-emption of knowhow, pre-emption of market positions and pre-emption of needed production capacity.. These actions can for instance be pre-emptive because the innovator establishes exclusive contracts (artificial scarcity) with a supplier or due to the an actual physical scarcity of either resources, geographical region etc.

Intellectual property rights

Finally, we identify intellectual property rights as the most common barrier to imitation (at least for product innovations). **Intellectual property rights** encompass all formal methods of protection provided by legislation to companies in order to protect their process innovation from imitation, including: *patents, utility models, registered designs, copyright, trademarks* and *trade secrets*. Operationalisation of this concept does not require any extensive definition or examples. Presence of any of these legal forms, in combination with the scope of protection they provide, should clarify whether this type of barriers is in effect.

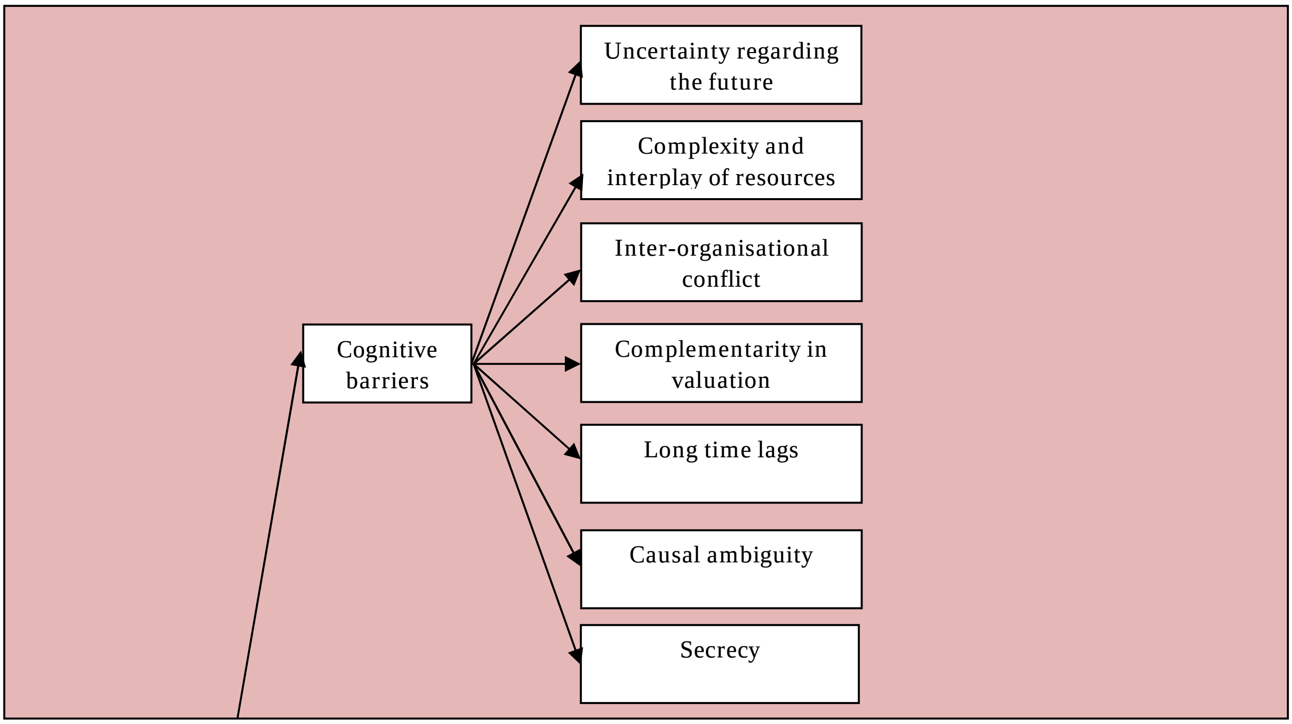
Conclusion

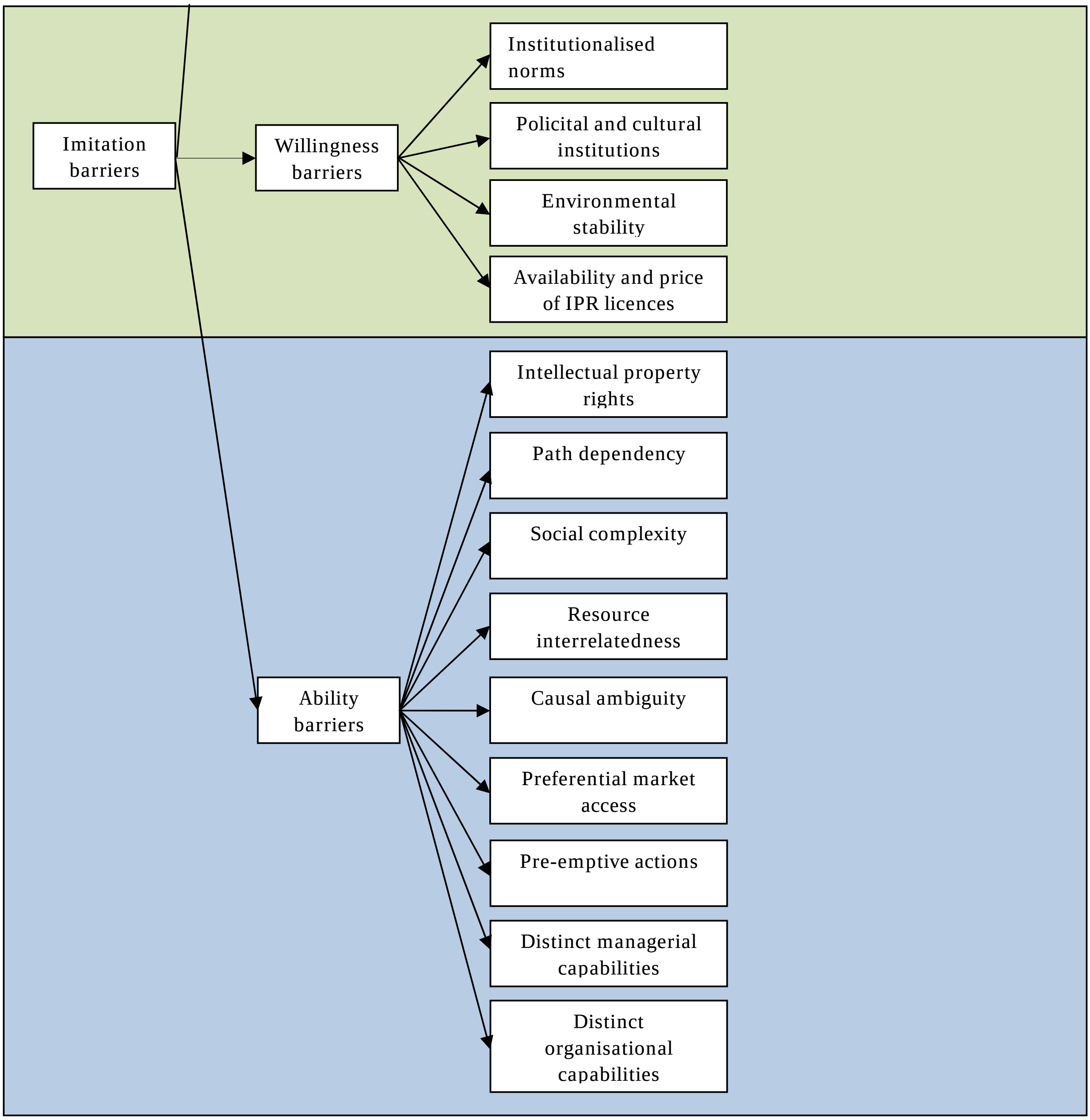
To conclude, as Rumelt (1987) already noted, "there is no unambiguous mutually exclusive list of these phenomena", but in this research the most important groups of imitation barriers are considered to be: Intellectual property rights; Path dependency; Social complexity; Resource interrelatedness; Causal ambiguity; Preferential market access; Pre-emptive actions; Distinct managerial capabilities; and finally, Distinct organisational capabilities.

2.3 Imitation barrier framework

Consolidation of above mentioned types of imitation barriers and manifestations within each type of barrier brings us to the following overview of imitation barriers literature. This framework will be used to base data analysis in this research on.

Figure 3: Manifestations of imitation barriers according to literature





2.4 Limitation in imitation barrier scope

Deliberate limitations to the scope of this research regard imitation barriers that were not build during the research to market trajectory, and entry barriers. Because of the clear focus in this research on the research to market trajectory, as the dominant phase to facilitate inimitability, only imitation barriers that can possibly be build during this phase were considered. Barriers related to for instance "reputation" (Lippman & Rumelt, 1982) were disregarded, because these are not particularly build during the research to market trajectory. Furthermore, the focus lies on barriers to imitation that were to a certain degree influenceable by the innovator firm. The "response lag", defined as a characteristic of an imitator (Ghemawat, 1986) for instance cannot be directly altered by the innovator's conduct, and therefore will be disregarded in this study.

Entry barriers were also deliberately omitted from the scope of this research. The similarity between entry barriers and imitation barriers in literature is apparent. Rumelt (1984) for instance describes his "isolating mechanisms" as an analogue of Caves and Porter's (1977) mobility barriers, which in turn are derived from the concept of entry barriers (Bain, 1956). Although some authors (Yao, 1988) make no distinction at all between the concepts of entry barriers and imitation barriers, in this research we clearly do. Wernerfelt (1984) in his work on the resource-based view sheds some light on the similarities and differences between both concepts. Whereas, entry barriers focus only on defending a resource position of incumbents from potential entrants, imitation barriers also cover the situation among incumbents. It is assumed that barriers to imitation also pose barriers to entry, and not the other way around. Entry barriers are a concept more related to a product based view of the company, in line with for instance Porter's five forces tool (Porter, Competitive Strategy, 1980), whereas in this research emphasis lies on the resource based view. Although, there are many dualities between both concepts, in line with the duality between both views (Wernerfelt, 1984), these were disregarded due to timely constraints of this study. To support this decision, it appeared that including these elements in the literature review would only increase the scope of the study without improving the quality. Most concepts mentioned in entry barriers literature are also covered by imitation barrier literature, like for instance "entitlement to the fruits of past investment, including investment in an honourable long history" as mentioned by (Demsetz, 1982), which basically resembles path dependency as described in the resource based view. Porter's (1980) economies of scale, switching costs, access to distribution channels and government policy, are also all covered by imitation barrier literature (Ghemawat, 1986).

2.5 Resource Orchestration

In this research data will be collected on resource orchestration during the development and commercialisation of process innovations. It is therefore important to get a clear and complete definition of what is meant with resources and how they can be orchestrated. Although the previous section of this literature review has been mainly based on the resource based view, for this part we extend our theoretical perspective to the "resource orchestration perspective", which makes a valuable contribution to the progression and understanding of resource based literature (Sirmon, Hitt, Ireland, & Gilbert, 2011).

Before we elaborate on the resource orchestration perspective, it is key to come up with a clear definition of both organisational resources and capabilities. Definitions of both concepts vary across literature, but in this research we consciously adopt a hybrid definition from resource based theory literature.

According to Barney (1991), firm resources include all assets, capabilities, organisational processes, firm attributes, information and knowledge, controlled by the firm that enables it to come up with, and implement strategies that improve either its efficiency and/or effectiveness. In this research, however, we make a semantic distinction between a firm's resources and capabilities, but investigate and capture both terms under the concept of organisational resources. This approach of distinguishing both terms is more modern and fits the resource orchestration perspective (Sirmon, Hitt, Ireland, & Gilbert, 2011).

Resources

The firm's resources will be defined as stocks of available factors that are owned or controlled by the firm. Resources are converted into final products or services by using a wide range of other firm assets and bonding mechanisms such as technology, management information systems, incentive systems, trust between management and labour, and more. These resources consist, inter alia, of knowhow that can be traded (e.g., patents and licenses), financial or physical assets (e.g., property, plant and equipment) and human capital, etc. (Amit & Schoemaker, 1993).

Barney (1991) does however, conveniently consolidate previous literature on organisational resources by distinguishing three categories of resources: physical capital resources, human capital resources and organisational capital resources. *Physical capital resources* include a firm's physical technology, plant, equipment, geographic location and access to raw materials. *Human capital resources* encompass training, experience, judgment, intelligence, relationships, and insight of individual managers and employees within the firm. Finally, *organisational capital resources* appear similar to capabilities, but are different to capabilities because they only include a firms' organisational systems and processes like the reporting structure, planning, controlling and coordinating systems, and information relations between different groups within and outside the firm.

Resources allow a company to develop and implement strategies and develop new technologies (Daft, 1983). As seen by traditional strategic analysts, resources are the firm's strengths which they use to develop strategies and attain goals (Learned, Christensen, Andrews, & Guth, 1969).

Capabilities

Capabilities, opposed to resource, refer to a company's ability to deploy resources, normally in combination, using organisational systems and processes, to effect a desired end. "Capabilities are often information-based, tangible or intangible processes that are firm specific and are developed over time through complex interaction among the firm's resources" (Amit & Schoemaker, 1993). In a way, capabilities can be thought of as intermediate goods, generated by the firm to enhance productivity of its resources, that offer strategic flexibility or protection for its products, processes and services. In contrast to resources, capabilities are based on development, retention and exchange of information through the company's human capital. Capabilities are often developed by combining physical, human and technological resources at the highest level. As a result, organisations might be able to develop capabilities like manufacturing flexibility, continuous innovativeness and responsiveness to market trends (Amit & Schoemaker, 1993).

Resource orchestration

In line with the resource orchestration perspective, this research does not only focus on what resources a firm possesses during the development and commercialisation of its process innovations, but focuses on how a firm deploys these resources in order to generate innovation. Empirical results have proven that "what a firm does with its resources are at least as important as which resources it possesses" (Hansen, Perry, & Reese, 2004). Both previous literature and critics to the traditional resource based view, claim that possession of certain resources alone does not generate sustainable competitive advantage. Instead, resources must be acquired, accumulated, bundled and leveraged in order to realise the resources' full potential. This implies that resources need to be managed effectively (Sirmon & Hitt, 2003) (Sirmon, Hitt, & Ireland, 2007).

Given aforementioned suggestions, Sirmon, Hitt, Ireland, and Gilbert (2011) draw up a integrated framework for reviewing resource orchestration in an organisation. This framework integrates processes included in Sirmon et al.'s (Sirmon, Hitt, & Ireland, 2007) resource management framework, with those described in associated asset orchestration reasoning. This provides a more comprehensive overview of what is meant with the concept of resource orchestration, as displayed in figure four.

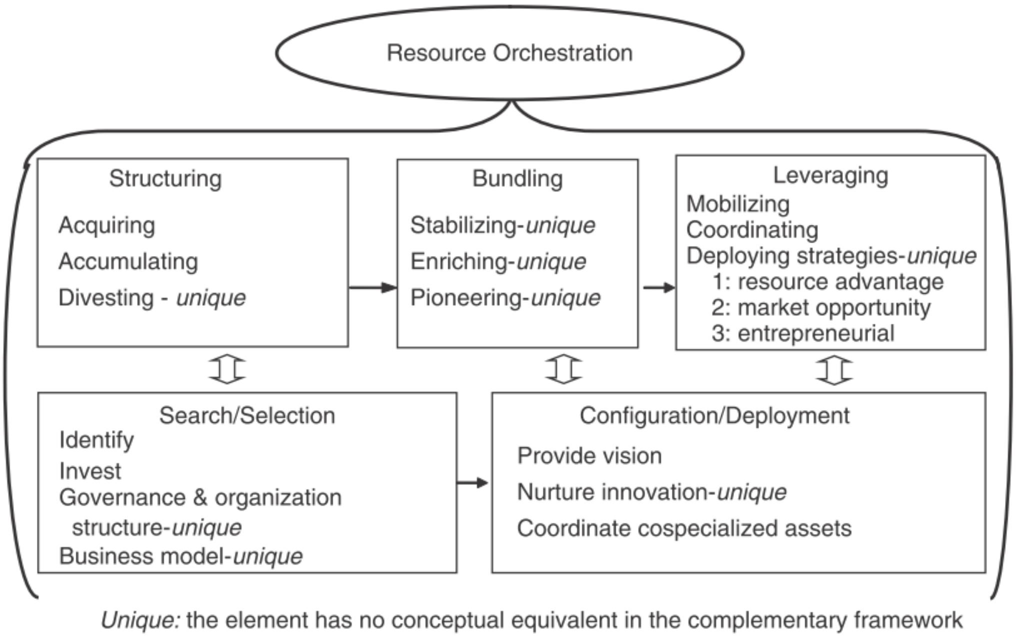
In addition to this integration, the authors increase the robustness of their model by including factors like a firm's scope, level of hierarchy and stage of maturity. These factors influence the manner in which managers should orchestrate their resources during development and commercialisation of innovations. This research's aim is not to assess whether a company deployed its resources adequatly, but to make a link between the manner of resource deployment and imitation barriers. Factors like a firm's scope, structure and maturity will be treated under the topic of process innovation context.

In order to adopt resource management and asset orchestration frameworks for analysis in this research, both have to be integrated into one. To avoid confusion, overlapping concepts will be omitted, resulting in an unambiguous framework. Because the resource management framework has more unique elements, we decide to take this framework as a basis and incorporate the asset orchestration framework's unique elements (as mentioned in figure four), as additions. Moreover, the resource management framework has been supported with more empirical evidence (Sirmon, Hitt, Ireland, & Gilbert, 2011). Omitting the non-unique elements of the asset orchestration framework and incorporating the unique ones in the resource management framework, leaves us with the integration as displayed in figure five.

Structuring

Structuring encompasses acquiring, accumulating and divesting resources to form the firm's resource pool available for deployment. This requires no further definition, as it simply refers to the actions taken to gain or lose certain resources. The two additions from asset orchestration, refer to the design of governance and organisational structures of the firm by managers and the creation of business models. The first concept refers to organisational structure types like functional, bureaucratic or matrix structures. The latter refers to a simplistic representation of how a venture aims to make profit, including a product/market combination, configuration of value creation activities and a revenue mechanism.

Figure 4: Comparison of Resource Management and Asset Orchestration Frameworks ((Sirmon, Hitt, Ireland, & Gilbert, 2011)



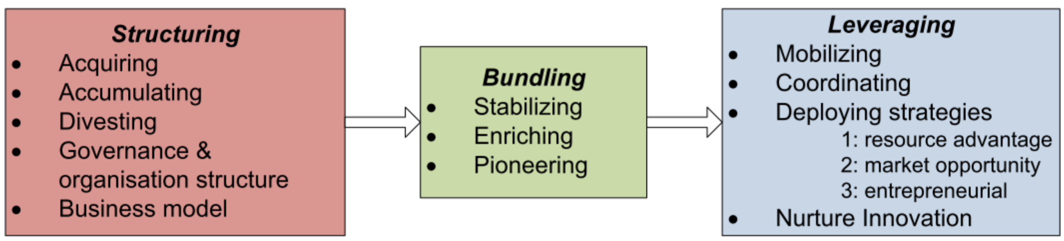
Bundling

Bundling refers to the integration of resources to form capabilities. Bundling consists of three sub-processes, namely: stabilising, enriching and pioneering. Stabilising is defined as anchoring or making minor incremental improvements to existing capabilities. Enriching goes further by making improvements and extensions to existing capabilities. Finally, pioneering is simply defined as the act of creating new capabilities (Sirmon, Hitt, Ireland, & Gilbert, 2011).

Leveraging

Leveraging refers to the act of exploiting a firm's capabilities and taking advantage of certain market or contextual opportunities. The sub-process of mobilising is defined as providing a plan or vision, which describes the required capabilities needed to form the vital capability configurations. Coordinating involves the integration of the different capability configurations envisaged at the mobilising phase. Deploying strategies refer to the act in which a resource advantage, market opportunity or entrepreneurial strategy is used to exploit the earlier formed capability configurations formed throughout the process. The addition from asset orchestration literature in the form of innovation nurturing is a broad concept and hard to define. This basically encompasses acts that stimulate innovation like partnerships with participative suppliers or customers (Sirmon, Hitt, Ireland, & Gilbert, 2011).

Figure 5: Resource Orchestration Framework



2.6 Process innovation context

To check whether the process innovation context has a mediating influence on the relationship between resource orchestration and created imitation barriers, we define several dimensions to assess each case on. We limit this concept to include the innovation characteristics, firm characteristics and key factors from the firm's meso and macro environment.

Innovation characteristics

We assess the nature of innovation based on six dimension (Gemünden, 2011) being:

1. Subjectivity of innovation: new for whom;
2. Process of innovation: where does it begin and end;
3. Roles of innovation: new with whom;
4. Degree of innovation: how new;
5. Success of innovation: is new also successful;
6. Categorisation of new manufacturing processes.

The degree of innovation is principally linked to a subject. This subject or subjects assess the degree of innovation. The first dimension refers to the innovation being only new to an individual, group or organisation, or whether the innovation is truly new to industry or society.

The process of innovation refers to where an innovation starts and how far it has already diffused. We identify different milestones in the development trajectory being the idea, invention, prototype, new process and diffusion to an early market or mainstream market. Each case will be assessed for the stage at which the firm started adopting the innovation, from the very first idea, invention or prototype?

The third dimension refers to the key contribution of external stakeholders that were involved with development of the innovation. These are for instance suppliers, customers, competitors, governments, distributors, consultants and research institutes. It also entails whether development of the innovation was either manufacturer dominated or customer dominated, resembling respectively a technology push, demand pull or cooperative innovation.

The fourth dimension, degree of innovation or newness, makes a distinction between four different types of innovation, based on the producer's and buyer's view. From the producer's view, technological change is assessed as either high or low. From the buyer's view, the increased benefit is assessed as either high or low. This results in the widely spread product/process innovation matrix, as displayed in figure six.

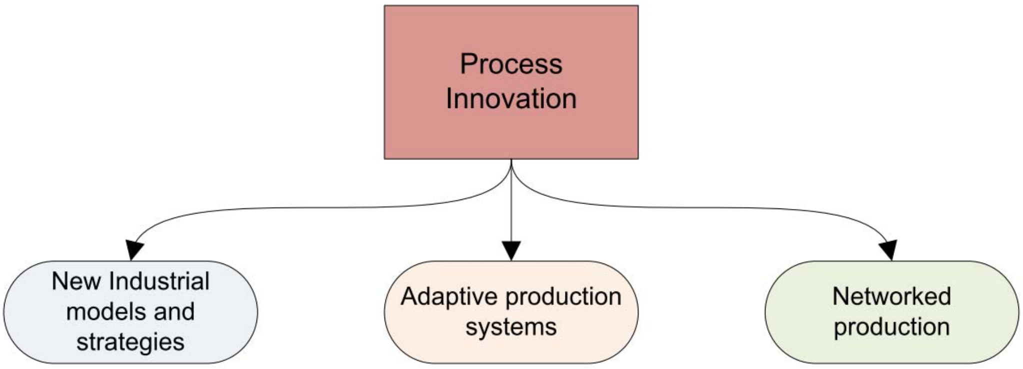
Figure 6: Innovation matrix

Buyer's view (Increased benefit) \ **Producer's view** (Technological change)	low	high
low	1 Incremental Innovation	2 Technical Innovation
high	3 Application Innovation	4 Radical Innovation

The fifth dimension assesses the degree of success the innovation has achieved up until now. This only entails the commercial success as this is more unambiguously determined, opposed to technological success. Sold units or costs savings (in case the process is only operated internally and is not sold) in combination with whether the beak-even point has been reached, will serve as measurement units.

Finally, the sixth dimension was mainly established to facilitate sampling. The ten cases will be selected based on three sub-groups of new manufacturing processes being “new industrial models and strategies”, “adaptive production systems” and “networked production” (figure seven). This categorisation is based on the division from the FP7 NMP Work Programme 2011. The first category entails process innovations that are either aimed at sustainable manufacturing, mass customisation, open innovation manufacturing, network-centric manufacturing, cloud manufacturing or lean production. The second category entails production systems that integrate different innovative processes, overcome existing process limitations and handle the transfer of manufacturing know-how into totally new manufacturing related methods. The main focus is on flexible and reconfigurable process innovations. The last category includes process innovations that were developed in close cooperation with partners, are configured in a network, or aim to cooperatively add value to a manufacturing system.

Figure 7: Process innovation categorization



Firm characteristics

Although not all dimensions below are direct characteristics of the firm, they are highly associated with the firm’s nature/identity. The following dimensions define the firm’s characteristics:

- Firm size, determined based on the amount of employees within the firm;
- Firm maturity, determined based on the time the company has been active;
- Organisational structure, determined based on Mintzberg distinction in five different organisational forms: entrepreneurial organisation, machine organisation (bureaucracy), professional organisation, divisional organisation and innovative organisation (adhocracy) (1993).
- Sector of origin and application sector, distinguished based on the NACE code or product sector system. The NACE code system is the European standard for industry classifications. The current version from 2008 is based on the ISIC of the United Nations (European Communities, 2008).
- Country of origin, where do the innovation and company originate from;
- Current availability on the market, determined based on in which countries the company currently offers the innovation for sale;
- Ownership structure of the firm refers to whether the company is a stand-alone firm, joint venture, spin-off, subsidiary or some other legal form;
- Manner in which the firm and innovation are funded, e.g. public funding, venture capitalists, private equity or internal funding.

Factors from the firm’s meso and macro environment

In recent years, process innovations have evolved as a reaction to many external forces and trends including the introduction of new manufacturing technologies, new materials, evolution of new products and the increased emphasis on quality, as well as the escalating global competition and pressing need for responsiveness, agility and adaptability. Internal drivers refer to the desire to reduce waste and increase efficiency and productivity while generating high value jobs with meaningful human involvement (ElMaraghy & Wiendahl, 2009). Below we elaborate on the key success factors and barriers, from the meso and macro environmental levels, which might have a critical influence on the development and commercialisation of new process innovation.

Meso level success factors/barriers

This dimension constitutes factors that are key to the success or failure of the development and commercialisation of the process innovation from the company’s direct environment. Examples of actors and elements from this environment that could have a significant influence on the success of the innovation are customers, competitors, suppliers, trends in industry and codes of conduct.

Macro level success factors/barriers

Although processes commercialised based on new technologies are private property, the generic technologies (underlying platforms) and supporting technologies on which they build, are both private and public assets. This infrastructure of private and public enabling technologies are the foundation on which new process innovation are build. Government actors can have a key role in supporting these fundamental infrastructures. Process and production infrastructure innovation are essential to both small and large, new and existing firms and benefit from governmental actions like providing access to leading R&D, processes and technologies (STPI, 2010).

Table 2: ***Micro level barriers***

Source of barrier	...to developing NMPM	...to adopting NMPM
Time horizon	Failure to recognize lengthy R&D period needed (often a decade or more) to develop a market for an innovation.	Lengthy learning and adjustment period needed to achieve desired product quality.
Technological	Resulting material's properties are not entirely suitable for existing market application; underdeveloped markets in some cases.	Resulting material's properties are not entirely suitable for specific industry application. NMPM may be more suitable for a new state-of-the-art facility and retrofit may not match scale production economies.
Financial or economic performance	Magnitude of required investment, given anticipated returns. Resulting products with high unit cost may be suitable only in industries requiring specific material properties. Limited initial production capacity or market demand, especially for improved or new materials.	Capital cost exceeds anticipated returns. Resulting products with high unit cost may be suitable only in industries requiring specific material properties. Existing process technology may embody sunk costs or possess lengthy remaining economic life.
Corporate culture	Organizational separation among units involved in R&D process; differences in attitudes and values among units. Territoriality among organizational units; suspicion of projects originating outside of unit.	Risk-adverse or risk-neutral approach to decision making; receptive to innovative NMPM but adopts wait-and-see approach.
Regulatory environment	Inflexible codes and standards preclude use of resulting material. Antitrust regulations inhibit collaborative R&D.	Inflexible codes and standards preclude use of resulting material. Strategic considerations prevent NMPM from being acquired by economic rivals or hostile foreign powers.

Potential success factors subject to governmental influence originate from categories mentioned below (Technologies, 2010):

- Research and innovation;
- Education and training;
- Standardisation;
- Cluster policy;
- Market pull through public procurement;
- Trade;
- Transportation.

Potential barriers from the macro level environment include:

- Risk assessment and protocols for industry;
- Environmental, health, life cycle analysis and safety issues;
- Consumers issues and media and public perception concerning the innovation;

- Gaps in policy and infrastructure;
- Gaps in support mechanisms like subsidy programmes and intellectual property legislation;
- Gaps in metrology, standards and investment strategies.

2.7 Theoretical framework

To conclude this chapter, the theoretical framework is presented which combines both the conceptual logic underlying the central research question and theoretical content on which each of the three main concepts are based. It is important to note here that the concept of "process innovation context" from the conceptual model displayed in figure one, has been separated in the firm characteristics, innovation characteristics and meso/macro factors. Based on the researchers assumptions and the literature study, these three concepts have been placed in the earlier displayed relationships model.

The direct influence of resource orchestration on imitation barriers does not need further elaboration. This connection is evident throughout RBV theory. We assume that resource orchestration is largely dependent upon the firm characteristics. This link follows both from theory (Barney J. , Firm resources and sustained competitive advantage. , 1991) and logical reasoning. Innovation characteristics and the firm's meso and macro context are expected to mediate the relation between resource orchestration and imitation barriers.

The mediating influence of the process innovation characteristics on the relationship between resource orchestration and created imitation barriers follows from logical reasoning based on theory. If the relationship between resource orchestration and created imitation barriers is mediated by the type of innovation (e.g. product, process or organisational) (Cadot & Lippman, 1995), it appears logical to assume that the type of process innovation also has this mediating influence.

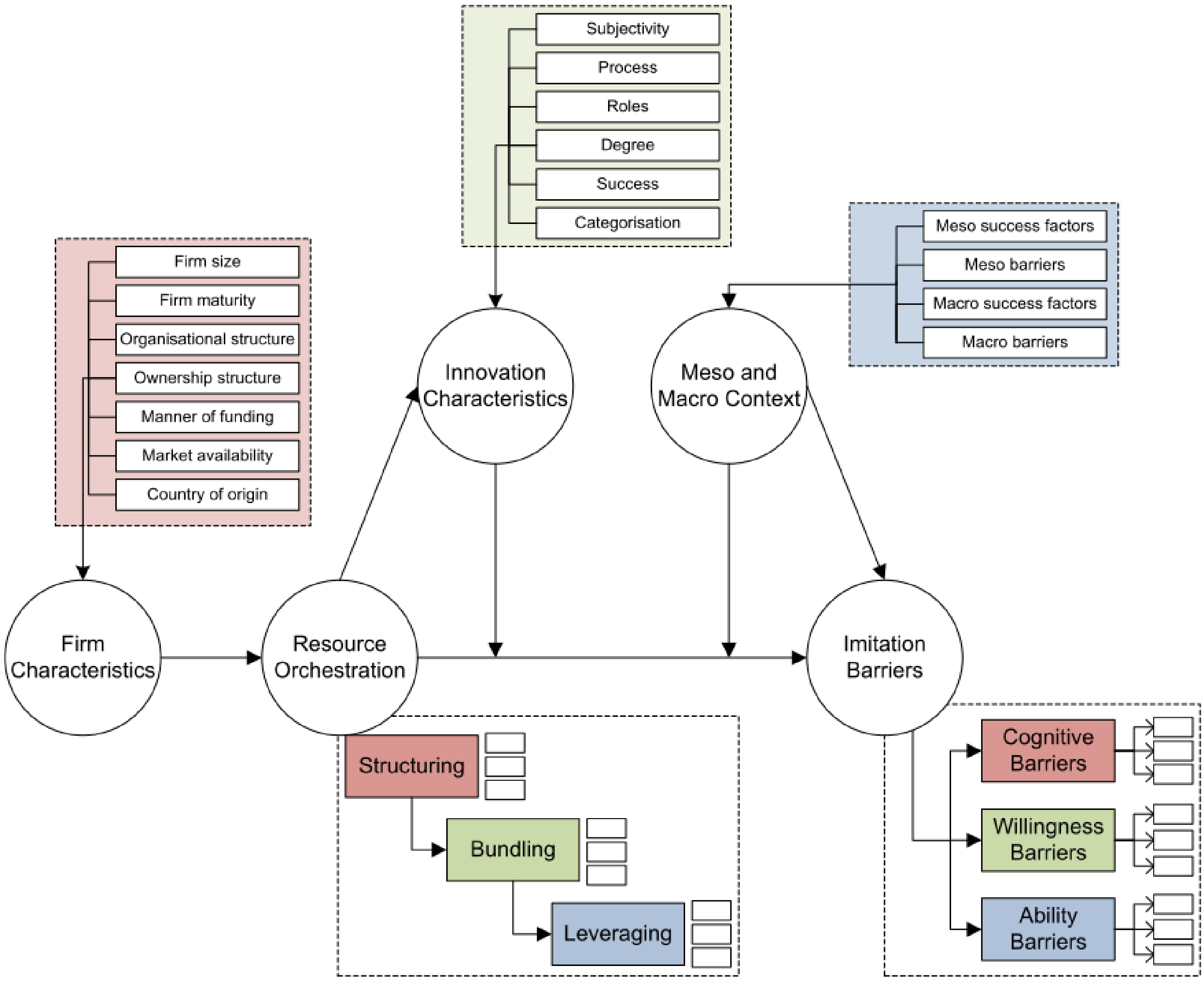
Regarding the mediation influence of the meso/macro environment, Ghemawat (1986) stated: "to create a sustainable competitive advantage, a firm must either be blessed with competitors that have a restricted menu of options or be able to pre-empt them". The author makes a clear link to the firm's environment here, as this is the place where opportunities might arise. We use this argument to support our predisposition concerning the mediating influence of the meso/macro context. Moreover, opposing strategic schools like the market-based view, claim that competitive performance of a company dependents on the industry structure (macro environment) and the resulting strategic conduct of a company (Scherer, 1980). A proponent of this school, Porter, contributes through his five forces model, which also confirm the relevance of a firm's suppliers and customers (meso environment) on its conduct. We therefore assume that factors from the firm's meso and macro environment mediate the relationship between resource orchestration and created imitation barriers.

Furthermore, it is expected that innovation characteristics are established as a result of resource orchestration. This can be logically assumed, because innovation are not created out of thin air and are always developed by the firm itself (or commissioned by).

Finally, factors from the firm's meso and macro context can also be directly responsible for the creation of imitation barriers, especially with regards to willingness barriers (e.g. institutionalised norms and environmental uncertainty) (Jonsson & Regnér, 2009) (Hehenkamp & Kaarboe, 2008).

The framework will be used to analyse, and display the results of analysis for, each case. Analysing each case on the five main concepts, the sub-concepts and lower level sub-concepts (not displayed here), and the manner in which they relate to each other should provide us with answers to the research questions and central question.

Figure 8: Theoretical framework



3 Methodology

3.1 Research approach

Based on the objective and the corresponding research questions, an inductive multiple-case research design is chosen to conduct this study. Within the multiple-case study design an embedded approach, including multiple units of analysis per case, will be pursued. Eventually this research approach allows for the inter-case analysis that is required to make generalisations about the phenomena being studied.

3.1.1 Legitimising the choice for a qualitative research approach

The objective of this study and the research context lead to a clear preference for a qualitative approach. The explorative objective, of understanding the relationship between resource orchestration during the research to market trajectory for process innovation and the creation of imitation barriers at the point of market entry, asks for an in-depth case analysis. Multiple cases should make the results of analysis more generalizable to process innovation in general.

Although there is an abundance of previous literature on sustainable competitive advantage and the resource based view, there seems to be a theoretical gap on how deployment of specific resources exactly leads to imitation barriers. Empirical evidence for the explanation of the link between both concepts will come from semi-structured interviews with stakeholders who were recently involved with the development and commercialisation of a process innovation. To accurately capture their perspective on the deployed resources during the research to market trajectory for the respective process innovation, semi-structured interviews are needed.

The sensitive, confidential and highly individual nature of the topic makes the choice for a qualitative approach evident. A company might be reluctant to disclose certain information concerning the development and diffusion process of their innovation. Moreover, commercialisation trajectories are often so specific that it is hard to capture them in several key words. Additionally, especially entrepreneurs or inventors, opposed to professionals, might have difficulty with understanding theoretical or managerial terms. All these mentioned reasons makes a qualitative, semi-structured approach, the most suitable way of conducting this research.

A final note on the choice for a qualitative approach, is that this approach also adds up to the data collection methods used in the larger research project, this particular research is part of. This commonality facilitates a broader sample and larger data collection to base analysis on. The data generated by other researchers and data collected in previous fieldwork, related to this research topic, will also be used in this study.

3.1.2 Legitimising the choice for a multiple-case study analysis

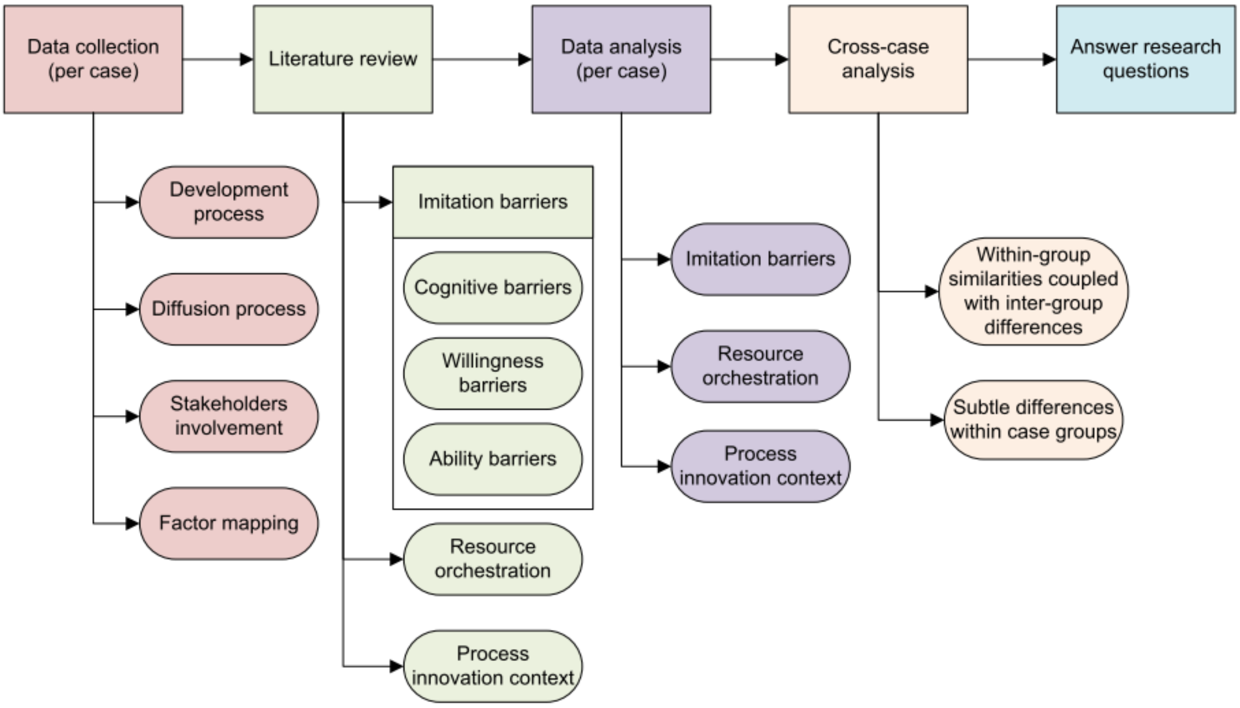
A multiple-case study analysis with an embedded approach is the most suitable research design to achieve the research objective. Multiple cases permit a replication logic in which cases function as experiments, each being able to confirm or reject inferences drawn from the others (Yin, 1994). Conducting a multiple-case study allows for inter-case analysis. This process generally generates more robust generalisations than single cases (Eisenhardt & Graebner, 2007).

A case-study approach in general is desirable for this particular study, because the phenomenon being studied and the situational context are interrelated and inseparable. The phenomena being studied: process innovation, resource orchestration and imitation barriers, are too complex and closely bound to their context to study them in the form of variables. The case aims to capture the context, embodied by a company's development and diffusion process of a process innovation, in which the phenomena under study take place. The aim of this study is to make generalisations, but also to consider contextual conditions and differences.

Furthermore, a multiple-case study approach suits the objective of the study to explore the relationship between the process innovation context, resource orchestration and created imitation barriers. Moreover, an embedded approach, including more than one respondent generates a more complete picture of the relevant phenomena in the case. Interviews with various stakeholders involved with development and diffusion of the innovation generate different perspectives on the deployed resources and created imitation barriers. This embedded approach also allows for intra-case analysis, although this is not the aim of this study. It could merely serve to verify certain statements and assumptions.

Based on the research objective, questions and corresponding approach, the methodology for this thesis can be roughly summarised by the model below:

Figure 9: Methodology overview



3.2 Target population

Selection of a research setting can be done using the principle of maximization (Morse & Field, 1996). This implies selecting a setting where the topic of study manifests itself most strongly. The selected target population is a combination of both this principle of maximization and the scope of the larger research project, this particular research is part of.

Within this larger research project, the research setting of this particular research encompasses all European, East Asian/Pacific and North American companies that have recently commercialised a process innovation. The focus on process innovation in particular should ensure the maximum difference between cases regarding the created imitation barriers. For these type of innovations, companies most often rely on alternative protection mechanisms to intellectual property rights. Intellectual property rights like patents and utility models can be considered the most common forms of imitation barriers and are widely used for products. “When it comes to process innovations, however, patents are the least effective means of appropriation due to the direct leakage of information as well as the demonstration effect” (Cadot & Lippman, 1995). The required information disclosure for acquiring a patent “leads many firms to refrain from patenting processes to avoid disclosing either the fact or the detail of an innovation” (Levin, Klevorick, Nelson, & Winter, 1987).

This target population is attractive, because recently commercialised process innovations and their development trajectories are a highly suitable unit of analysis to study the phenomena under research in. This is because for the research unit (company’s CEO, founder or inventor) it is much easier to identify for instance causality between resources and imitation barriers for a individual process innovation, than it would have been for whole company’s conduct (which is more complex and extensive). As is mentioned by Lippman and Rumelt (1982), this uncertainty or causal ambiguity is most concrete at the level of individual projects (so a specific process innovation project). They use this argument to deliberately not focus on individual projects, in this research it, however, is used as an argument to specifically focus on individual innovation projects. Moreover, the authors also mention that “the ambiguity surrounding the linkage between action and performance in large firms virtually guarantees the existence of substantial uncertain imitability”. With this research, we want to distinguish between the different types of imitation barriers and find out whether they are deliberately created, and therefore want to observe whether a certain imitation barrier is emphatically present, to protect the innovation and not just because it is always present (as in most large firms).

Wernerfelt also makes an, for this particular research setting, important link between the origin of the "resource barrier" (synonym the author uses for imitation barriers) and the way in which the resource was acquired. He recognises that, by their nature, most resource barriers are self-reproducing; "that is a firm which at a given time, finds itself in some sense ahead of others may use these barriers to cement that lead" (Wernerfelt, 1984). So he states that the development process or process of acquisition of a certain resource or capability is highly correlated with its imitative properties. This again highlights the relevance of studying the orchestration of resources underlying an innovation, to assess the innovation's imitative properties.

The focus on the research to market trajectory is due to the research objective of this particular study. In order to find out which resources were accumulated and deployed, a clear overview of the development process and context in which the company was operating before the innovation was commercialised, is needed.

The choice for a relatively broad target population is made deliberately, in order to have a large population to draw the sample from. The target population is not limited to certain industries or types of companies.

3.3 Sampling

In a multiple-case study research sampling takes place at two levels. The first level entails the selection of cases that are investigated. This level of sampling has been rather limited by the larger research project in which this thesis is conducted. In this context ten cases were selected based on the aforementioned sub-groups of new manufacturing processes (figure 7).

Within these three categorisations, the researcher aimed to find extreme situations or polar types in which the process of interest is transparently observable (Eisenhardt, 1989). For this study, the researcher focused sampling on polarising types like internal commercialisation vs. external commercialisation, hard innovation vs. soft innovations and loosely managed innovation vs. tightly managed innovation. These three polarising types are expected to have different consequences on resource orchestration and thus the created types of imitation barriers. The first type encompasses whether the process is sold to external parties or is only operated internally. In the latter case, imitation is considered to be more challenging. The second type regards the technicality of the innovation and thus for instance patentability. Hard innovations are based on technological changes and new technologies, while soft innovation are based on new business models and company-customer interaction. Again, it is expected that different types of imitation barriers are relevant for both types of innovation. Hard innovation might be better protected by patents, while soft innovations benefit more from socially complex resources (strong user community). Finally, the degree of management of the innovations refers to whether the development process is tightly coordinated and predetermined or more based on a more emergent scenario and learning by doing. This is expected to clearly influence resource orchestration and thus imitation barriers.

Furthermore, all cases will have to fulfil the criteria mentioned below, in order to deliver the most accurate and interesting results:

- Cases should cover both incremental and radical process innovations to see whether this factor has any influence on the deployed resources and in turn created imitation barriers. Basic assumption is that the more difficult or complex a problem is, the fewer solutions deliver the wanted result and the more attractive imitation of an existing solution is. This in turn assures the need for imitation barriers and heightens the chance of them being present.

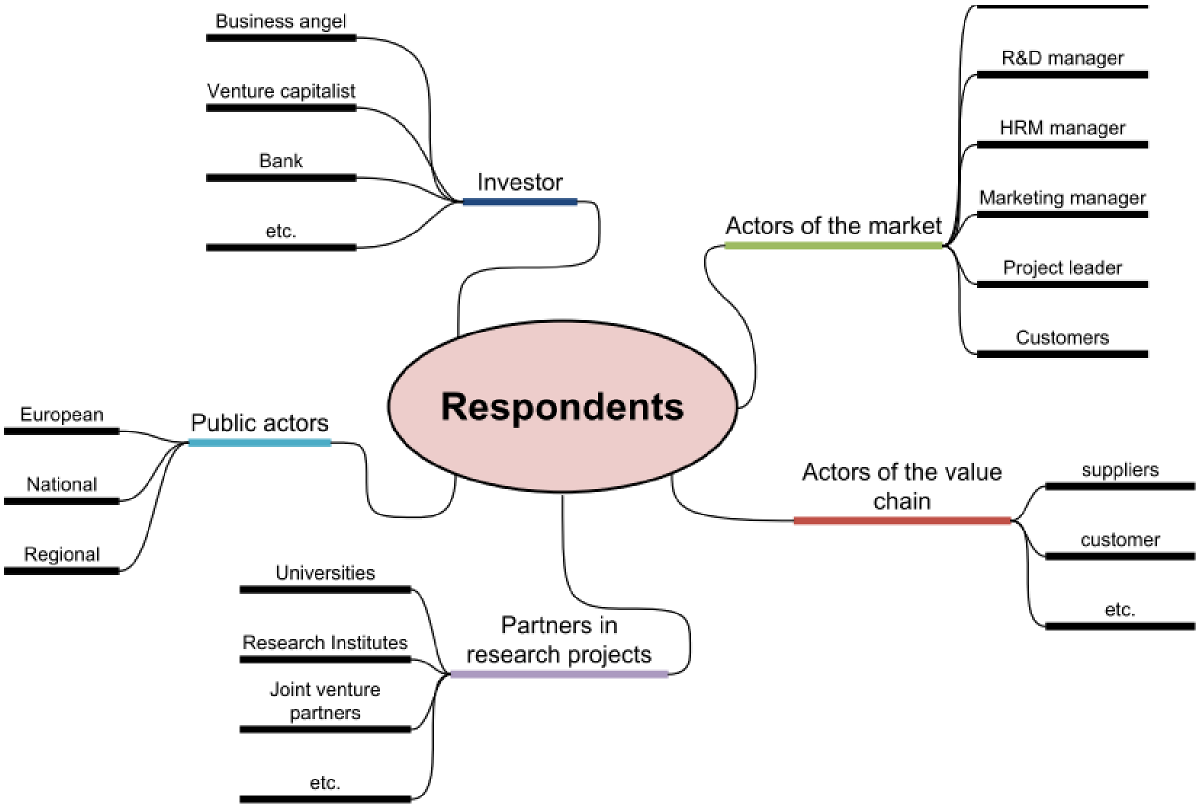
- Process innovations have to be new to the world, as this limits the possibility of existence (or short-term emergence) of a substitutable process, delivering the same result, but which does not fulfil the conditions for sustained competitive advantage. Existence of substitutable process would take away a competitor's need for imitation, and in turn the relevance of imitation barriers.

- Process innovations should already have some commercial success, either through sales or internal implementation. First of all, successful implementation is a prerequisite for something to be an innovation at all. Furthermore, it is assumed that if a process innovation is not successfully implemented yet, there is less incentive and opportunity for competitors to imitate that process. This in turn implies that the need for imitation barriers is not yet so urgent.

- Process innovations should have been commercialised in the last five years, in order for the respondents to deliver relatively accurate recollections of the research to market trajectory and deployed resources during that period.

- Finally, only companies that developed their process innovation for a substantial part internally, are selected for this study. It is assumed that these companies have more insight into resource orchestration during development, than companies who largely outsourced the development of their process innovation.

Figure 10: Overview respondent types



The second level of sampling entails the data sources or units of analysis that are investigated within the cases. In this research multiple units of analysis will be investigated per case. Cases are build using data from both desk research and semi-structured interviews. Desk research will be mainly aimed at preparing interviews and filling remaining data gaps after the interviews. Depending on relevance and availability of respondents, interviews will be arranged with actors of the market, actors of the value chain, partners in research projects and public actors. These categories are illustrated above (figure 10). Relevance of each respondent type varies per case. For example, a case in which a process innovation was funded internally and developed by an internal R&D team does not require any interviews with investors and partners in research projects. In this case, actors of the market will be sufficient. Availability also varies per case. It is expected that especially larger firms are less cooperative in providing the researcher with follow-up contacts to external parties involved with the process innovation. In these cases, actors of the market are maybe not sufficient, but will have to suffice.

The sample in this research was chosen as heterogeneous as possible, in order to increase the generalizability of the results of this study as much as possible. Dispersion among different industries and geographical regions is relatively equal. Firms vary from individual entrepreneurs who perceived a problem and generated the desire to come up with a solution, to global multinationals being technology leader in their industry. Table two summarises the characteristics of the sampled firms and process innovations. These firms were selected based on desk research and the aforementioned criteria and types.

Table 3: Case sample overview

		Characteristics					
Case name	Case description	Country of origin	Underlying principle/ technology	Type of company	Type of process innovation	Novelty	Year of market entry/ implementation
Case 1: Rare earth extraction	Extraction of rare earth materials from low energy light bulbs	France	Chemistry	Multinational	New industrial models and strategies	New to the world	March 2012
Case 2: Textile dyeing	Textile Dyeing using liquid CO2	Netherlands	Liquid CO2	Company spin-off	New industrial models and strategies	New to the world	June 2010
Case 3: Metal sorting	Material sorting based on material properties	Netherlands	Magnetics & nanotechnology	Joint venture	Adaptive production systems	New to the world	May 2011
Case 4: Car construction	Crowdsourced car manufacturing	USA	Crowd sourcing	Start-up	Networked production	New to the operating market of the firm	August 2010
Case 5: 3D printing	Crowdsourced manufacturing through 3D printing	USA	Crowd sourcing/3D printing	Start-up	Networked production	New to the world	April 2009
Case 6: Butanol fermentation	Butanol fermentation process	UK	Fermentation	SME	New industrial models and strategies	New to the operating market of the firm	2012
Case 7: Platform manufacturing	User manufacturing platform	New Zealand	ICT platform	Start-up	Networked production	New to the world	2008
Case 8: Leaded glass recycling	Recycling of CRT screens	UK	Glass manufacturing	SME	New industrial models and strategies	New to the world	October 2011
Case 9: Copper scrap extraction	Extraction of copper from scrap metals	Netherlands	Magnetics & recycling	University spin-off	Adaptive production systems	New to the world	2009
Case 10: In-cell production	Flexible in-cell production process for high performance printing	Japan	Flexible in-cell manufacturing process	Multinational	Adaptive production systems	New to the world	2005

3.4 Data collection

Data collection in this research is focused on the research to market trajectory of each process innovation within the corresponding company. To acquire a rich data overview of resource orchestration during this development process, interview questions included everything from the technical origin of the innovation (working prototype, patents, university knowledge etc.) until the commercialisation of the innovation to a mainstream market (if this was already applicable). Focus within these interviews lies on getting a clear overview of the case's process innovation context and the orchestration of resources. The theoretical reasoning for the topic list was developed by PwC. The literature review on process innovation context and resource orchestration, as described in the previous chapter, was therefore mainly used to base the analysis on. The topic list (displayed as table 3) and thus data collection does not exactly use the same concepts and terms with regards to resource orchestration and process innovation context, as were mentioned in the literature review. This, however, does not prove to be an issue, because the case reports resulting from the extensive questionnaire (Appendix A) are so detailed that there is enough data corresponding with the used (sub)concepts for analysis.

In this research three types of data collection were used: desk research, interviews and one field visit. Data collection for each case was started with desk research, mainly focused on internet sources providing information on the respective company and innovation. Desk research mainly functioned to see whether the cases complied with the aforementioned criteria, and to prepare for the interviews. Company websites and news articles on the innovation were mainly used as sources of information. Company and innovation related information was located mainly using the firm's name as a keyword. As most firms in the sample are start-ups, founded with the goal to commercialise the respective innovation, nearly all found information on those companies was relevant for the study.

Data collection was then continued using semi-structured interviews with different, aforementioned internal and external respondents. The interviews were conducted within a larger research setting. An average of two to three interviews were conducted per case, accumulating a total of 25 interviews from March to the end of July 2012.

Access to the respondents of the ten cases was acquired through the formal path used by PwC. An email was sent to a high ranked official, involved with the process innovation, within the company. His name and contact information, if available were identified through desk research. This message was accompanied by an official letter from the European Commission, to reinforce the attempt.

The first interview was typically with the founder, CEO or BU director. This initial interview was used to get a clear picture of the case and to get to know the different stakeholders. Afterwards, based on the nature of the case, the founder or CEO's network was used to get in touch with other involved stakeholders that might provide more data on the case, like launch customers, technical personnel or marketing managers. The founder or CEO's insight provided the criterion on which to select subsequent respondents.

The interviews range from 30 to 90 minutes in length. All interviews were conducted by phone, because this approach suits the nature of the data needed. Non-verbal information would have made the data richer, but does not really contribute to achieving the purpose of this study. Telephone interviews also save a lot of time and money, considering the large geographical distances between interviewer and interviewee, in most cases.

The conversation with respondents started with a brief introduction to the research and its purpose. Both the larger research setting (as part of PwC) as well as this particular research were elaborated upon. Before the interviews started, permission to record the conversation was asked, to simplify the process of making accurate transcripts.

The interviews were transcribed in English (some interviews were held in Dutch) and structured along the topic lists, which also forms the basis for the case reports. Transcriptions were made word for word, as much as possible (sometimes difficult due to translation or unclear syntax of respondents), to enable quoting in later research steps. In these interview reports, all information that could have identified participants was omitted. Each interview report was sent to the interviewee for checking and confirmation of whether all information was interpreted correctly.

The interview questions that were used, are based on a PwC questionnaire that is structured along the dimensions described in table three. The first dimension encompasses all activities, resources and capabilities that were deployed in order to develop the respective process innovation. This dimension also encompasses the barriers that were encountered during development and the sources of funding that were used. The second dimensions basically regards the same issues as the first, however, applies to the diffusion or commercialisation of the innovation. The third dimension discusses all stakeholders involved with the development and diffusion of the innovation, and their respective interest, impact and investment they contributed. The last dimensions wraps-up the case by outlining the key success factors and barriers from the company level as well as the firm's meso and macro level.

This topic list only functioned as a guidance and did not limit the respondents in their answers. Interviews for the first three cases were helpful in restructuring the topic lists and enhancing the interview approach. This basically came down to a more open and flexible approach. In case the respondents were taciturn, more concrete questions for each dimension and sub dimension were used to start-up the conversation. These questions are included in appendix A.

Table 4: Topic list

Dimension 1: Innovation Cycle	
1.1	General
1.2	Step 1: System design
1.3	Step 2: Modelling, analysis and simulation

1.4	Step 3: Final design and implementation
1.5	Step 4: Reconfiguration
Dimensions 2: Diffusion	
2.1	General
2.2	Segment 1: Innovators/technology enthusiasts
2.3	Segment 2: Early adopters/visionaries
2.4	Segment 3: Early majority/pragmatists
2.5	Transition from early market to a mainstream market
Dimension 3: Stakeholders analysis	
3.1	General
3.2	Internal stakeholders
3.3	What was their impact/interest/investment etc.
3.4	External stakeholders
3.5	What was their impact/interest/investment etc.
Dimension 4: Factor mapping	
4.1	Micro-level success factors
4.2	Micro-level barriers
4.3	Meso-level success factors
4.4	Meso-level barriers
4.5	Macro-level success factors
4.6	Macro-level barriers

The desk research combined with the interviews resulted in case reports of 13 to 17 pages per innovation/company. Each case consists of a fact sheet or summary and a detailed description per dimension. The result is a relatively complete and accurate understanding of a process innovation's development and commercialisation trajectory, which will form the basis for analysis.

3.5 Analysis

Analysis is begun with in-depth analysis per case through the lens of the central question: *What is the relationship between resource deployment during the research to market trajectory and the creation of imitation barriers for different process innovation contexts?* No a priori hypotheses were formulated, but some theoretical preferences have been established.

Each case was analysed independently to answer the research questions. The goal of this analysis was to identify respectively the manner of resource orchestration, imitation barriers that might be based upon those resources and process innovation context characteristics. This process of identification was conducted using the concepts and their operationalisation as established in the literature review part of this study. The theoretically established concepts functioned as axial codes to which different fragments of the case study report were linked. An Excel-table was used to draw up case overviews, displaying each axial code with the corresponding fragments of code from the respective case, if applicable. This table facilitated both in-case descriptions and cross-case analysis in a later stadium. Case content for each (sub)concept (if applicable) was included in the Excel-sheet, whereas in the in-case descriptions only the most relevant information was included. Through this within-case analysis the researcher gained familiarity with the data and it helped to form a preliminary notion of the relationship between the different concepts.

It is key to mention here that the focus of analysis is always on imitation barriers and imitation barriers in combination with resource orchestration and/or process innovation context and never solely on the latter two. During cross-case analysis, we first examined the overall presence, absence and immeasurability of certain ability barriers across different cases.

Cross-case analysis using differing techniques forces the researcher to look beyond the initial impressions and identify evidence through multiple lenses (Eisenhardt, 1989). Humans are poor processors of information, which have the tendency to jump to conclusions, are influenced by superior respondents ignore statistic properties and neglect disconfirming evidence. Due to these information-processing biases, the key to good cross-case analysis is to counteract these human tendencies by analysing the data in a divergent ways. Several strategies are mentioned throughout literature, of which two are adopted in this research. The first strategy makes use of the aforementioned Excel-table. This table displays the dimensions on which each case is assessed. We then look for within-group similarities coupled with intergroup differences (Eisenhardt, 1989). We combine this strategy with a second tactic in which pairs, threes and fours of cases are selected that resemble each other. We then list the similarities and differences between each group of cases. This forces the researcher to identify subtle differences and similarities between cases and can breach too simplistic frames (Eisenhardt, 1989).

Eventually, this cross-case analysis in which selective coding linked all involved concepts to a few core concepts, provides the results to base the answer to the central question on. Throughout the analysis procedure, an iterative process of switching between literature, data and findings was used. Data analysis was done in parallel with data collection. This was a kind of messy approach, as is customary in qualitative research.

Finally, in the discussion chapter we enfold literature by comparing the findings of analysis with conflicting literature and similar literature. Comparison with conflicting literature helps to build internal validity, raises the theoretical level of the established relationships and sharpens construct definitions. Comparison with similar literature improves generalizability, enhances construct definition and also contributes to the theoretical level of established relationships (Eisenhardt, 1989).

3.6 Quality procedures

During the whole research process, use of memos made sure that useful thoughts on monitoring the development or assertion of quality of the research were not forgotten. These memos are especially useful for a qualitative research approach, because of the messiness of the process. Observational, methodological and theoretical memos were being systematically recorded in a digital document, to maintain a clear overview. This also allowed for the tracking of the evolution of the research project, and helps to argue later on why certain decisions were made (Boeije, 2010).

Data storage of the interviews did not need require specialised computer programmes. The total amount of interviews was relatively low and simple folder storage sufficed. Of course, access to this files was only possible for the researcher and members of the research team at PwC.

According to previous literature, the use of multiple investigators has two key advantages. First, it enhances the creative potential of the study. Team members usually have complementary insights, which add to the richness of the data, and the different perspectives increase the chances of identifying and reporting any novel insights which may be in the data. Secondly, data observations from various researchers improves the confidence in the findings and increases the chances of surprising findings (Eisenhardt, 1989). Although data analysis in this study is performed individually, case report construction is done in collaboration between a team of five researchers.

Finally, some measures were taken to reduce the potential for retrospective bias. First of all, including only recently developed and commercialised innovations in the sample, should reduce inaccuracy of respondents' recollections as much as possible. Second, including multiple respondents per case should facilitate some form of data triangulation. This prevents single respondents from generating significantly inaccurate responses. Finally, preparatory desk research was always compared with respondents' retrospective accounts, in order to see whether both complied with each other.

3.7 Constraints and limitations

First of all, as mentioned before, data collection for this thesis will be performed within PwC as part of a project for the European Commission. This poses some restrictions on the research, which have to do with confidentiality and conflicts of interest. The issue of confidentiality mostly concerns the communication between researcher and supervisor. Not all information can be as openly shared as would be desirable. Through clear agreements and frequent contact with both parties (supervisor and PwC), however, the researcher aimed to nullify this obstacle.

Being part of a larger research project also posed opportunities for this thesis. Data and cases produced by other researchers in the project on companies who match the target population, could also be used to base analysis on and generate findings and results. Of the ten cases, four were generated by the researcher itself.

Furthermore, because this research is a mere master graduation assignment, budget and manpower is minimal. To conduct the interviews by phone, therefore, is an obvious choice. This, however, limits the richness of the collected data, but costs and time savings outweigh the drawbacks. Time constraints also limit sampling possibilities. In this research a relatively heterogeneous target population was selected, to simplify sampling and get easier access to respondents. The researcher is aware that a heterogeneous target population requires a larger sample in order to generate generalizable results. The chosen sample size of ten cases could therefore pose a limitation to the generalizability of the results.

Dispersion of companies within the sample among different industries and geographical regions is relatively equal, although Europe is rather overrepresented. Contact with European companies was easier to establish and maintain due to the absence of time zone differences. Furthermore, the sample has rather many cases that focus on some form of recycling. This form of process innovation appears to have been commercialised plentiful in recent years. These recycling innovations, however, cover a broad field of applications and are very distinct in their nature. It is therefore expected that this does not pose a problem for generalizability.

Other data collection methods, like focus groups and participant observation, are not used during this research. This is mainly due to budget, time constraints, and lack of manpower. Moreover, methods like participant observation would not be useful to uncover historical events and decisions. Also, because some of the expected barriers to imitation are very latent, participatory observation nor focus groups would be able to unravel these. Talking to individuals who were closely involved with the development of the process innovation and know the motives for certain decisions, would.

Finally, despite the measures that were taken to reduce the potential for retrospective bias, like multi respondents, only including recently commercialised process innovations and preparatory desk research, there is always the chance of respondents' bias occurring within the data collection.

4 Results

4.1 Within-case analysis

As described in the methodology section, first each individual case will be analysed along the research questions, mentioned below. To facilitate both in-case and cross-case analysis, data from each case was analysed and sorted based on the different concepts and sub-concepts. These findings were extracted from the case reports and consolidated in a extensive Excel-sheet covering all concepts of the three different domains, imitation barriers, resource orchestration and process innovation context, for each individual case. The resulting Excel-sheet has been attached in appendix B. In the following paragraphs short descriptions are given of each case, covering the innovation characteristics, firm characteristics, key meso and macro environmental factors (if applicable), the most relevant and key activities regarding resource orchestration and the created types of imitation barriers. Each case description is consolidated in a relationships model covering the relationships between the three concepts in that case. This model is based on the theoretical framework as displayed in figure eight, and displays the actual situation in each specific case. The thick lines in these models highlight the most important relationships with regard to imitation barrier creation. Case names and numbers are taken from aforementioned table three.

Research questions:

1) *How are organisational resources orchestrated during the research to market trajectory of different types of process innovations contexts?*

2) *Which imitation barriers can be identified based on the orchestrated resources per process innovation context?*

3) *How do imitation barriers prevent competitors from imitating a process innovation, in practice?*

4.1.1 Case 1: Rare earth extraction, "tightly managed innovation process within a technologically superior multinational"

The process innovation in this case was developed and commercialised by a ***large established French multinational*** specialised in chemicals and plastics for a wide variety of applications. The company can be characterised as a divisional organisation with business units for various products and appliances, and is publically listed. Due to the sheer size of the firm, the innovation could be ***funded with internal cash reserves***. The company does not sell the process innovation, but has implemented it internally at two of its plants in France.

The company, the ***world leader in rare earth-based formulations***, has developed a new process for the ***recovery and separation of rare earth materials*** contained in used low-energy light bulbs. Rare earth elements or rare earth metals are a set of seventeen chemical elements in the periodic table. Six of these elements are used variably in CFLs (Compact Fluorescent Lamps), of which the five most common are yttrium, europium, terbium, cerium and lanthanum . In the past, rare earths contained in CFLs were considered waste and ended up in landfills. By use of the company's new recycling process, these materials can now be extracted for reuse. Due to their scarcity and unique application benefits, these metals are highly valuable.

The process innovation in this case can be considered ***new to the world***. Other firms already hold patents on the recycling of yttrium and europium from used lamps, but this process is the only one that is able to recycle all different types of material at once. This innovation can be considered an ***application innovation***, because the technological change from the producer's view is relatively low, but the increased benefit from the buyer's view is high, because waste is transformed in a valuable resource. Most of the capabilities and equipment required for this process were already present within the company. The ***company already knew the forward approach*** of manufacturing phosphate precursors. As the company's BU manager stated, "***it is easier to apply reverse chemistry if you are already familiar with the forward approach***". Because the company is a large multinational, employing over 14,000 people, the company's permanent R&D department had sufficient resources and capabilities available in-house to develop this innovation largely independent from external stakeholders, ***from beginning to end***. The development process for this innovation was manufacturer dominated. The technology was, however, developed as a result of both ***technology push*** and ***market pull***. There is a clear need from the market for additional suppliers of rare earth material, due to China's monopoly position in this market. The innovation is considered a success, because it allows for the ***transformation of useless CFL waste into valuable raw resources,*** and generates substantial cost savings for the company.

A key factor from the meso environment of the company, was the ***presence of suppliers that operate the collection circuit for CFL waste*** in France and many other EU countries. This enabled the company to focus on its core competency of process development. Moreover, this ***mediates the effect that resource orchestration has on the creation of imitation barriers***. By establishing contracts with these CFL waste collectors, the company effectively ***pre-empts the required input*** material to operate this technology, at least in its own operational region (France).

The company basically applied the ***existing resources and capabilities*** present within the firm to **reversely engineer** its own process of manufacturing phosphate precursors. The company applied its standard, relatively tightly managed, procedure for innovation management. The physical capital resources deployed for development were the financial resources, originating from the company cash reserves; laboratory facilities and simulation and testing equipment present within the company's permanent R&D department; the technology used for the forward process of manufacturing phosphate precursors; and the existing equipment present at the two plants at which the current process innovation was implemented. According to the company's BU manager: "***Today, more than 90% of the main equipment that is being incorporated in the technology is previously used equipment. This is part of the whole business philosophy of the company***". Human capital resources that were deployed originate from the company's various functional departments like, R&D, marketing, legal/IPR, public relations, operating and hygiene and environmental safety departments. Organisational capital resources in the form of patent application, permit application, innovation management and internal communication procedures helped to develop and diffuse this innovation.

The company only needed to acquire capabilities from external stakeholders with regards to optimisation of a few process steps, and resources in the form of CFL waste material as input for the process. The company wanted to stick to its core competencies and wanted to outsource the collection of waste to subcontractors. This was one of the reasons why the firm chose CFL waste as a source of rare earth material in the first place.

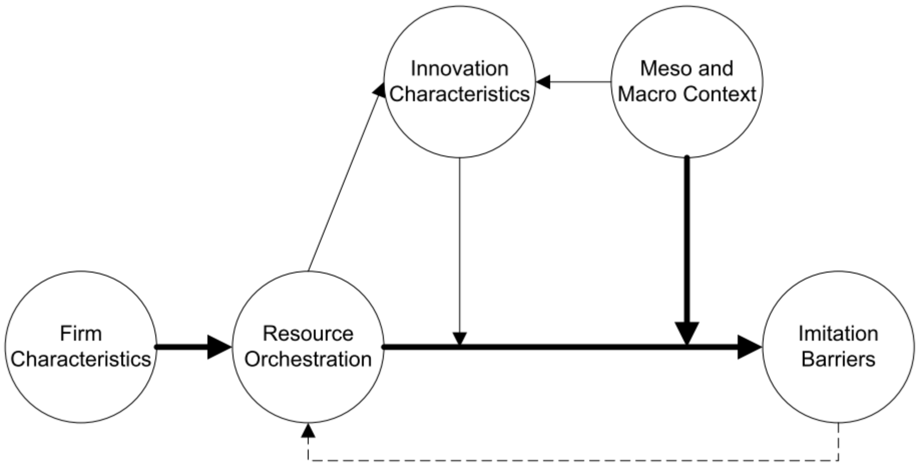
Through above described resource orchestration, several imitation barriers are created. By only implementing this technology internally, the company creates ***cognitive barriers to imitation*** in the form of causal ambiguity, because ***secrecy*** surrounding the technology is more easily maintained. Furthermore, ***inter-organisational conflict*** as experienced by the innovator, as a result of the required collaboration between chemists and recycling experts, which do not speak each other's language, might prove an substantial barrier to imitation for a competitor wanting to implement this technology. Finally, the company enjoys ***complementarity in valuation*** through its diversity, because it can use the extracted rare earth as input material for some of its other processes, effectively resulting in higher margins, possible deterring imitators that not have this advantage.

Willingness barriers to imitation of this innovation arise from the ***political context*** of this innovation. Acquisition of permits for recycling activity (especially those which involve mercury) require substantial amounts of time, money, skill and effort. Something which might prove insurmountable for smaller companies which do not have permanent departments for such issues. Moreover, acquisition of input waste material at a reasonable price proved very challenging, due to the hard competition from Chinese companies. Due to the ***less stringent environmental standards and ethics***, these companies are able to offer much higher purchase prices to recyclers that sell CFL waste. In combination with the earlier mentioned ***pre-emption effect***, other non-Chinese competitors might find it hard to acquire the required inputs at an economically feasible price.

Finally, several ability barriers arise as a result of resource orchestration during the development trajectory. First and foremost, the company had the key inventive step within the process ***patented*** by its highly experienced legal department. In practice, ***pre-emption of knowhow*** is almost always associated with having IPR in place, because potential imitators cannot commercially apply the same knowledge. Furthermore, the company experienced ***time compression diseconomie***s during development. The company chose speed over quality and went for methods that were available and that delivered a sufficient result. These results, however, are still not optimal. According to the BU manager, "***it takes time to generate optimal solutions, which is done in parallel to the implementation process***". ***Asset mass efficiencies*** were also present through the permanently active and experienced R&D department. The company already developed, managed and implemented several process innovation internally, in the past and has experienced substantial amounts of ***producer learning***. Resource interrelatedness in the form of ***economies of scope*** were achieved between the development of the current process technology and existing technology already possessed by the firm. This existing technology, the forward approach of producing phosphate precursors, made development of the current technology much easier.

Some ***socially complex resources*** were engineered during development of this innovation. Synergy that was created between new and experienced operating staff and engineering specialists from different fields (pyrometallurgy, hydrometallurgy, liquid separation and sieving), proved valuable for the success of this innovation. Balancing of this substantial amount of human capital resources poses a significant barrier for imitation. By being the first company on the market to commercialise this technology, the firm generates substantial amounts of ***advertisement and exposure***. In combination with the fact that the process is environmental friendly, because it makes reuse of resources possible, the company reaches out to customers and the general public in a manner that potential imitators might not achieve with the same budget, due to ***channel crowding***.

Figure 11: Relationships model case 1



To conclude, the firm characteristics clearly influence resource orchestration. The multinational firm possessed existing equipment and technology, cash reserves for funding and a permanent R&D department to develop the innovation. Resource orchestration influences the innovation characteristics, because the latter are largely established as a result of the first. Innovation characteristics are also shaped by contextual factors through hygiene and safety laws and customer preferences for greener products. The influence of resource orchestration on the created imitation barriers is mediated by the innovation characteristics and contextual factors. The innovation's characteristics, like its patentability mediated the imitation barriers that were created. Contextual factors, like the presence of cooperative supplier of CRT waste, influence the effect that the company's resource orchestration had on the pre-emption of inputs. Finally, imitation barriers like the acquisition of a patent and strict safety laws, directly influence subsequent resource orchestration.

4.1.2 Case 2: Textile dyeing, "generating market pull through partnerships with influential stakeholders"

This Dutch company is the world's first supplier of industrial CO2 textile dyeing equipment. The company was founded in 2008 as a ***spin-off*** of a SME specialised in various pressurised CO2 applications, and currently employs ten employees. The organisational structure can be characterised as innovative or an adhocracy. The initial prototype on which the current innovation is based, was funded by three partner organisations, two companies and a university. The final version of the technology was funded by private investors and the Dutch national government. The company is partially owned by its former mother organisation, its commercial manager and some private investors.

The current innovation replaces water with pressurised CO2, through which the process of textile dyeing becomes more economically and environmentally friendly. The innovation is a completely water free dyeing process with considerable lower operational costs compared to the conventional dyeing processes. This process is sold in the form of a machine with a large pressure vessel and small peripheral equipment. Other advantages of the innovation include: the elimination of wastewater discharges; reduction in air emissions; reduction in dyeing time; surfactants and auxiliary chemicals in dyes eliminated; dye utilization is very high with very little residue dye; and unused dye can be recaptured; approximately 95% of used CO2 will be recycled.

The process innovation is new to the world and can be characterised as a ***radical innovation***, because the technical change from the producer's view is high and the increased benefit from the customer's perspective, as elicited above, is incredible. Being a spin-off, the company could adopt the working prototype from its mother company and did not have to start development from scratch. The innovation can be considered a combination of both ***technology push*** and ***demand pull***. The demand pull was deliberately created by the company's commercial manager and also provides one of the most substantial sources of imitation barriers for this innovation, as will be described below. The innovation is considered successful, because it realises significant reductions in cost, energy and pollution. The first machines have already been sold and implemented at a launch customer in Thailand.

A key factor from the meso environment of the company, with regards to the creation of imitation barriers, is formed by collaborative and highly specialised supplier companies, which significantly supported in development of the innovation. Furthermore, interested and influential players in the textile industry (a global fashion label and large textile processing company) were willing to partner with the company in order to diffuse the current technology. Both factors significantly mediated the relationships between the company's resource orchestration and the creation of imitation barriers, as will be explained below.

A key factor in the company's resource orchestration was the relationship it had with its mother company. Through this relationship, the company had access to a fully working prototype on which it based the current technology. Furthermore, the technical expertise, with regards to liquid CO2 engineering, residing in the mother company, was at the disposal of the spin-off company. Firm characteristics thus clearly influence resource orchestration in this case.

The company's key resource orchestration activities, which were both responsible for development of the innovation and creation of the most important imitation barriers, are its machine design and assembly capacities, and capability to outsource and clearly communicate development of machine components to subcontractors. The company's internal R&D team was responsible for the design of the machine layout, patenting and assembly. Development of most machine components was done by specialised suppliers, with some of which the company established exclusive supplier contracts, effectively ***pre-empting inputs*** for potential imitators. Assembly of all parts was conducted by the company itself. During assembly, resources and capabilities from all suppliers were basically coordinated and merged into one functioning process. This resource interrelatedness in the form of ***economies of scope,*** provides the second key imitation barrier for this technology.

The third key imitation barrier for this process are the ***intellectual property rights*** that the company acquired on its invention. The company possesses seven patents to protect different parts of the process. The company has experience with intellectual property law and management, partially through its mother company, and managed to file the patents in such a way that they cover broad protection without disclosing any crucial inventive steps of the process. This way, the company managed to deliberately create a substantial amount of ***causal ambiguity*** through information ***impactedness***. The company also stochastically generated some causal ambiguity, due to the ***trial and error approach*** it took to develop substantial parts of this innovation. Trial and error implies that the company also conducts many activities that have no desired result, possibly misleading the imitators in its moves. To maintain ***secrecy***, parts of patented process components are manufactured by external suppliers but are assembled at the company's plant.

By establishing partnership with a large fashion label and a launch customer, the company respectively put pressure on textile dyeing companies to adopt this technology and acquired key feedback from a real life industrial environment. The fashion labels have such a strong market position that they are able to demand from their supplier that they adopt this technology, by for instance promising to keep their order books filled. Without these partnerships, potential imitators face significantly more trouble in diffusing this technology.

Regarding cognitive barriers to imitation, several manifestation are in effect for this innovation. ***Interplay of resources*** and ***inter-organisational conflict*** originate from miscommunication that occurred between employees skilled in different disciplines. By having these different employees communicate frequently and informally, chemists and mechanical engineers could however overcome this problem. Chemists for instance had to be notified of the restrictions of the process, which dictated their freedom to operate. Because the team was relatively small, just ten employees, this did not pose significant problems.

With regard to willingness barriers there are ***institutionalised norms*** that might deter competitors from imitation. There was some initial resistance from industry especially among for instance pigment and dye suppliers. These companies lose some of their margin due to the new technology. Liquid CO2 dyeing requires less pigment and chemicals, both supplied by these companies. It therefore indirectly decreased their sales. The textile processing industry has ***historically been very conservative***. The industry is cost driven and does not like change. These companies however appear to have dropped their resistance and are now more open for change.

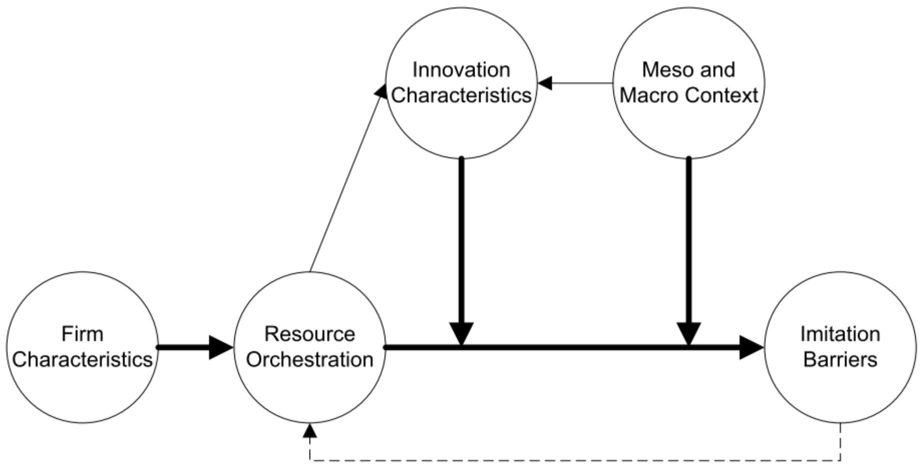
Based on the commercial manager's quote: "***There were no significant success factors for development in this phase of the project, except for adequate time for testing and trial and error***", we derive the presence of time compression diseconomies, implying that imitators, at least in the short run, will be deterred from imitation. ***Experience economies*** arise from the company's test runs with the technology, which were conducted in 2011 during 8 months of testing, simulation and analysis.

Distinct organisational capabilities in the form of organisational learning were displayed during development. The process of scaling up this prototype to a full working industrial machine was based on trial and error. According to the commercial manager: "***to create something which is not already existent cannot be done using predetermined steps and frameworks***". The company had to learn how to come up with a solution based on trial and error.

Additional less important imitation barriers, like socially complex resources, preferential market access and distinct managerial capabilities were also created in this case. However, due to the large amount of imitation barriers for this case, these were not included here, but can be consulted in the Excel-sheet attached in the appendix B.

To conclude, the most important relationships in this case were: the influence of the firm characteristics on resource orchestration, due to the relationship the spin-off had to its mother company; the influence of the firm's resource orchestration on the created imitation barriers, through for instance the acquisition of seven patents on the technology; the mediating influence of the innovation characteristics on the relationship between resource orchestration and imitation barriers, elicited by the patentability of the innovation in the first place and the possibility to outsource large parts of its development; and finally the mediating influence of the company's meso context on the relationship between resource orchestration and imitation barriers, through the presence of highly specialised and cooperative suppliers and partnerships with influential industry players.

Figure 12: Relationships model case 2



4.1.3 Case 3: Metal sorting, "developing innovation in close cooperation with suppliers"

A Dutch joint venture implemented and commercialised a process that allows for the separation of various metals based on their material specific density. The joint venture was founded in 2008, as a result of a partnership between a Dutch magnet system engineering company and a Dutch metal recycling company. The joint venture currently employs 15 people and can be characterised as an adhocracy or innovative organisation. The innovation was funded with one of the joint venture partner's cash reserves. The technology is available on the global market and is already being operated by a large American customer.

The new process incorporates a magnet system and iron oxide fluid, which in combination allow for an adjustable process liquid density. This process liquid is used to separate different types of metal waste from each other. By adjusting the density of the process fluid, only the metal type with the lowest density in a waste collection composed of different types of metal, is made to float. Subsequently the floating metal fraction is extracted and the whole process is repeated with a different fluid density setup. Opposed to its competitors, the new technology allows the company to separate waste input based on its specific material density. Competitors are still using optical separation techniques based on for instance colours or particle size, factors that are not directly related to the material's properties. A large share of material sorting is also still being done manually. If particle size, however, drops below 50 mm, it becomes very hard to manually sort the material. Moreover, sorting material based on its colour is not a reliable method, because many used materials have been treated with either paint or a coating, hiding their material specific colour.

The innovation is new to the world and can be characterised as a radical innovation, because both the technological change from the producer's view is and the increased benefit from the buyer's view are high. Development of this technology was manufacturer driven. There is no direct demand pull from the market, but increasing resource prices stimulate adoption of this technology. The patented magnet system underlying the process, was developed by one of the mother companies, and encompassed the first development step. Subsequent development steps were largely conducted in the joint venture and in close cooperation with suppliers of process components. The innovation is considered to be successful, because the company earns money through internal operation of the technology, royalties on licensed patents to customers, and joint venture constructions with customers.

From the company's meso context, especially the cooperativeness of the joint venture partner and suppliers of key machine components were key to both development of the innovation and generation of imitation barriers. Two types of imitation barriers, resource interrelatedness in the form of ***economies of scope*** and ***pre-emption of inputs***, derive their existence from this cooperation.

The joint venture's resource orchestration activities largely originate from both joint venture partners. One of which is a world leader in magnet systems for recycling purposes and was responsible for development and patenting of the underlying magnet technology. The other partner specialises in metal recycling and has substantial experience with developing and operating recycling facilities. By combining their own resources, capabilities and acquiring development capacities from several key suppliers, they managed to come up with the current innovation.

There are no observed cognitive barriers to imitation. Willingness barriers, however, arise from two different sources. First, ***institutionalised norms*** in the recycling industry, with regard to liquid density separation, might deter competitors from imitation. Most industry players associate liquid density separation with processes incorporating salted water, with which a higher density can be reached, which allows for the separation of various metals in water. Salted water, however, accelerates the oxidation of metals, making the sorted metal less valuable for reuse. The recycling industry, therefore has a negative predisposition towards liquid sorting, because it associates this with salt water practices.

Another factor that makes competitors less willing to imitate this process is that the patented technology is ***available under license***. The joint venture offers licenses at a reasonable price for interested parties. Indeed, this is the business model the company preferably opts for. It creates a joint venture with the customer company and sells licenses to the newly founded JV. A certain percentage is then agreed upon, to divide the potential profits.

With regard to ability barriers several types are in place, three of which have already been mentioned. A crucial part of the process, the magnet system, was patented by one of the joint venture partners. According to the company's commercial manager, "***the company has the financial power and expertise to defend the acquired patents***" and this therefore poses a strong imitation barrier. The company already has substantial experience in intellectual property management and fighting infringement. "***One of Europe's best patent attorneys was involved with acquiring the patent and makes sure that the patent is properly defended***", according to the earlier mentioned respondent.

The company conducted several strong ***pre-emptive*** actions with regard to ***input*** and ***knowledge***. As mentioned earlier, having patents on the technology basically implies pre-emption of knowhow, because potential imitators are not allowed to commercialise the same know-how in a similar process. Furthermore, by setting up exclusive contracts with the JV's suppliers of the custom-made iron oxide process fluid, potential imitators cannot make use of the knowledge residing in these technology leaders for this respective product (high-tech process fluid). The properties of the liquid substance are of high influence to the success of the process. Substantial amounts of time and money were spend to optimise this fluid and significant errors were encountered when parameters of the fluid were setup slightly different.

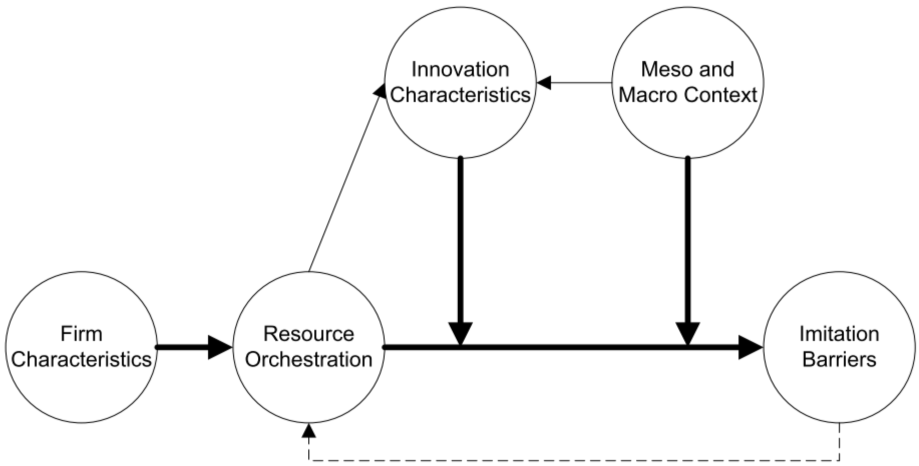
According to the JV's commercial manager and shareholder, "***the company consciously chose to keep the development of this process isolated from the rest of the organisation. The general goals and***

aims of the project were communicated to other employees, but details concerning the technology were kept secret by the development team". This was key for acquiring the patent on the magnet system, which would have been impossible if key details of the innovations would have leaked to the public. This can also be considered a form of deliberately creating causal ambiguity through ***secrecy*** or information impactedness.

Finally, the company achieved inimitable ***economies of scope*** with regards to resources and capabilities required for development of this technology. The process innovation was realised through combining resources and capabilities of both JV partners, the two suppliers of the process liquid and the other four key suppliers of facility components. Many of which are technology leaders in their respective industry, for instance one the joint venture partners, the two process fluid developers/suppliers and one of the machine parts suppliers.

To conclude the most important relationships in this case were: the influence of the firm characteristics on resource orchestration, due to the relationship the company (JV) had to both joint venture partners; the influence of the firm's resource orchestration on the created imitation barriers, through for instance the acquisition of a patent on the magnet technology and availability of licenses; the mediating influence of the innovation characteristics on the relationship between resource orchestration and imitation barriers, elicited by the patentability of the innovation and its composition of different high-tech components requiring a broad variety of expertise in order to develop; and finally the mediating influence of the company's meso context on the relationship between resource orchestration and imitation barriers, through the presence of an experienced joint venture partner and cooperative suppliers with whom the company was able to establish exclusive contracts.

Figure 13: Relationships model case 3



4.1.4 Case 4: Car construction, "Creating an automotive experience through crowdsourced manufacturing and a closely involved user base"

This U.S. based ***start-up***, founded in 2006, has developed a new crowdsourced process for car construction. The company was founded by two entrepreneurs, of which one had extensive working experience in McKinsey's automotive practice. The firm can be characterised as an innovative/adhocracy structured organisation, currently employing over 20 employees. The company and innovation were funded by prize money from competitions, and to a large degree by angel investors and a wealthy industry individual. The company commercialises it process through its online platform and micro-factory were the cars are respectively designed and constructed.

The current car production process is novel because it is based on crowdsourced manufacturing. Crowdsourced car manufacturing allows a customer to contribute to the construction of its own car. The company is applying what the traditional automobile firms already know and applies it to their co-creation initiatives. Crowd sourcing gets customers and suppliers involved through the company's platform, where everybody can meet and interact immediately. Consequently, this results in user designs and manufacturing engagement. These efforts result in shorter product development times, a more cost effective development process from the start, and more attractive products. Thus, besides offering the customer the highly individualised end product, it also offers an entertaining automotive experience.

The innovation can be characterised as an application innovation, because the increased technical change from the producer's view is limited. Neither the technology underlying the online platform nor the manufacturing plants are novel. The increased benefit from the customer's view, however, is high due to the completely new experience that is offered and the degree of individualisation and involvement that is enabled. The company was involved with development of the innovation from the very first beginning until the end. The process is considered new to the operating market of the firm, worldwide. Similar approaches have already been applied in different industries. The innovation is successful, in so far that the company has already attracted 10,000 users to its online community and the process seems to be both technically capable to produce vehicles, and profitable enough to reach its break-even point.

A key factor from the company's meso environment concerns the ***presence of participative users*** for the current product. As the founder stated: "I think crowdsource derived co-creation will not likely work for all industries. Crowdsource derived initiatives are more suitable for appealing consumer products such as housing, electronics and obviously the automotive industry". Lack of this factor would have made user community building difficult and sabotaged the whole innovation. Furthermore, to decrease the cost of maintaining its user base, the firm ***opened up the community to other companies*** that desire to tap into the talent pool and collaborate on hosting design competitions. Thus, meso contextual factors mediate the influence that resource orchestration has on the type of innovation that is generated.

Resource orchestration in this case focused on the three main elements of the innovation: the online platform, the community and the micro-factories used for manufacturing the cars. Of these three elements, ***build-up and maintenance of the community*** or user-base are by far the most important resource orchestration activities with regard to the generation of imitation barriers. Especially the ***PR manager*** within the company is key to this, as she creates momentum inside the community. The company's founder refers to her as the "***Community Evangelist***", who ensures the well being of the community and realises the groundwork for activities. Her experience stems from customer-outreach programs for Volvo and General Motors, which helped to build the community. Moreover, the founder learned that the company should target the 80% of graduates, from top automotive design programs, who did not find employment with major car manufacturers. The PR manager sought close online contact with those potential members from automotive and other industrial design community sites. She tried to convince them of the company's credibility and into uploading their portfolios. To encourage community's growth at that point, a number of competitions were hosted but no actual cars would be sold. Once the community started to grow and people ceased to question the legitimacy of the company's endeavour, efforts to attract more members became much more manageable.

Regarding cognitive barriers, ***long time lags between cause and effect*** can be observed. The investments made in building the community through various low-level, simple events and online-tool building which eventually led to customer engagement and customer co-designs for the cars, had substantial intervals. It might be hard to observe for potential imitators that something as simple as offering free hamburgers during a simple welding workshop might contribute to the much needed community building.

Willingness barriers originate from the ***institutionalised norms*** in the car industry. The car industry is very conservative and has not radically changed over the past decades. It would be very unlikely that traditional car manufacturers would copy this co-creation approach.

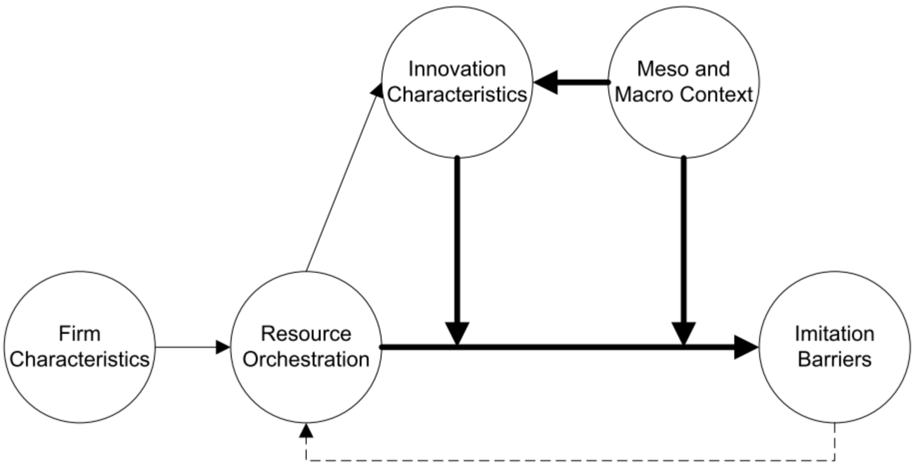
The strongest ability barrier in this case arises from the ***social complexity*** of the community model. It not only requires social engineering to accumulate community members, but also to imitate the community mechanism that, through synergy between its members comes up with unique and creative designs for new car models. Clearly, ***preferential market access*** also originates from the community model. ***Communication good effects*** arise from the community. They are generated through the synergy that is created between the different capabilities of users. The more users engage in co-creation, the better the result will be for all. The ***buyer evaluation cost*** are kept relatively low, for the early majority and late majority. The process and its community is mainly aimed at automotive enthusiasts, which also largely form the market's opinion leaders that might influence mainstream customers. These opinion leaders and other community members have already invested time and effort in coming up with designs. They had to become familiar with the design tools and other software the company offered. This therefore creates substantial ***buyer switching cost*** for the existing user base. The aforementioned lock-in of car enthusiasts with valuable design skills, can also be seen as ***pre-emption of inputs*** (considering active users as input variables). Finally, because the company is the first in the world to commercialise this process innovation, which due to the nature of the innovation is done with substantial amounts of public disclosure, provides the company with **advertising benefits**. Without investing significantly more money, it will be hard for competitors to imitate this exposure due to **channel crowding**.

Path dependency barriers also apply to this case. ***Irreversibility of investments*** largely applies to established car manufacturers. Investments made in mass production models and production lines for mass production models first need to be earned back by traditional car manufacturers, before they would even consider something somewhat similar to the mass individualisation that the current company enables. ***Time compression diseconomies*** apply to community building. It is impossible for a potential imitator to just buy customer loyalty and engagement in the form of a customer community. This takes time, investments and perceived user benefit. Furthermore, the company already generated ***experience economies*** in building, cultivating and engaging their community. The company is not only relying on its community for sales, but it also plays a key role in development and production of new models.

Resource interrelatedness originates from the hard ***balancing of resources*** it takes to determine which actions have to be performed by the engineers of the company and which by the design community. Furthermore the balance between creating an interesting automotive co-construction experience and executing the required construction work, also requires a delicate balance. According to the founder: "A trade-off must be made between exiting, and less exiting but necessary actions, but so far it seems possible to strike a balance." Finally, the company also possesses ***distinct managerial capabilities*** in the form of ***firm-specific knowledge*** possessed by managers and an ***entrepreneurial vision*** of its management. One of the founders worked for a world leading strategy consultant's automotive practice and gathered substantial amount of knowledge and experience with regards to this industry. Besides, his father used to own an American motorcycle company. Furthermore, he envisaged the development process for this innovation in the form of a ***clear mental model*** or road map. This mental model proved to be a guiding line throughout development.

To conclude, the firm characteristics influence resource orchestration in that financial resources were limited and that being a start-up, the company was not bound to industry's usual business conduct. Resource orchestration influences the innovation characteristics, because for co-creation and crowdsourcing to occur, a community must first be build up and activated. Innovation characteristics are also shaped by contextual factors through the availability of a participative and skilled user base for an appealing product like automobiles. The influence of resource orchestration on the created imitation barriers is mediated by the innovation characteristics and contextual factors. The innovation's characteristics, being co-creation centred and thus based on a community, largely mediated the imitation barriers that were created (social complexity and preferential market access). Contextual factors, like the conservatism among industry incumbents, influence the effect that the company's resource orchestration has on the willingness to imitate. Finally, imitation barriers like communication effects, indirectly influence subsequent resource availability and orchestration (a larger user base results in higher availability of resources but also the attraction of even more resources).

Figure 14: Relationships model case 4



4.1.5 Case 5: 3D printing, "A new form of customer co-creation enabled by previously developed product innovation"

This American company claims to be the first in the world to conduct crowdsourced manufacturing through 3D printing. The company was founded in 2009 by three experienced entrepreneurs and can be characterised as an innovative or adhocracy organisation. The firm currently employs approximately 50 employees and conducts it crowdsourced activities across the globe. The company was funded by the founders, and to a larger degree by a venture capital firm. Development and execution of the process innovation itself, however, did not require any specific funding.

The company is the first to have developed and commercialised a low entry level 3D printer for consumer household usage. The company was, however, unable to keep up with demand for their 3D printer, so they turned to their customer base and asked them to manufacture some of the parts (pulleys) for them, using the existing 3D printers at their homes. The owners of the 3D printers were thus helping the company with producing new printers. The novelty in this innovation does not encompass the 3D printing technology, but the crowdsourcing on which production was based for a certain amount of time. The concept of crowdsourced manufacturing generally implies that instead of having a centralised factory that produces parts and then distributes them to the people who want them, individuals have the tools they need to build what they want and distribute it without a central hub. In this case, manufacturing was decentralised, but distribution still used the hub model. The company claims to be the first one in the world to use such a crowdsourced manufacturing scheme.

This innovation can be described as an ***application innovation***. The technological change from the producer's view is low. It's entails more of a business model change and not a technical change. The increased benefit for the customer is perhaps not very high, but the relationships with the customer is changed substantially. The company came up with the innovation itself, but obviously required its user base support for implementation. Development of this process was ***manufacturer driven***, because it originated as an emergency solution for a production capacity shortage the company faced. The innovation is considered successful in that it helped the company to overcome a temporary production capacity shortage.

A crucial factor from the ***company's meso environment*** for the successful implementation of this process innovation was the presence of an already existing user base equipped with the company 3D printing technology. This allowed the company to tap into their user base's production capacity and design skills.

The most important sources for resource orchestration in this case originate from the ***human capital present*** within the company's founders, the ***company's cooperative user base*** and the ***company's earlier developed product innovation*** already in possession of the user base. Together they allowed for the development and implementation of this form of crowdsourced manufacturing, and moreover were also responsible for the generation of the most important imitation barriers. The company's founders were the key human capital resources. One of the founders was already involved with a foundation he founded, aimed at advancing research in 3D printing. All three founders are enthusiasts of open source innovation. The company's user base was build during the sales of a previously developed process innovation, the 3D printer. The company already had an online platform in place, which customers used for exchanging designs for printing various items. This platform was used to communicate with the user base and distribute the necessary digital designs for customers to print pulleys. Finally, without the customer base being in possession of 3D printing technology, they would not have been able to join in crowdsourced manufacturing. A potential imitators thus, also needs to have access to a user base in possession of the required technology.

With regards to ***cognitive barriers***, only ***complementarity in valuation*** can be distinguished. A potential competitor clearly would have to have access to a consumer base with 3D printing or similar enabling technology that would allow customers to engage in manufacturing, to conduct crowdsourced manufacturing and derive benefit from it. This particular obstacle can also be seen as a ***willingness barrier***, because without a user base with a particular technology, crowdsourced manufacturing might not prove an efficient manner of production at all. No other willingness barriers could be identified.

Ability barriers were observed in several different forms, two of which were directly related to the type of innovation (a form of co-creation), socially complex resources and preferential market access. ***Socially complex resources*** in the form of the participative user base, poses a significant ability barrier. The committed user base is the key prerequisite for crowdsourced manufacturing. To develop such a community, social engineering is required. In turn, crowdsourced manufacturing not only helped the company to solve the technical issues with faulty parts, lack of production capacity, but it also helped the company to build and strengthen its user community base. This highlights the indirect influence of the imitation barrier on resource orchestration.

Preferential market access is the strongest represented ability barrier for this innovation. ***Communication good effects*** arise because community members benefit from an increasing community size. This is due to the exchange of 3D printing designs, which facilitated crowdsourced manufacturing and benefits all users. The company also benefits from an increasing community, because it has more potential co-manufacturers available. ***Buyer evaluation cost*** were lowered by the company. At the start, the company shipped a product that would eventually fail, due to faulty pulleys. Most companies would recall those products. This company, however, saw this occurrence as a challenge and as a problem that could be turned into success, through crowdsourced manufacturing. The company saw the importance of keeping production and shipments levels high, to keep on enlarging the community. At that time, the company's customers were mainly so called technology enthusiasts and engineers, who were open towards challenges and found it exciting to be able to work on the solution together with the company. By cooperating with its user base of technology enthusiasts, the company got valuable feedback early in the design cycle and acquired supporters who would influence other buyers in the marketplace. Several factors contribute to relatively ***high buyer switching cost***. To be part of the community and make use of the growing collection of designs, a customer first has to purchase a 3D printer. It then takes some learning to get used to the system. These two factors create substantial buyer switching cost, in case a rivalling system would arise.

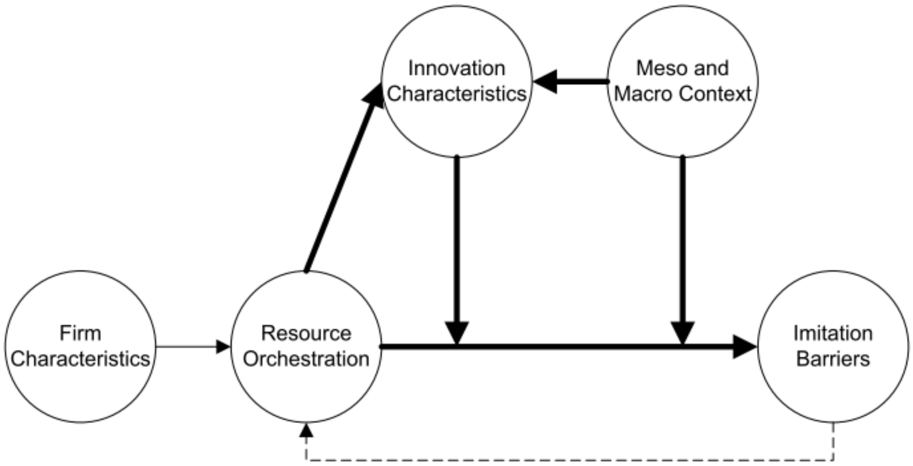
Path dependency, in the form of ***time compression diseconomies*** were identified. Because a substantial share of learning had to be conducted by individuals in the user base, which generally only have their spare time as an available resource. Thus learning was largely dependent upon the time factor. There basically was no substitute for time, like additional investments, parallel research teams etc. The aforementioned synergy between crowdsourced manufacturing and the sold technology, as a ***complementarity in valuation***, also goes for resource interrelatedness, in the form of ***economies of scope***.

According to the company's founder, "***existing research shows that the best way to reach technology enthusiasts is to place a message on the internet. Direct email with factual information will also work. This is exactly what the company did, and application of the appropriate communication means can partially explain the success of this whole endeavour***". It will be hard for potential imitators to reach and engage as many customers through advertisement, because many technology enthusiasts are already bound to the current technology. Furthermore, the current company being the first to use a crowdsourcing approach, will have generated substantial exposure, which will be hard to imitate using the same resources, due to channel crowding.

The ***entrepreneurial vision*** of the managers provided the company with distinct managerial capabilities. The three founders are clear proponents of empowering customers and other people around them. They were already involved with open innovation in the past and had a clear vision to develop this innovation. Finally, ***distinct organisational capabilities***, in the form of producer and organisational learning, were also identified. Producer learning was not only present at the company, but also at the customer base, which was able to improve its productivity independently from the company. Business development and technology development within the company were both done in a "***do-it-yourself***" or "***learning by doing***" process.

To conclude the most important relationships in this case were: the influence of the firm's resource orchestration on the created imitation barriers, through for instance the entrepreneurial vision of the company's founder and complementarity in valuation; the mediating influence of the innovation characteristics on the relationship between resource orchestration and imitation barriers, the process being co-creation centred and thus based on community participation, largely mediated the imitation barriers that were created (social complexity and preferential market access); the mediating influence of the company's meso context on the relationship between resource orchestration and imitation barriers, through the presence of an already existing user base already in possession of the required technology to participate; and finally the indirect influence of imitation barriers on resource orchestration, through the socially complex resource base and corresponding communication good effects.

Figure 15: Relationships model case 5



4.1.6 Case 6: Butanol fermentation, "pre-emption of scarce production facilities combined with both incremental and radical process innovation"

This UK based company has developed an advanced fermentation process through its cutting edge research in advanced microbial technology. The company was founded in 2007 and currently employs approximately 40 employees. The organisation can be characterised as an adhocracy and was funded by friends and family, business angels, venture capital, and grants and subsidies by government.

The company possesses a large library of biocatalysts and has developed a fermentation process that produces low cost and renewable butanol from waste and agricultural by-products. It delivers high performance with strains and sustainable feed stocks at the lowest cost, and with minimum negative environmental and social impact. The company provides fermentation technology to idle customer fermentation facilities in various countries to enable a restart of the facility and low cost bio-butanol production from sustainable feed stocks for the chemical market. Furthermore, the company's novel process has the potential to reduce cost so that bio-butanol can compete in the bio fuel market.

This innovation can be characterised as a radical innovation. The technological change from the producer's view is relatively high, due to the advanced use and genetic engineering of microbes, which improves fermentation productivity. Because this advanced technology allows for the reopening of idle, existing fermentation plants, the increased benefit from the customer's view is also high. The innovation is the result of both technology push and market pull. The founder of the company noticed a huge demand for bio-butanol in the chemical market in the last three or four years. It pushed the new process on the market by first introducing an incremental change to the customer production facility and after it is familiar with the technology, the firm implements its more radical technology. The founder established the company from scratch by offering contract research services in order to generate budget for R&D. The butanol fermentation process, however, is not completely new. Its development can be traced back to the year 1912, when it was first developed and commercialised in the UK. The innovation is considered a success in that it produces low cost butanol and has already several customers in China.

A key factor from the company's meso environment arises from the presence of existing idle fermentation facilities. The fact that the current technology is compatible with these existing facilities, allows it to effectively ***pre-empt input*** required to commercialise this technology on short-term.

The most important resource orchestration activities for the development and imitative properties of the current technology are: the firms human capital resources highly skilled in fermentation research; the relationship-driven diffusion model the company uses; and the incremental implementation of the technology at customer sites.

Complementarity in valuation is the only cognitive barrier that was generated during development. The company closely inspects the existing facility at the customer site. Next, it tries to understand the possible engineering solutions that could be implemented at the site. This might involve the consideration of factors such as fermentation reconfiguration, provision of utilities, waste water treatment, the water recycling approach, and the ability to integrate ABE butanol with existing logistics in place. These factors provide evaluation criteria to choose an optimal engineering approach. The firm aims to maximise the use of existing facilities rather than changing everything. This approach, in turn, leads to a more economic outcome.

Willingness barriers arise from the ***cultural context*** and ***availability and price of IPR licenses***. With the current business climate being more and more appreciative of sustainable solutions, this aspect provides a key value proposition for the current process innovation. It is noted that the customers and end-users are enthusiastic about adopting a sustainable process. The sustainability of the process offered by the company does improve its marketability. On the commercial side, the company selects appropriate instruments for how to deal with royalties, development programmes, investments, and provision of long term support. The company either licenses its technology to the plant owners and other customers or forms a joint venture with the facility owners by investing in the existing facilities. Due to the access to the technology for competitors through reasonably priced licenses, ***willingness to imitate*** should decline.

There are several ability barrier types for the current process innovation in place. The company has several ***patents*** that are strain-specific, covering genetically modified strains such as clostridia, and also thermophilic microbes for butanol production. Currently, it has filed one patent for each of these processes in the U.S. and in Europe. The patents have not been granted yet. Both the patents broadly cover the fermentation process.

Socially complex resources are present through the company's close relationships with its customers. The company promotes its process largely on a relationship basis. It usually engages in dialogue with the potential beneficiaries of the process, such as people with existing butanol and bio-butanol plants in China, entities with sugar mills in the company's key markets, ethanol plant owners in the U.S., and also end-users of butanol. The company focuses on establishing ***long-term partnerships*** with customers by working closely with them. It transfers its technology through licensing and also offers customer support onsite. One of the company's core values centres on its ability to ***collaborate with its partners***. It is very well reflected in the company's partnership initiatives spanning across the whole value chain of the process. It not only requires advanced technology to set up these partnership, but also substantial amounts of social engineering.

Concerning ***resource interrelatedness***, the company closely inspects the existing facilities at the customer sites. The company tries to understand the possible engineering solutions that could be implemented at the site. It aims to achieve the most optimal economy of scope between the customer's existing resources and a certain configuration of the technology.

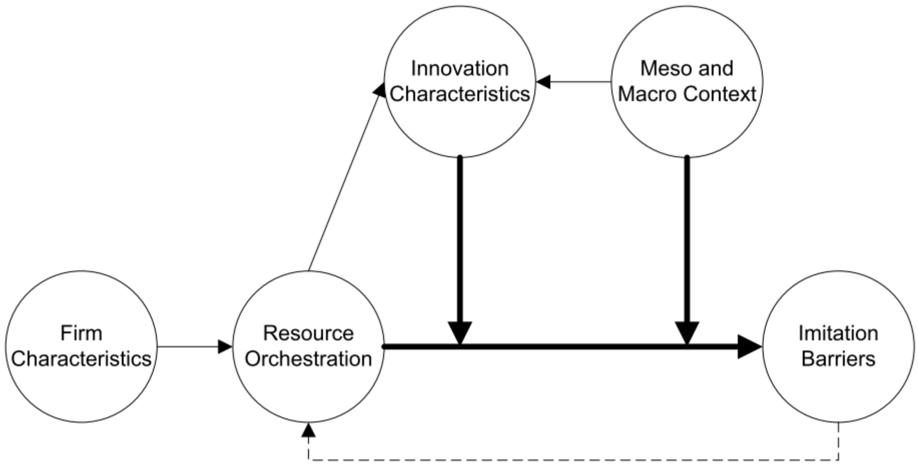
Preferential market access originates from ***buyer evaluation cost*** and ***buyer switching cost***. The company first installs the first generation fermentation process which is relatively easy to commit to. Once the plant starts running smoothly and profitably, it is easier to retrofit the advance fermentation process onto it. This way, buyer evaluation costs are lowered, because they can first get used to less radical technology. Substantial buyer switching cost arise when a customer's plant has the first technology of the company installed. It has to learn how to use it, adjust its purchase competencies and other peripheral plant layout features. Moreover, the prospect of having the more advanced technology installed at the plant, provide significant opportunity costs, in case of switching.

Pre-emptive actions in the form of ***pre-emption of inputs*** and ***know-how*** are also present. The company establishes commercial deals with each customer site. This way the company is effectively pre-empting existing production capacity, which other competitors can no longer access. To implement the technology on the short-term, existing production capacity is needed. Pre-emption of know-how is achieved through the company's patents.

Finally, ***distinct managerial capabilities*** arise from ***firm-specific knowledge*** possessed by managers and development of ***strategic complexity***. The founder of the company holds a PhD degree in biochemical engineering and a BSc in microbiology. He has worked on various aspects of the butanol fermentation process for past twenty years. With regards to the development of strategic complexity, the company realigned its commercialisation strategy to focus on re-commercialising existing ABE fermentation facilities, in 2007. It speeded up its efforts in taking its butanol fermentation process to the market. The initial strategy adopted by the company is to commercialise the first generation fermentation process at a scale and then retrofit the advanced fermentation on to it. This is a low-risk strategy for customers. This strategy will help customers turn their existing unprofitable plants into profitable ones. The company will then aim for improved performance and the production of higher value derivative products. This approach quickly ties customers to the company and prepares them for more drastic measures.

To conclude the most important relationships in this case were: the influence of the firm's resource orchestration on the created imitation barriers, through for instance the acquisition of patents and availability of licenses; the mediating influence of the innovation characteristics on the relationship between resource orchestration and imitation barriers, through patentability of the innovation and possibility to implement the innovation gradually; and the mediating influence of the company's meso context on the relationship between resource orchestration and imitation barriers, through the presence of already existing idle fermentation production capacity to which the technology can directly be implemented.

Figure 16: Relationships model case 6



4.1.7 Case 7: Platform manufacturing, "customer contributions of both resources and capabilities from design until manufacturing"

This company developed an online marketplace for everyone to click to make real things. The New Zealand based firm employs over ten employees and was founded in 2008. It can be characterised as an adhocracy. The current process innovation provides an online place where creators, designers, digital fabricators, materials suppliers and buyers can meet to make (almost) anything, based on digital design software and innovative fabrication methods such as 3D-printing, laser cutting, and CNC routing. The company allows designers, fabricators, material suppliers and buyers to find one another and co-create in a manner that is efficient, transparent and mutually profitable. The concept allows for many new business models employed by various companies that make use of the concept, from artistic designers, to clockmakers and architects.

Although some functionalities of the new process are quite advanced, the technological change from a producer's point of view is relatively low. The increased benefit from a customer's view, however, is high. This innovation, therefore, can be characterised as an application innovation. The innovation is new to the world, according the company's founders. It was the result of market pull. In the early 1980's New Zealand went through a period of major liberalisation of the economy. This lead to a situation where in the early 2000s there were only a few manufacturers in New Zealand. Getting an item or a product manufactured was difficult. The process is successful in that it already generates profit. In four years, the company managed to spread to four continents, featuring manufacturing hubs in various countries, and allowing new businesses to be founded and made profitable based on the platform's concept.

As appears to hold in all customer ***c0-creation cases***, a key factor from the company's meso environment for the development and inimitability of the process concerns the ***presence of participative users*** which are active in the company's user community. Due to the aforementioned lack of production possibilities in New Zealand, these users were incentivised to participate. This context facilitated the co-creation innovation type, which is subsequently responsible for two key imitation barriers, ***social complexity*** of resources and ***preferential market access***.

The ***key resource orchestration activities*** that were conducted with regard to the development of the innovation and generation of imitation barriers are the community building capability, the capacity to closely communicate with users and process feedback to improve its functioning, and development of the online platform facilitating the co-creation.

From a ***cognitive perspective*** only one barrier can be distinguished. The new process allows for a completely new buyer/producer relationship and functioning. At first nobody understood the concept of the process innovation. A big hurdle to take was the proof of concept, as the company was first to organise production in this way. The ***future for this particular process is still uncertain***. Rivalling managers' judgements and choices are likely to display individual degrees of aversion to risk and ambiguity, which might influence their cognitive ability to imitate.

Willingness barriers originate from the ***political context***, and the ***availability of IPR licenses***. The aforementioned lack of production possibilities, due to neo-liberalisation, provided the opportunity for the current process innovation to emerge in New Zealand and will deter potential imitators from other countries, which might face competition from domestic manufacturers. As the platform concept grew and developed further, an additional type of stakeholder emerged from the fabrication hubs that the company organised on different continents. This stakeholder ***licenses*** the concept and storefront from the company for a start-up lump sum-fee and a monthly fee. Then, for each platform order this stakeholder processes, both he and the company get a share of the revenue. This decreases the willingness of competitors to imitate because they have access to the process innovation at a fair price.

Ability barriers are present in various forms. At first the company had the opinion that it had commercialised the technology two years to early. At that time the company defined a careful narrative and it took great patience to bring about the change that the market required for the company to succeed. They were sceptical about the idea that a market by itself would have evolved without them. According to the company's founder "***We have observed other markets, and these markets were clearly shaped by market entrants very heavily***". ***Irreversible investments*** were made during the development of this innovation. With regards to ***time compression diseconomies***, it was important to have at least part of the concept ready as soon as possible, so that the company could interact with customers. The customers then could shape the company's understanding of how the concept was received, and the company could shape the customer's understanding of the concept. This also provided the company with ***experience economies***.

Socially complex resources are present in the form of the company's user base. More specifically, the platform allows designers, fabricators, material suppliers and buyers to find one another and co-create in a manner that is efficient, transparent and mutually profitable. A large number of flexible business cases can be made to work based on the platform's concept of digital transportation of design files and local fabrication of items in production hubs throughout the world. Imitating this user base requires substantial amounts of social engineering.

The platform becomes more attractive to both producers and buyers with increasing user numbers, due to the shared designs and capabilities, thus creating ***communication good effects***. ***Buyer evaluation cost*** are relatively low. It was hard to reach a good level of understanding among the general public, and a lot of people still do not understand the company's concept and the benefits it offers. A famous American technology venue, however, found the platform interesting enough to have the company present at their event. This familiarised a significant amount of potential users with the innovation. Moreover, the community gave voice to any potential disappointments in a very public fashion, such as through Twitter, Facebook, and blogs. The most unhappy community members are those members that send emails expressing their complaints. Successful processing of this feedback results in positive word of mouth, and lower buyer evaluation cost.

In line with other cases, being the first process of its kind and being associated with heavy user involvement, ***generated public attention,*** which cannot be imitated with the same level of resources by competitors, due to ***channel crowding***.

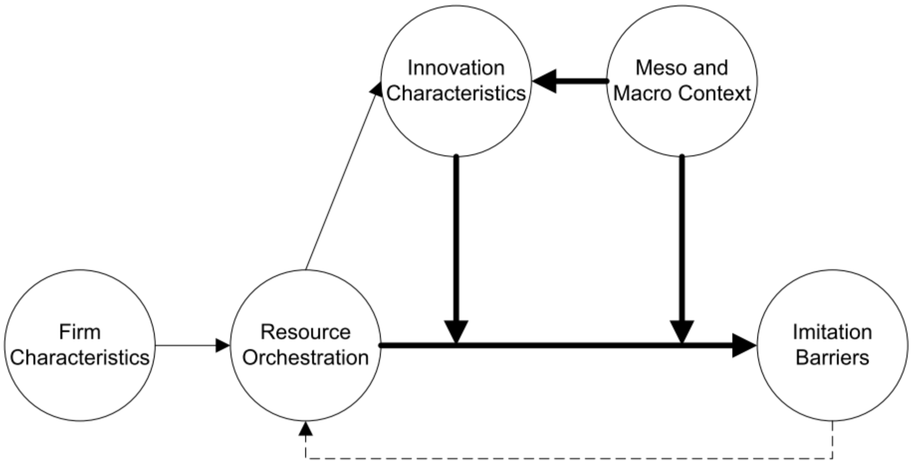
The platform concept incorporates a tool that requires a specific level of skill for people to engage with it. It does not naturally occur to people and requires a new type of thinking. Users need to learn specific things and they need to investment time and energy before they can use it. According to the founder, "***this allows for drawing a parallel to the early computer market, where people would need to learn computer language to use computers. The market in which the company operates is similar to the 1978 computer market, where sellers need to invest in up-skilling potential buyers***". The management says to have always known their endeavour would be a market building exercise. However, they consider themselves to have been naïve on the time it would cost and amount and types of messages to convey for people to "***catch on and get it***". ***Buyer switching costs*** for the user base are high, and deter competitors from possible imitation.

Pre-emptive actions of ***inputs*** and ***know-how*** are also present for the current innovation. By being the first company on the market to commercialise this technology, the company pre-empted technology enthusiasts, innovators, and manufacturers with production capacity, which have already been tied to the community and face a certain ***lock-in***. In line with other cases, know-how was pre-empted through acquired ***patents***.

Finally, distinct managerial capacities are present in the form of ***entrepreneurial vision***. A strong desire and feeling resided within the company's founders that they could and wanted to build the company.

To conclude, the most important relationships in this case were: the influence of the firm's resource orchestration on the created imitation barriers, through for instance the acquisition of patents and availability of licenses; the mediating influence of the innovation characteristics on the relationship between resource orchestration and imitation barriers, the process being co-creation centred and thus based on community participation, again largely mediated the imitation barriers that were created (social complexity and preferential market access); the enabling influence of the meso context for this particular innovation type; and the mediating influence of the company's meso context on the relationship between resource orchestration and imitation barriers, through the presence of users incentivised to participate due to the political context.

Figure 17: Relationships model case 7



4.1.8 Case 8: Leaded glass recycling, "resource deficits, time compression diseconomies and a closing window of opportunity"

This UK based SME has developed a process innovation that allows for the separation and recycling of lead from leaded glass or CRT waste (Cathode Ray Tubes, or old television screens). The company was founded in 2001 and currently employs six people. It can be characterises as an entrepreneurial organisation. The firm and innovation were almost completely funded with the founder's private savings, and money from his family and friends. This person is the full owner of the company.

Key benefits of this innovation are not only that the lead and glass is separated for reuse in new applications, but that the whole process is designed to be environmentally friendly. The process is conducted within a relatively small facility, combining techniques from chemistry, electrical engineering and glass manufacturing.

This process innovation is new to the world and can be considered to be a radical innovation. The technological change from the producer's view is relatively high. Although it is based on existing principles, nothing remotely similar exists. The increased benefit from the buyer's view is significantly high, because the process allows the transformation of hazardous CRT waste into valuable raw material. The development of this innovation was manufacturer dominated, although there was also a clear need from the market for a solution to CRT waste. The founder initiated development after he perceived the need for such a process. The process was largely developed internally from beginning until end. The innovation is successful in that it has already been sold to one customer in the UK and the company will start operating facilities at two customers sites in the USA in the near future.

A key factor from the company's macro environment for the inimitability of this process originates from the ***declining CRT television industry***. When the production cost of LCD technology drops below that of CRT screens, this industry will completely disappear. A ***closing window of opportunity*** is present. This means that the production of input material for this process innovation will end and sustainability of this innovation is only limited. More importantly, however, it means that potential imitators only have limited time to imitate.

The key resource orchestration factors required for development and inimitability of the innovation are the persistence and vision of the founder, the multidisciplinary development team and substantial amount of time that was available for the generation of this process innovation. The process itself is a novel combination of already existing processes and theories. For example, the method of getting the lead to separate from the oxygen is called a reducing process, already stemming from the 19th century. Combined with relatively basic technologies, originating from electrical engineering, glass arts and chemistry in a very specific balance, this allows for the extraction of lead from CRT waste. There are many different factors involved, and if any parameter is set-up wrong, the process will not work. The process demands exactly the right combination of temperature, chemicals, molten glass flow and timing. The final solution runs a very thin line between everything that has been done before. According to the founder, "***this balancing of resources is actually one of the reasons why the process was successfully developed and is so difficult to imitate***".

For this process innovation two types of ***cognitive barriers*** exist. The aforementioned disappearance of the industry producing the required input material for this process (CRT screens) creates significant ***uncertainty regarding the future*** of this technology. Especially if potential imitators currently still have to start the process of development of this technology. To keep the process a company ***secret***, the company uses a very thick ***non-disclosure file***. This became especially important when in 2007, the founder started to employ people within the company. Everybody that has ever seen the process, e.g. customers, universities and employees, had to sign a non-disclosure-agreement that lasts for six years. It is expected that by the time this contract expires, any player that has not already implemented the process will be too late to benefit from the window of opportunity.

One key source of willingness barriers can be identified. ***Institutionalised norms*** in the recycling would prevent established players from thinking outside the box. Traditional glass manufacturing processes would incorporate the use of expensive platinum of which the use in similar (reversely engineered) processes was thought to be inevitable. Traditional manufacturers did not perceive the need to drop this old custom, because they had plenty of financial resources. For the current company, creative thinking was needed to circumvent the use of this high-cost material, which eventual brought them to use stainless steel. This turned out to be more cost efficient while offering the same performance. Furthermore, the owner of the first customer company for the technology stated that "***in the recycling industry big players generally buy small existing companies with a running facility as opposed to purchasing a bit of innovative engineering***". Secondly, according to the founder, "***competitors are unwilling to imitate, because the people that are involved in electronic waste recycling view leaded glass as a burden. For our company to take the problem from them is most attractive, by just buying the CRT waste from the customer. For potential imitators to start a research programme to copy the technology versus the price of just buying one, is just not worth it.***" The money that would have to be spend on developing the equipment, would cost a competitors three or four times the price it would cost to just buy one of the company's furnaces.

Ability barriers for this innovation are rather limited. Although this process innovation is new to the world, the technology is not patented. It is a company secret. An IP lawyer, who had been with the company during the developing years, stated that applying for a patent would be commercial suicide, because the company did not have the financial resources to fight infringement. According to the company's founder: "***A patent is only as strong as the amount of money there is to defend it." Moreover, a patent would still not enable the company to properly defend the invention in foreign countries like China***".

Path dependency in the form of ***experience economies*** and ***irreversibility of investments*** prevent competitors from imitating this process. Development of the current innovation required significant amounts of irreversible investments made over time. It took the company a total of 18 years to conduct all the inquiries, design, scale-up, analysis, experiments and test-runs to optimise this technology. According to the company's founder: "***The most significant barrier for anybody else doing this, is that even if they were to have the basic idea of what our company is doing, which would not be difficult because we are quite open in it, the testing methods and the research work to realise it, would take years and years to conduct. There is not much time to do all this. If you are not running it now already, you will not be able to do it, due to the closing window of opportunity.***" Thus, because potential imitators did not invest in this technology in the past, they will not be able to commercialise the technology in the future.

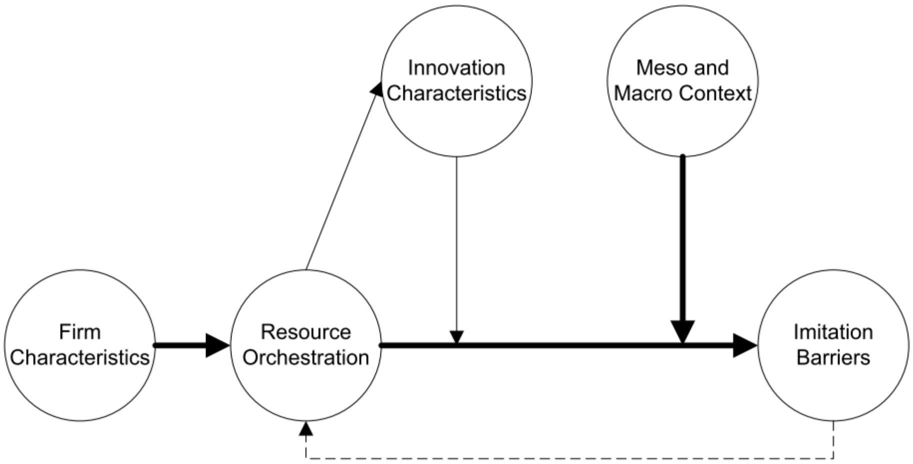
The company seeks to keep the core processes underlying the technology secret. Through ***secrecy*** and NDAs the company deterministically tries to generate and maintain causal ambiguity regarding the functioning of their technology. ***Causal ambiguity*** is also stochastically generated due to the substantial share of trial and error and learning by doing during the development process. This always encompasses a good share of luck, in which the company itself does not even exactly knows why a certain parameter setup works better than another, except that it achieves a better result.

The technology is heavily based on ***distinct managerial*** and ***organisational capabilities***. Many people who tracked the development of the process stated that if the founder would have had a chemical or glass manufacturing background, he would have never pursued this solution. Many critics of this approach have claimed that what the company was trying to achieve, was impossible. The lack of a solution to the problem of CRT recycling was a source of motivation for the inventor to develop this process innovation. The founder can be considered a persistent leader with a clear vision, who keeps generating diverse solutions.

Finally, the company has shown a significant level of both ***producer learning*** and ***organisational learning*** in general. The company deliberately ran the process for a full year to prove that the process is both economically and technically sound. During this year, the company improved the technology and enhanced its own technological understanding.

To conclude, the most important relationships in this case were: the limiting and facilitating influence of firm characteristics on resource orchestration, through respectively resource scarcity and out of the box thinking; the influence of the firm's resource orchestration on the created imitation barriers, through for instance the founder persistence and combination of various technical disciplines; and the mediating influence of the company's meso context on the relationship between resource orchestration and imitation barriers, through the presence of a closing window of opportunity in combination with time compression diseconomies.

Figure 18: Relationships model case 8



4.1.9 Case 9: Copper scrap extraction, "too much emphasis on diffusion instead of development"

This Dutch spin-off company developed a recycling technology for separating copper rich parts from metal scrap. The company was founded in 2008 and can be characterised as a adhocracy. The company was founded as a partnership between a technical university and a venture capitalist firm. The former owns 30% of the shares, the latter the other 70%. The company and process innovation were funded by the venture capitalist and through grants and subsidies from government.

The goal of the clean scrap machine is to extract non-contaminated copper parts from a mix stream of metal scrap. By getting the ferrous scrap completely clean, while concurrently doubling the quantity of copper that can be extracted from the ferrous scrap stream, the company ensures that scrap continues to serve as a vital source of raw materials for both the steel and copper production industries. The new separation technique is able to separate copper from metal scrap by using the concept of magnetism combined with velocity and material density. The material is sorted based on density, shape and magnetic properties. The advantages of this technology are higher copper revenues, higher scrap quality, less hand sorting, consistent quality of outputs and a simple and robust recycling system.

This new process can be considered an application innovation. The technological change from a producer's view is rather limited, because it mainly uses existing principles from the recycling industry. Existing Eddy Current separators are known to use both velocity and magnets to separate ferrous and non-ferrous material. The increased benefit from a customer's view, however, is high. Incumbents from the steel industry have highlighted the increasing problem of copper contamination in steel production. This requires more robust techniques that can deliver a clean, copper-free scrap input for steel production, which the current technology realises. The company therefore can be considered to be the result of market pull. Being a spin-off of a Dutch university, the company had access to an advanced prototype on which the current technology is based. The innovation is successful in that it has already been implemented at several customer companies and has won an innovation award.

No key factors from the firm’s meso or macro environment for the development of the innovation or imitation barriers could be identified. Early involvement of a venture capital firm provided the company with substantial financial resources, but also resulted in pressure on swift commercialisation and resulted in initial failure.

The most important resource activities conducted with regard to the development of this innovation and generation of imitation barriers are: the companies ties with the university that possessed valuable research capabilities and knowledge on the required technical disciplines, the acquired patent on the technology and financial resources to defend it, the availability of time to improve the innovation after initial commercialisation failure and the attraction of an experienced CEO after initial commercialisation failure.

Cognitive barriers for this process innovation might originate from ***inter-organisational conflict***. Although inter-organisational being present within the innovator company does not necessarily imply that this should also occur at an imitator firm, it might occur at an imitator that finds itself in a similar situation. There was substantial conflict or friction between the innovator company’s and university's interest to first improve the technology, and the venture capital firm’s interest to commercialise the innovation as quickly as possible.

Willingness barriers arise from different sources, namely ***institutionalised norms*** in the recycling industry. The recycling business, according to the company’s manager is often considered to be highly conservative when it comes to new technologies, which can partially be explained by the high investments that are required for the machinery. This also has a direct impact on the ability to sell new recycling processes to the industry. According to the company’s CEO, ***“It has been a tough business to pitch new ideas in, and stakeholders noted that it has only appeared to become tougher the last few years”***. This might deter potential imitators from imitating this technology.

Different types of ability barriers are present for the current process innovation. With regards to IPR, the company acquired a ***patent*** on the magnet technology underlying the process. The university professor leading the research activities for this technology is an experienced researcher. Aside from the company's technology, he has patented several of his other innovations. His experience as a researcher and his connections both within and outside the university were prerequisite for the initial development steps and existence of the innovation.

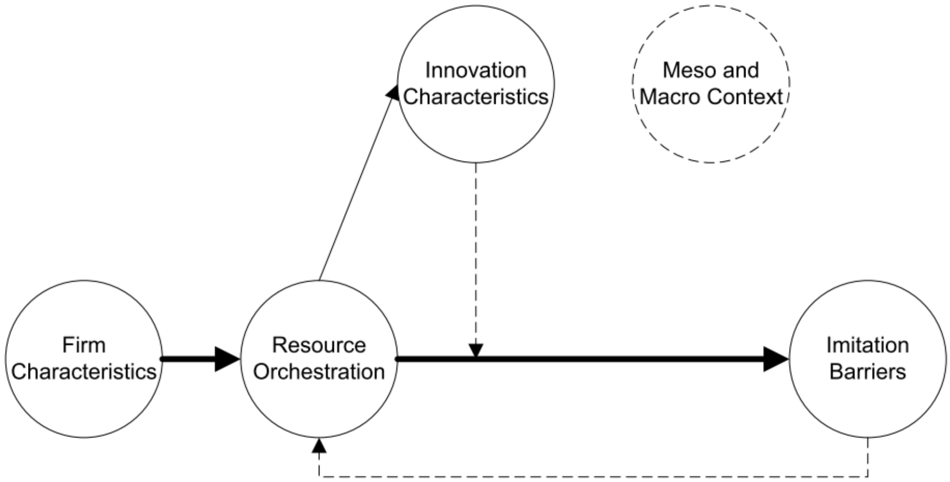
The company experienced the effects of path dependency, in the form of ***time compression diseconomies***, during development of the innovation. The company was too quick to market the new process, due to pressure from the VC company. The CEO acknowledges that “***innovations like these need time to diffuse and that instead of aggressive marketing, fundamental improvements needed to be made to the process***”. After restructuring, the company started to approach potential clients in a much more focused way. By focusing on fewer potential clients, but investing more time in the relationship with them, they managed to make extra sales. Time therefore was an irreplaceable resource.

The company also established ***advertisement and channel crowding advantages*** through the construction of demonstration models, which it did in collaboration with an external manufacturer. The first (of three) external manufacturing companies helped with the basic design of the machinery and produced the first two demonstration models/prototypes with the help of the university. Early realisation of this working demonstration models (only after two years), allowed the company to generate exposure in an early stage of development. In line with other cases, potential imitators might not experience similar exposure due to channel crowding.

The interim manager that was hired by the VC firm after the initial failed commercialisation, had ***firm-specific knowledge*** in the form of 10 years experience in the waste industry. After careful consideration, he concluded that the innovation first needed to be further developed. This manager changed the company's culture and demanded the required changes from the VC firm. The manager subsequently developed a new and complex strategy to foster more sales with a highly focused marketing and sales strategy. By short listing approximately 20 potential clients and subsequently only approaching 5 of those, sales activities became more focused. According to the manager, "***it is much easier to grasp the needs of five companies than it is of as many as 70 at the same time***", which is the number of clients they initially approached.

To conclude, the most important relationships in this case were: the facilitating influence of firm characteristics on resource orchestration, through the spin-off relationship the company had with the technical university; and the influence of the firm's resource orchestration on the created imitation barriers, through for instance the managers firm-specific knowledge and the acquired patent. The innovation characteristics only mediate the relationship between resource orchestration and imitation barriers in that the innovation's content is patentable. The mediating influence of meso and macro context is neglectable, because its negative and positive effects balance each other and were not of direct influence on imitation barriers.

Figure 19: Relationships model case 9



4.1.10 Case 10: In-cell production, "spreading innovation willingly to other companies"

The process innovation in this case was developed and commercialised by a ***large established Japanese multinational*** specialised in printers, scanners and photocopy machines. The company can be characterised as a machine organisation or bureaucracy and is publically listed. Due to the sheer size of the firm, the innovation could be ***funded with internal cash reserves***. The company does not sell the process, but has willingly diffused it to other Japanese manufactures, without commercial aims.

The process innovation in this case entails a change in the company's production logistics. Conventionally, a conveyor belt would transport a product across different stages of assembly, with workers placed along-side the conveyor belt, repeating their task within the assembly process for every unit passing their work station. In the current case, this has been replaces by a new "in-cell" based process, wherein a small number of workers assemble units from start to finish. As a practical implication of the cell-based process, the cart pulling method uses carts as a transport tool. The unit to be assembled is loaded on a cart, and the cart is then pulled or propelled along different work stations for different assembly operations.

The process innovation in this case can be considered ***new to the world***. The process generates massive efficiency increases, but is only characterised as an ***incremental process change***. Although the innovation provides substantial cost and time savings, it does not provide a significant increased benefit to customers nor a substantial technological change from the producer's view. Because the company is a large multinational, employing over 100,000 people, the company's permanent R&D department had sufficient resources and capabilities available in-house to develop this innovation independently from external stakeholders, from beginning to end. The technology was developed as a result of ***technology push***. No customers or external parties were involved with development. The innovation is considered a success, due to cost savings, and has already been diffused to other large Japanese manufacturers, however without commercial aims.

In this case there were some meso and macro contextual factors that influenced development of the innovation, but they did not have direct effects on the generated imitation barriers.

The ***key resources*** that were deployed during development were the required funding, which was available internally; the company's existing computer-aided design tools and simulation models; the engineering staff residing in the company's permanent R&D department; the company's existing information infrastructure, which helped implementation by communicating the change to employees, getting them involved and having them provide feedback to the engineers based on their user evaluation of the new technology. Especially close communication with production floor workers was essential, because there was some initial resistance to the innovation.

The ***key capabilities*** that were deployed and enriched during development comprise the R&D department's engineering talent, getting production floor workers involved and having them provide usable feedback for the R&D department. The engineering talent of R&D workers was responsible for constructing prototypes and allowed testing and analysis in a controlled setting. Based on this input, the process could be enhanced. To get the production floor workers involved, the company first had to overcome resistance to the process among the workers by clearly communicating the added value of the innovation. The capability that the company really pioneered with is the ability to assess existing production facilities and implement customised in-cell production systems at those sites. The company not only implemented in-cell production at several of their own production sites, but also assisted four other large Japanese electronics manufacturers in adopting this technology.

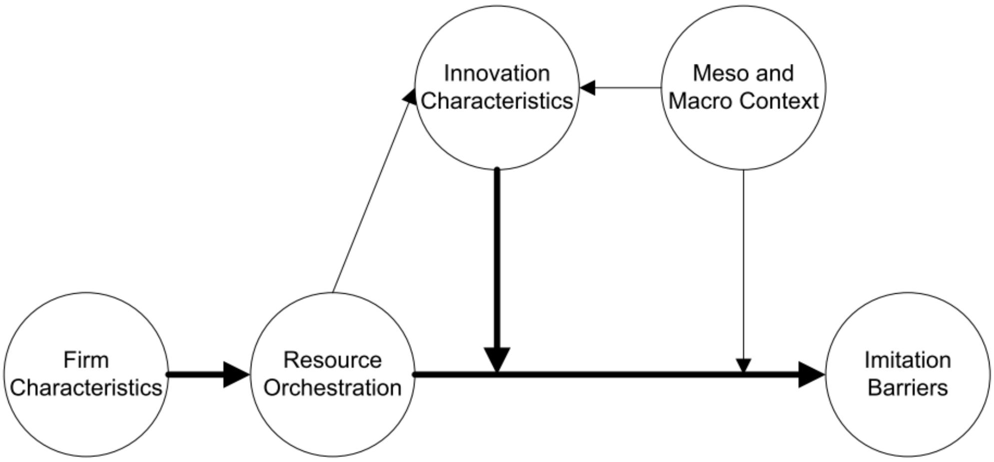
Key to the generation of imitation barriers for this process innovation appears to be that the ***technology is not underlying the company's business model***, like it does in the cases with start-ups and SMEs. It is only meant to improve the company's manufacturing process and improve flexibility while reducing cost and time. This is probably also why the company was willing to diffuse the process to other manufacturers without setting up a commercial partnership of any kind. They appeared to have no intention of protecting this innovation from imitation whatsoever.

Had the company wanted to protect its innovation from imitation, a few barriers would have been in effect. From a cognitive standpoint, ***inter-organisational conflict*** might prove an imitation barrier. Adopting an innovation that has such a substantial influence on the manner in which employees work, can induce ***resistance towards this change***, as was the case in the current company. The firm overcame this by emitting clear communication through its information infrastructure to the employees and involving them in this change process. Regarding willingness barriers, there is a certain ***complementarity in valuation***. Due to the particular market demand and nature of the product being manufactured (flexible and quickly changing demand), the current process innovation turned out to be more efficient than the old conveyor belt technology. Without these particular complementary factors, a competitor ***might not be willing to imitate*** this technology.

From the ability barrier domain, ***producer learning*** is the most viable source for inimitability. An established player like the current company already has substantial experience with manufacturing high quality products in very high volumes. This experience was beneficial to the development of this innovation. ***Asset mass efficiencies*** were also present through the permanently active R&D department. The company already developed, managed and implemented several process innovation internally in the past. Because the company (if it had refrained from willingly diffusing the innovation to other companies), only had to implement the innovation internally to reap its rewards, ***causal ambiguity*** would have been significant. This facilitates secrecy better than selling the process in the form of a machine or facility to all interested customers. Finally, because the process innovation substantially decreases energy consumption, it provides the company with a good opportunity to communicate a greener image to its customer base. In combination with being the first company to commercialise such a type of innovation, this generates significant ***advertising exposure***. Potential imitators will not be able to match this with similar resources, due to ***channel crowding***. This is especially key to a multinational, whose reputation/image is worth millions of dollars.

To conclude, the most important relationships in this case are summarised. The firm characteristics clearly influence resource orchestration. The multinational firm had substantial amounts of internal cash reserves to fund the innovation and a permanent R&D department. Resource orchestration influences the innovation characteristics, because it eventually determines what the innovation looks like. Innovation characteristics are also shaped by contextual factors through laws and customer preferences for greener products. Finally, the influence of resource orchestration on the created imitation barriers is mediated by the innovation characteristics and contextual factors. The innovation's characteristics, like its value to the company mediated the imitation barriers that were created, for instance not acquiring a patent on it and diffusing it willingly to other manufacturers. Contextual factors, like customers' preference for greener products, influence the effect that advertising can have as an imitation barrier, but was not key in this case.

Figure 20: Relationships model case 10



5 Cross-case analysis

Cross-case analysis will start with examining whether certain imitation barriers are predominantly absent, present or immeasurable across all cases. Subsequently, the researcher aims to identify apparent patterns between cases by identifying within-group similarities and couple these with intergroup differences. Based on these patterns, the different cases can be grouped. Then, these within-group similarities and intergroup differences will be described in more detail. Finally, it is checked whether this apparent grouping is valid, by listing the subtle differences within each group.

5.1 Overall absence, presence and measurability of imitation barriers

With regards to cognitive barriers, in general these were rather hard to identify. All of them were present at least in one case, but time lags between cause and effect, as a sub-category of causal ambiguity could not be specifically identified as a source of inimitability in most case. This is mainly because the respondents themselves were not able to mention the exact periods between certain causes and effects. Furthermore, it was hard to determine whether, if present, this would pose a insurmountable obstacle for competitors.

Secondly, inter-organisational conflict appeared to be immeasurable from an innovator's perspective. Even if, in some cases, inter-organisational conflict was present within the innovator company as a result of resource orchestration, it does not necessarily have to occur within an imitator firm.

Finally, the presence of causal ambiguity in some instances, both with regard to cognitive and ability barriers, was hard to determine. In case of deliberate secrecy, where a company did not have the money to acquire and defend a patent, this was easy. Especially the use of NDAs were good indicators of secrecy and thus causal ambiguity. Deterministically generated causal ambiguity could be identified in case a company managed to disclose largely non-enabling information in its patents. This requires both legal and technical expertise and clearly inhibits potential imitators from seeing cause and effect. Stochastically generated causal ambiguity mainly originated from trial and error research and learning by doing, in which there are so many "causes" that it is hard to observe which one led to the desired "effect".

Concerning willingness barriers, environmental instability was only explicitly identified as a barrier in one of the cases. This case concerns the only technology that focuses on a downward or disappearing industry, which generates substantial uncertainty. Strangely enough, in this particular case the environmental instability represents the strongest imitation barrier, as identified by one of the respondents.

Finally, with regard to ability barriers, several types were significantly underrepresented. Trade secrets or NDAs were only explicitly mentioned in one case and appear to be absent if IPR is present or in case of non-technical process innovations.

With regard to path dependency, irreversibility of investments was particularly hard to identify. This again has to be largely determined from the competitor's perspective and therefore was hard to establish. Furthermore, because investments in general have a largely irreversible nature, it was hard to determine where irreversibility was of particular influence on inimitability. This was for instance the case with the production platform innovation, in which the company shaped the new market around it by its early presence.

Asset mass efficiencies (success breeds success) from the path dependency category and communication good effects (network externalities) from the preferential market access category, appear to be interlinked. Based on analysis it can be determined that the presence of communication good effects implies the presence of asset mass efficiencies.

Product complementarities, as a form of establishing preferential market access, was only identified in one case. This is due to the very narrowly chosen definition of this concept. Some cases did have complementarities or synergies, but these were allocated under either complementarities in valuation or economies of scope. Furthermore, it was hard to determine whether advertisement and channel crowding were providing particular imitation barriers, as it appears that all "new to the world" innovations benefit from this type of barrier.

Concerning pre-emptive actions, all three manifestations were widely present. Furthermore, pre-emption of knowhow appear to be always present in the case of patents. Patents, however, are not a necessary condition for pre-emption of knowhow to be present. Exclusive contracts turn out to be a good alternative manner of pre-empting both knowhow and inputs.

No specific subtypes of distinct organisational and managerial capabilities were predominantly absent or present.

5.2 Within-group similarities coupled with inter-group differences

When comparing the ten different cases with each other based on resource orchestration, imitation barriers that were generated and/or process innovation context, four different groups of cases emerge. First of all, a clear division can be made between the so called soft and hard innovations.

Soft innovation refers to process innovation that can use of technology, but are not novel due to this technology. These application innovation are novel because they change the traditional manufacturing paradigm and the producer and consumer relationship. Three process innovations cases belong to this soft innovation group and are all novel because they are based on co-production and/or co-creation practices. The companies in those three different cases all apply the concept of co-creation or crowdsourcing slightly different, but they share largely similar resource orchestration strategies and imitation barrier types.

Hard innovation refers to process innovation that are more based on the development of a new technology, machine, facility or element in a production facility. These process innovations are novel because they are based on new techniques or combinations of existing techniques in a new context. The different nature of these innovations (opposed to the first three) has clear implications for the resource orchestration strategies and generated imitation barriers, in this research. A subdivision can be made within this group of seven cases. Two cases describe process innovations that were largely developed internally and were developed within an existing multinational under relatively tight innovation management. Three cases concern processes that were developed with the aim of external commercialisation or sales of the machine/facility and which were largely developed by SMEs (e.g. start-up, spin-off or newly found joint venture) in close collaboration with external stakeholders. The last two cases are the odd ones out and are grouped based on the fact that they both were largely developed internally and commercialised independently by SMEs.

Thus, four groups of cases can be identified that display within-group similarities and intergroup differences. Each group is described below and is consolidated in a relationships model that results from combining the respective models displayed at the in-case analysis for each case.

Application innovations with resource orchestration through customer co-creation (Car construction, 3D printing & Platform manufacturing cases)

The so-called co-creation cases are similar in that they all have a clear emphasis on community building regarding their resource orchestration and also derive particular imitation barriers from this. All three cases depend on specific physical resources in the form of technology to communicate with their community and enable them to interact with each other, create output and exchange output. These physical resources encompass ICT platforms, design tools and manufacturing equipment in possession of customers.

These resource orchestration strategies and the nature of the innovation lead to particular ability barriers to imitation that all three cases share and lack. None of the cases possesses intellectual property rights on the core element making the process novel, due to the nature of the innovation (soft).

For all three cases socially complex resources in the form of the highly involved user base form the single most important imitation barrier. This user community is also associated with another ability barrier in the form of preferential market access. All three cases display communication good effects, or network externalities for its users. With more users in the community, more capabilities and resources are shared, and more new users are attracted, which again will increase the capability and resource pool at the company's disposal. This way a snowball-effect is created with which potential imitators can only hope to catch up.

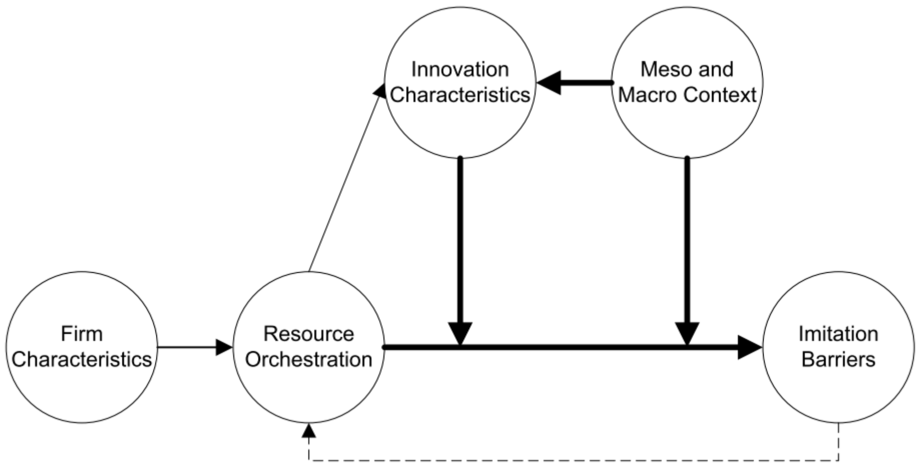
Buyer evaluation cost for all three cases are kept relatively low due to the inclusion of technology enthusiasts and opinion leaders in the user base. These opinion leaders, according to theory (Rogers, 1962), have a large influence on the impression of the early and late majority. Furthermore, because the opinion leaders benefit from a larger community they have an incentive to communicate their positive experience regarding the company's process innovation. This creates synergy with the advertising and channel crowding barrier. All three companies were the first in the world to commercialise their respective process, and therefore acquire advertisement and public exposure easy because they are still interesting and fresh. Potential imitators will face increasing channel crowding and will not be able to reach the same levels of exposure with equal resource levels.

All three cases benefit from buyer switching cost, which are generated because the process innovations require the user base to make an investment, either in the form of time to learn how to use the company's tools and make designs, or in acquiring the required technology to enable co-creation. Once a user has chosen to become a member of the community it will not change very easily in case a rivalling process emerges from an imitator.

Finally, although not unique for this group of process innovations, an entrepreneurial vision of the managers is present within each case. This appears to be a prerequisite for successfully commercialising such paradigm changing innovations. These distinct managerial capacities are more important in cases where a process innovation was developed by a start-up, spin-off or other SME, as was the case in this group.

To conclude, this group of three cases shows particular similarity with regards to the relationships indicated by the thick arrows in the model displayed below. The particular innovation type, being co-creation centred, is largely enabled by the presence of participative customers from the company's meso context. This particular innovation type mediates the relationships between resource orchestration and imitation barriers in that it is associated with the creation of socially complex resources and preferential market access. The companies' meso context also mediates the relationship between resource orchestration and imitation barriers, through both substantially increasing the resources that can be orchestrated by the company (by user participation) and simultaneously facilitating the most important source of imitation barriers for these cases (the community). To a lesser degree the firm characteristics like its founders' entrepreneurial vision always influences resource orchestration. The same goes for the influence of resource orchestration on the innovation characteristics, as these always are most influential in determining what the innovation looks like. Finally, imitation barriers like communication good effects are responsible for increasing the community and thus the resource orchestration possibilities open to the company.

Figure 21: Relationships model group 1



Radical innovations with resource orchestration in close collaboration with suppliers
(Textile dyeing, Butanol fermentation & Metal sorting cases)
These cases are similar in that they all show strong resource interrelatedness in the form of economies of scope, as a result of the combined resources and capabilities of suppliers (or customers that are simultaneously customer and supplier, in the butanol fermentation case) during development and commercialisation. In two cases a variety of suppliers of key components of the two machines played an essential role in the development of the technology. First of all, it takes substantial coordination capabilities to integrate the different supplier contributions with the core technology, developed by the company itself. Secondly, both companies established exclusive contracts with suppliers of crucial parts of the technology.

In the butanol fermentation case, the company creates a joint venture with, or licenses its technology to owners of idle ethanol plants and facilitates the restart of the production capacity by implementing a individualised version of the core technology developed by the company. The company thus effectively pre-empts scarce butanol production capacity, needed to implement this technology on short term.

Thus, through close collaboration with suppliers, the companies also effectively pre-empt inputs in the form of either machine parts or production capacity. Because the pre-empted inputs originate from either exclusive contracts with technology leaders in their respective industries or joint venture constructions with limited available global production capacity, potential imitators are significantly hindered.

Beside these two most important and distinct imitation barriers, the three cases in this group also share other barriers. Regarding cognitive barriers, aforementioned complexity and interplay of resources during all three development procedures deter competitors from recognising what to imitate.

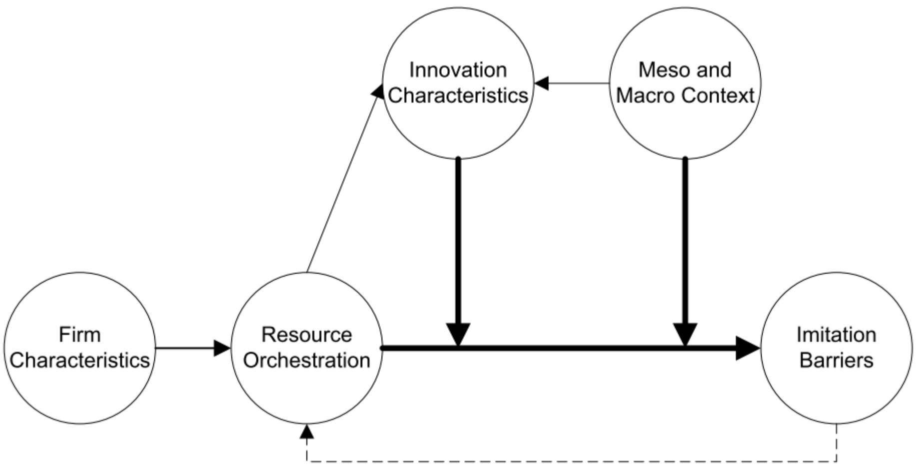
Concerning willingness barriers, institutionalised norms from industry might significantly discourage competitors from imitation. All three cases commercialised an innovation either in an industry that is very conservative and change aversive or partially based on a method that proved unsuccessful in the past. All three case industries: textile processing, recycling and fuel production, were characterised as highly conservative. Furthermore, one technology makes use of some form of liquid density separation, which is associated with negative side-effects from historical endeavours. The other one aims to restart non-economical production facilities, which were disregarded by industry in the past.

With regards to ability barriers, all three companies acquired patents on their process innovation and thus also effectively pre-empted know-how.

Finally, because all three companies are relatively small firms with less than 40 employees, management had a big influence on development and commercialisation of the new process. Distinct managerial capacities in the form of firm-specific knowledge within managers therefore poses imitation barriers in all three cases. All three companies had a manager as technological champion present during development of the innovation, of which two had a PhD degree in the underlying technical discipline. At two out of three cases an experienced commercial manager with distinct capabilities was present.

To conclude, this group of three cases shows particular similarity with regards to the relationships indicated by the thick arrows in the model displayed below. The particular innovation type, being radical and thus technologically based, mediates the relationships between resource orchestration and imitation barriers in that it is associated with acquisition of patents and the possibility to outsource large parts of development to external parties. The companies' meso context also mediates the relationship between resource orchestration and imitation barriers, through both substantially increasing the resources that can be orchestrated by the company (by supplier collaboration) and simultaneously facilitating the one of the key sources of imitation barriers for these cases (the pre-emption of inputs through exclusive contracts). As was the case with the previous group, other, lesser relationships can be observed between the different concepts, indicated with a thin arrow. Imitation barriers like the acquisition of patents, for instance, have a clear effect on subsequent resource orchestration, because it incentivises the firm to make additional investments due to better appropriation possibilities.

Figure 22: Relationships model group 2



Internally commercialised innovation by multinationals through internal resource orchestration
(In-cell production & Rare earth extraction cases)

These cases are similar in that they both encompass process innovations that were largely developed and commercialised by established industry incumbents under relatively tight innovation management. This particular innovation context strongly influences resource orchestration and subsequently the generated imitation barriers.

With regards to cognitive barriers to imitation, complementarity in valuation and inter-organisational conflict were present within both cases. In the In-cell case, due to the particular market demand (highly individual and strongly changing) and nature of the product being manufactured, the current process innovation turned out to be more efficient than the old technology. In the other case, complementarity in valuation originated from a related process the company already developed and operated. The company already performed the "***forward process***" of manufacturing phosphate precursors. The resulting rare earth material from the current process could be used as input material for some of the company's other production processes. Furthermore, 90% of the technology is made out of recycled components and tools and part. Without these particular complementary factors, the technology change might not have been realised by both innovators. Furthermore, without these complementary factors, the technology might appear less useful for potential imitators.

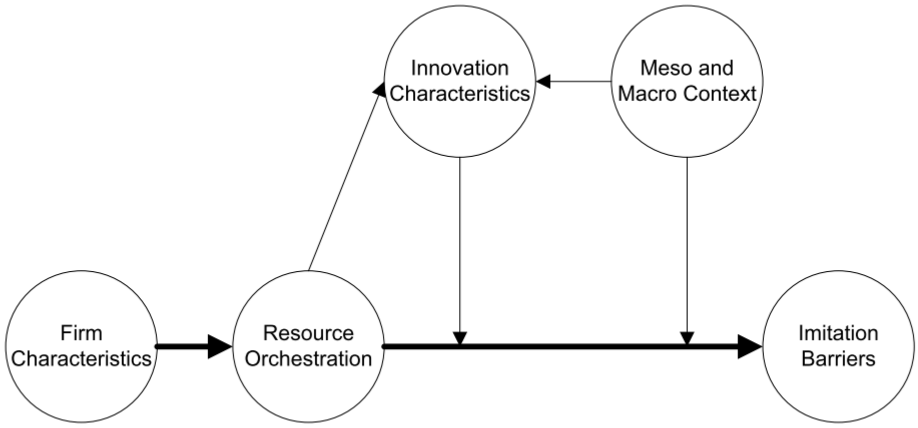
Inter-organisational conflict in the In-cell case was present in the form of initial resistance to the implementation of the new innovation among operating personnel. It proved to be very challenging to design an optimal manufacturing layout. Repeated practice runs and trial-and-error tests, however, allowed the company's engineers to resolve all encountered issues. In the CFL case, recycling of hazardous waste required employees from different disciplines to cooperate. Chemists are familiar with encountering barriers in communication with other specialists. When chemists communicated with recyclers, they faced the problem that recyclers are not familiar with the chemical names of certain materials and processes. When they have to talk to an external design institute, they again have to adapt their language and jargon. Inter-organisational conflict resulting from employee cooperation was only observed within these two cases and appears to be associated with the size of both companies.

Concerning ability barriers, asset mass efficiencies, advertising and channel crowding and causal ambiguity could be observed in both cases. Path dependency in the form of asset mass efficiencies was observed in both cases based on the permanently present R&D departments of both large companies. Furthermore in the CFL case, the company already had the assets and knowledge to develop the forward approach.

A surprising result, with regard to the advertising and channel crowding barrier, arises because both companies only commercialise the respective technology internally. In these cases, advertising and channel crowding do not form ability barriers, but rather willingness barriers. Because both process innovation are sustainable and environmental friendly and both companies were first to develop and commercialise the innovations in their respective industries, they generated positive exposure among the general public and improved their image. This will not lower the ability of competitors to imitate, but it will lower the willingness of certain potential imitators.

Both process innovations were commercialised internally, therefore causal ambiguity was created because it makes analysis of the cause-effect relationships for potential imitators significantly harder. These are the only two cases in the sample in which the technology can be properly defended from corporate espionage. Whether this causal ambiguity is created deterministically or stochastically is hard to define, because it can be a side-effect of the decision to commercialise internally. Finally, distinct managerial capacities do not have a significant presence as imitation barriers in both cases. This appears to be directly associated with the vast size of both companies.

Figure 23: Relationships model group 3



To conclude, this group of two cases shows particular similarity with regards to the relationships indicated by the thick arrows in the model displayed above. Only the relationships between the firm characteristics and resource orchestration, and between resource orchestration and imitation barriers were key in both firms. Both firms being large multinationals, offers them substantial internal resource orchestration possibilities, with which they were largely independently able to generate most imitation barriers.

Independently commercialised innovations by start-ups through internal resource orchestration *(Leaded glass recycling & Copper extraction cases)*

These cases are similar in that they both encompass recycling processes that were largely independently developed and commercialised within start-up companies. These two cases are the odd ones out, because they do not clearly show similar traits concerning imitation barriers as a result of resembling resource orchestration.

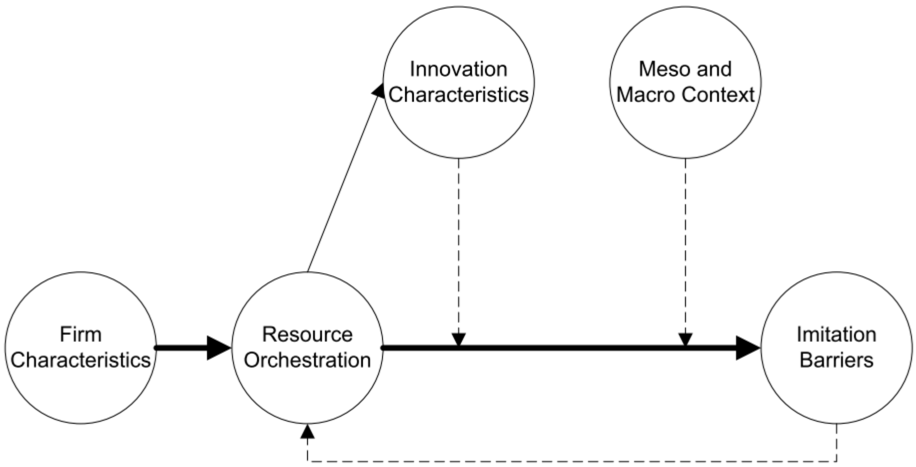
Both cases, however, do show some resemblances that distinguish them from the other cases in the sample. No similar cognitive barriers were generated within both cases. Willingness barriers, however, were generated in both cases in the form of institutionalised norms. Both companies operate in the waste recycling industry. This industry was characterised by both companies as being rather conservative. Industry players do not like change and are risk aversive. The institutionalised norm might discourage potential imitators.

Ability barriers were observed in both cases as path dependency, resource interrelatedness and distinct managerial capacities. Path dependency in the form of time compression diseconomies was observed in both cases. In the Leaded glass case, these diseconomies showed through the company's success. Although various industry players claimed that it was impossible to develop a solution to CRT waste, through learning by doing and trial and error, the company managed to come up with a solution. There was no real substitute for the lapsing of time, because a large variety of parameters needed to be tested in different setups of which the results needed to be inserted as inputs for subsequent tests. According to the company's founder, the required time in combination with the closing window of opportunity (referring to the end of the CRT-screen industry) poses the key barrier to imitation. In the copper extraction case, the venture capital firm was pushing too early for commercialisation. As a result, not enough time and money were put into further R&D, which eventually led to failure and dismissal of the first management team.

Both companies faced difficulty or challenges in balancing their resources in order to successfully develop and commercialise the respective processes. The copper extraction company especially experienced difficulty in balancing its financial and human capital resources among R&D activities and marketing and sales activities. The first management team, due to pressure from the VC firm, put too much emphasis on marketing and sales too early and burned most of the substantial budget on those activities. The results was that the technology was not developed far enough to convince potential buyers. The technology the leaded glass recycling company developed is a result of the mixture of a variety of different technical disciplines. This required substantial amounts of coordination among the different R&D experts within the team and testing and experimenting to reach the right balance of process parameters. As the manager stated: "***The company teeters on the edge of many different technologies. We were not bound to business as usual like companies that specialise in chemical processes or businesses that do smelting only***".

Distinct managerial capacities were present in both cases through firm-specific knowledge possessed by both managers, complex strategy development by one of the managers and entrepreneurial vision of the other. Success of both cases depended heavily on the firm-specific knowledge possessed by managers. These resource orchestration configurations and corresponding imitation barriers, however, are not unique for this group, but are widely observed across all but the multinational group. Finally, IPR (patent and a trade secret) and resulting pre-emption of know-how can be observed as ability barriers in both cases, although these are not unique to this group.

Figure 24: Relationships model group 4



To conclude, this group of two cases only shows particular similarity with regards to the relationships indicated by the thick arrows in the model displayed in figure 24. Only the relationships between the firm characteristics and resource orchestration, and between resource orchestration and imitation barriers were key in both cases. Both firms experienced limiting and enabling effects on resource orchestration as a result of their firm characteristics. In the Copper extraction case the innovation characteristics had a mediating influence on the relationship between resource orchestration and imitation barriers, and in the Leaded glass recycling case the firm's meso and macro context had a mediating influence on that relationship.

5.3 Listing of subtle differences within case pairs/groups

Application innovations with resource orchestration through customer co-creation
(Car construction, 3D printing & Platform manufacturing cases)
All three cases in this group conducted co-creation in a different manner, without having significantly different results on the generated imitation barriers. In the car construction case the user base does not participate in all activities of the production cycle, only design and some construction activities. The company is still responsible for substantial amounts of physical and human capital resources. In the platform manufacturing case, the user base is responsible for all steps of the production cycle. Here, the company contributes fewer physical and human capital resources to the process. In both cases, however, the whole company and its business model are build around the user base and co-creation activities. In contrast, in the 3D printing case, co-creation and thus the applied process innovation was born out of necessity and only implemented temporary and to take care of an emergency. As a result, the process innovation is less valuable to the company, and subsequently potential imitation is not so much a threat. The process innovation can be seen as a sort of flexibility option facilitated by the 3D printing technology, a preceding innovation developed by the company.

Some other differences with regard to imitation barriers originate from the company's specific operating context. For the platform manufacturing case, political institutions pose imitation barrier, for the car construction case the institutionalised norms of industry.

Finally, at all three cases several manifestations of path dependency can be observed. Asset mass efficiencies, due to the snowball effect in the form of network externalities or communication good effects, were observed in all cases. The platform production case and car construction case also displayed irreversibility of investments. The platform production company changed its market by being the first participant in it. The founder indicates that "***they were are sceptical about the idea that a market by itself would have evolved without them***". They observed other markets, and these markets were shaped by participants very heavily. Thus, the new market was shaped around the company. The car construction case benefits from irreversibility of investments, because potential imitators from the conventional, mass production, car industry first need to earn back their investments made in mass production models and lines, before they will attempt mass customisation.

Radical innovations with resource orchestration in close collaboration with suppliers
(Textile dyeing, Butanol fermentation & Metal sorting cases)
A significant difference between the three cases with regard to imitation barriers is the moment at which the barriers were generated. All three companies generate barriers through close collaboration with suppliers, but in the butanol fermentation case, the barriers are generated during commercialisation, while in the other two cases they are generated during development. During development, the innovation is less exposed to potential imitators and the risk of potential imitators circumventing the barriers is lower. In the fermentation case, however, potential imitators still have to come up with the required technology before they could possibly start to tie suppliers of idle ethanol production capacity to them.

Another difference is that in the fermentation case, the customers act simultaneously as suppliers of scarce resources (production capacity). In the other two cases, specialised machine component suppliers facilitate pre-emptive imitation barriers, through exclusive contracts.

Furthermore, two out of three companies (Metal sorting and Textile dyeing) originated from a mother company, respectively through a joint venture and spin-off, with substantial specific industry expertise. Both companies derive firm-specific knowledge of managers from these mother companies. Moreover, key elements of the technology were derived from the mother company's efforts, respectively a patented magnet system and working prototype.

Finally, the Textile dyeing and Butanol fermentation cases both created strong preferential market access barriers, opposed to the metal sorting case. The company in the textile dyeing case did this by commercialising their new process through an influential launch customer and by partnering with large sports fashion labels. This way buyer evaluation cost were lowered and advertising and channel crowding benefits were generated. The Butanol fermentation case did this by implementing their technology at customer sites in two phases. The company first installs the first generation fermentation process which is relatively easy to commit to. Once the plant starts running smoothly and profitably, it fits the advance fermentation process onto it. This way, buyer evaluation costs are lowered, because they can first get used to less radical technology. Substantial switching costs arise when a customer plant has the first technology of the company installed. It has to learn how to use it, adjust its purchase competencies and other peripheral plant layout features.

Internally commercialised innovation by multinationals through internal resource orchestration
(In-cell production & Rare earth extraction cases)

With regards to the nature of the innovation, both cases differ slightly. In the in-cell case, the company was able to adjust an existing production method drastically, by changing the manner in which the operators interact with the production line. This way, the same product is being made, but with more flexibility and efficiency. In the Rare-earth extraction case, the company also largely relied on existing technology. It took existing equipment from some of its other production processes and combined these to come up with a completely new production process.

Surprisingly, in the In-cell case the company helped to diffuse the process innovation among other large Japanese manufacturers without charging any compensation. This clearly discards the effectiveness of any build imitation barriers. In line with these events, the company did not patent their invention. The technology was, however, not diffused to direct competitors of the company, e.g. companies in the same industry. In the Rare earth extraction case, the company filed for patents in order to appropriate its R&D investments. The company is only commercialising its technology internally and does not want it to spread to other companies.

Because the rare-earth extraction technology is based on more different disciplines and principles, it combines a larger variety of capabilities and resources, generating imitation barriers like: complexity and interplay of resources, socially complex resources and balancing of resources, that the in-cell case lacks.

Inter-organisational conflict was observed in both cases, but originated from different sources. In the in-cell case, inter-organisational conflict originated from resistance among operating personnel that had to work with the new technology. Whereas, in the rare-earth case, conflict originated from the cooperation between specialists from different disciplines and with different backgrounds.

To conclude, both companies have roughly similar approaches of developing an innovation, e.g. tightly managed predetermined innovation cycles, with permanent R&D and legal departments. Both companies, however, come to some different imitation barriers, due to purpose and perceived value of the innovation for the respective company. This is why in the Rare-earth extraction case, the variety and strength of imitation barriers is significantly higher than in the In-cell case.

Not all process innovation can be considered to be equal. The value of the innovation and importance of the innovation for the company has a clear effect on the imitation barriers that are created. This appears to apply to process innovation in particular, because process innovation are generally more widely applicable than product innovations. The In-cell case proved that one particular process innovation can be applied across different industries. When an innovation is beneficial but not part of a firm's unique selling point or core competence, imitation barriers are less relevant and thus apparently not consciously created.

Independently commercialised innovations by start-ups through internal resource orchestration
(Leaded glass recycling & Copper extraction cases)

Although both cases have IPR as ability barriers in place, they do not make use of the same types of intellectual property rights. The Copper extraction case did apply for and got a patent granted on its technology. The professor from university that was highly involved with development had experience with patenting and acquired the current patent. Furthermore, the company had access to the required financial resourced needed to defend their patents. The lack of these resources was exactly the reason why the Leaded glass case did not acquire a patent. According to the founder/manager of the company: "***a patent is only has strong as the resources you have to defend it***". The company did not want to apply for a patent and subsequently disclose critical information concerning the inventive step in the process, without having the financial resources to defend it in court. To compensate for the lack of a patent, the company handles the critical information as a trade secret and uses extensive non-disclosure agreements.

The copper extraction case had plenty of resources available for development and commercialisation through their relationship with a venture capitalist firm. The leaded glass recycling case had a permanent lack of funding because it could not find external investors. Both firms, however, experienced problems due to their financial situation. The copper extraction case had plenty of available resources, but invested them wrongly, due to strong pressure from the investor on short-term gains. The leaded glass recycling case had extreme difficulty in acquiring the required resources, which substantially slowed down development and commercialisation.

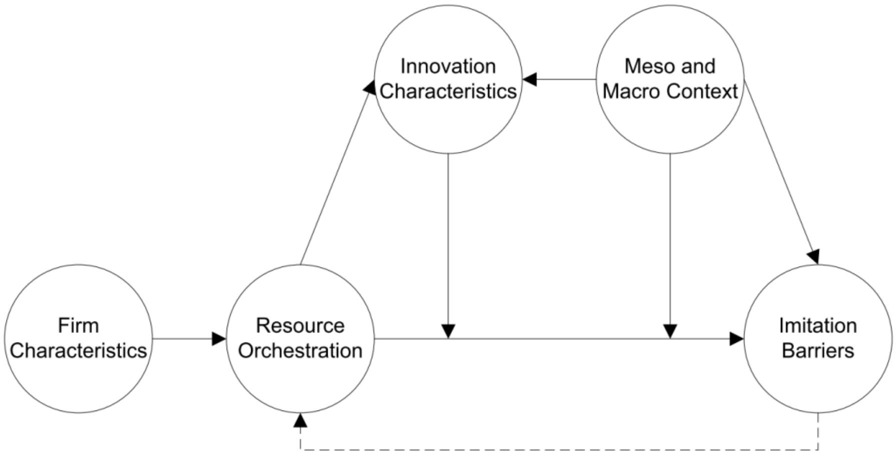
With regard to the distinct managerial capacities within both firms, there is a clear difference between both cases in the firm-specific knowledge possessed by the respective managers. In the leaded glass case, the manager did not have an engineering or chemistry degree or substantial industry experience. This, however, according to industry critics was the key reason why he succeeded and did not give up where others might have quit. The found solution was thought to be impossible to achieve based on industry standards. In the copper extraction case, the ten years of industry experience the newly appointed manager had, proved to be key to the subsequent successful commercialisation of the innovation. He knew how to convince industry sceptics.

6 Discussion

6.1 Conclusions

Based on the literature study, data collection, data analysis and subsequent answers of the four research questions, the following conclusions can be drawn with regards to the central question. Cross-case analysis showed that the assumed theoretical model on the relationship between resource orchestration, imitation barriers and process innovation in the form innovation characteristics, firm characteristics and meso/macro factors, was fairly accurate. The only relationship that was missing, is the influence of factors from the firm's meso and macro environment on the innovation characteristics, as displayed in figure 25.

Figure 25: Conclusion relationships model



Some relationships can be observed across all cases. First and foremost, resource orchestration always directly influences the generated imitation barriers. This was observed in all ten cases under study. Furthermore, in all but one case, created imitation barriers in turn also influence subsequent resource orchestration (e.g. certain investments are only made, based on the establishment of a certain imitation barrier). In the single occurrence where this was not the case, the company had no aim to deter imitators and willingly spread the innovation. In all cases firm characteristics had a substantial influence on resource orchestration. In some cases this relationship was strong and decisive. The size and maturity of the firm largely influences which type and the amount of resources are available. The influence of the firm's resource orchestration on the innovation characteristics follows logically and was also observed in all cases.

Not all depicted relationships are present in every case though. The mediating influence of innovation characteristics on the relationship between resource orchestration and created imitation barriers is of high relevance in more than half of all cases. Here, particular innovation characteristics were prerequisite for generating certain imitation barriers through resource orchestration (e.g. patentability, customer involvement or ability to outsource parts). Moreover, innovation characteristics are not only influenced/facilitated by resource orchestration, but also by the presence of favourable factors from especially the firm's meso context (cooperative suppliers or participative users), which enabled certain innovation types. The firm's meso and macro context also mediates the relationship between resource orchestration and created imitation barriers at least to some degree, in all but one case. The exception to this, arises from a case in which positive and negative factors from the meso and macro neutralise each other. In the other cases analysis showed that the presence of certain cooperative stakeholders or a trend/event in industry in combination with the firm's resource orchestration led to the creation of, otherwise not present, imitation barriers.

Not all imitation barriers are generated as a direct result of resource orchestration. In general, willingness barriers are not created as a consequence of resource orchestration, or only to a minor degree. Across cases, all but one of these type of barriers originated from the firm's meso and macro context (e.g. through political or institutional context). Cognitive and ability barriers, in general, were created as a result of resource orchestration.

Cross-case analysis showed that process innovations that are grouped either based on the type of innovation or firm, show similar configurations of imitation barriers. Moreover, the configurations of imitation barriers in those cases reinforce each other and appear to be dependent on each other.

Finally, more indirect, latent relationships between the concepts can be identified; the influence of resource orchestration on a firm's characteristics, the influence of imitation barriers on the firm's meso and macro environment (competitors and customers) and even the influence of resource orchestration on the firms meso and macro environment. These, however, are more long-term effects, not directly under research in this study and are therefore not so relevant.

6.2 Theoretical implications

6.2.1 Comparison with conflicting literature

As mentioned afore, literature on competitive advantage and profitability of companies in general can be distinguished by the strategic management school that they belong to. Mintzberg & Lempel (1999) reflect on these strategy schools and distinguish between prescriptive, descriptive and configurational schools. A well known strategy school within the prescriptive domain is the positioning school. In this field of research the studies of Porter have become well known and popular. A so called market-based view of the firm is propagated by followers of this school. In short, this view is largely the opposite of the resource-based view and claims that strategy-related rent (performance) of a company dependents on the industry structure and the resulting strategic conduct of a company (Scherer, 1980). It therefore assumes that resources of an industry are homogenous and mobile and therefore cannot provide a source of sustainable competitive advantage. This clearly conflicts with most of the theory and conclusions drawn in this report.

Due to the inclusion of meso and macro environmental context in our model, however, we incorporate elements of both views. The conclusion shows that neither strategic school or view is completely right or wrong, but that the truth lies somewhere in the middle. The inclusion of the firm's meso and macro environment as factors that determine the sustainability of a competitive advantage in this study, conflicts with pure resource-based view.

It is important to note here that analysis in this study was based on the consolidation of different concepts across RBV literature. As the content of these articles were used as a lens to analyse the collected data through, only few conflicting issues (other than the ones with regard to definitions already highlighted in the literature review chapter) were identified.

As mentioned afore, the approach this study takes on defining causal ambiguity conflicts with what influential authors like Lippman and Rumelt (1982) use. This is more a matter of relevance than right or wrong. Cognitive barriers, like causal ambiguity could not be specifically identified as a source of inimitability in most cases. It was hard to determine whether, if present, this would pose a insurmountable obstacle for competitors. Measuring ambiguity appears to be rather ambiguous.

The following paragraph probably partly explains why the link between establishing theoretical concepts and measuring them in real life is rather hard. There is a lack of research on how resource orchestration leads to imitation barriers in practice (Teece, Pisano, & Shuen, 1997). This research aimed to contribute to knowledge in this domain by generating extensive case descriptions. This research might provide an initial insight into this topic, at least from an innovator's perspective. Besides the aforementioned conclusions on the causal relationships, this research also shows that identifying imitation barriers in practice can be quite subjective. Analysis of the imitators perception on the existence and effectiveness of created imitation barriers, might provide theorists with new insights.

Previous literature on imitation barriers predominantly takes a theoretical perspective and makes no empirical link through for instance cases, as this study does. Authors that do use cases to reinforce their theories (Ghemawat, 1986) solely consider multinationals and incumbents in their sample, and analyse company conduct in general and do not focus on innovation in particular. For these companies, creation of imitation barriers appears to be more obvious (as will be elaborated upon below), than for start-ups and SMEs that cannot rely on superior know-how or resource positions for this. This study therefore contributes to literature by not only providing empirical evidence for the existence, origin and functioning in practice of imitation barriers, but also highlights this topic from the perspective of start-ups and SMEs. It shows theorists that there is a certain distinction between the imitation barriers that start-ups and SMEs create, and those created by incumbents. Especially imitation barriers originating from open innovation based processes (six out of ten cases) are applicable for smaller companies. These companies often do not develop and commercialise an innovation independently.

Finally, previous literature never mentions the notion of configurations of imitation barriers. This study showed that certain types of companies and certain types of process innovations are likely to generate a particular pattern of reinforcing and interlinked imitation barriers, e.g. social complexity and preferential market access in case of co-creation driven innovations. Thus besides the division in cognitive, willingness and ability barriers, (of which the former two were also largely neglected by theorists) imitation barriers can be distinguished as reinforcing configurations that are associated with particular types of process innovation, contextual situations, types of firms or combinations of those. This can be considered one of the key contributions of this study to theory.

6.2.2 Comparison with similar literature

Conclusions in this report are in line with the mentioned theory in the literature review chapter, in that both claim that imitation barriers are generated as a result of resource orchestration. These authors, however, largely disregard the other factors in this study's relationship model and do not explain the nature of the imitation barriers. A more modern research stream called the dynamic capabilities approach, does try to explain how firms can exploit existing internal and external firm-specific competences to address changing environments (Teece, Pisano, & Shuen, 1997). Authors like Teece, Pisano and Shuen (1997) and Eisenhardt and Martin (2000) better cover the manner in which imitation barriers are analysed. Just like this study they aim to find a balance between both the resource-based and market-based view.

Across imitation barrier literature not many authors take a (multiple) case study approach. In fact, one of the few that does appears to be Ghemawat. Ghemawat (1986) uses several case studies to prove the existence and origin of different barriers to imitation. His example case of Wal-Mart shows similarity in that sustainability of its success is also largely based on pre-emptive actions. Wal-Mart effectively created local monopolies and pre-empted customers in small Sunbelt towns, because they were the first to settle in these regions where only one discounter could be supported (Ghemawat, 1986). Six out of ten cases in the current study also have pre-emption of market-positions or stakeholders as key imitation barriers. Two other cases of the author confirm the importance of pre-emption of inputs through beneficial contracts with suppliers, as was the case in this study with group 2: Radical innovations with resource orchestration in close collaboration with suppliers.

Another example case of the author shows the importance of experience effects or producer learning as an imitation barrier for industry incumbents. The case company, Lincoln Electric, due to its lead on the experience curve, is still able to maintain a 7% to 15% cost advantage over its major competitors. The two multinational companies in this study also showed producer learning, asset mass efficiencies and economies of scope as factors that were largely responsible for successful development and constitute to its key imitation barriers. Scope economies in particular are also observed in Ghemawat's (Ghemawat, 1986) example case of Cincinnati Milacron, a large machine tool manufacturer. This case showed that activities have to be coordinated and allowances must be made for contributions from one business to the success of another, as was also observed in this study's Rare-earth extraction and Textile dyeing cases.

Furthermore, the cases of ReaLemon and Tandem (Ghemawat, 1986) confirm this study's claim that market access advantages, or preferential market access as it is coined in this study, through buyer switching cost (especially in the co-creation cases) and consumer risk aversion constitute substantial imitation barriers. The author also makes a link here between this type of imitation barrier and sensitivity of customer preferences. This supports this study's claim of the mediating influence of the firm's meso context on the relationship between resource orchestration and imitation barriers.

Finally, the presence of certain imitation barriers appears to be interconnected. Pre-emption of knowhow appears to be always present in case IPR is in place. Asset mass efficiencies (success breeds success) from the path dependency category and communication good effects (network externalities) from the preferential market access category, also appear to be interlinked. Based on analysis it can be determined that the presence of communication good effects implies the presence of asset mass efficiencies. Trade secrets or NDAs were only explicitly mentioned in one case and appear to be absent if IPR is present or in case of non-technical process innovations. This interconnectedness was not observed in previous literature on imitation barriers and supports the notion of configurations of ability barriers.

6.3 Managerial implications

The findings in this study are particularly useful for managers of start-ups and SMEs that want to develop and commercialise a process innovation and aim to better appropriate the returns on their investment. As this study was partially conducted at PwC, some recommendations will also be targeted at their public policy consulting services.

First of all, a rather general implication for managers is that when developing and commercialising a process innovation a company should focus on its core strengths. This applies in particular to start-ups and SMEs. Attraction of resources and capabilities from external stakeholders that are more specialised in certain tasks, results in time and cost savings, and higher quality of development. Furthermore, this does not have to impede the creation of imitation barriers. In fact open innovation based cases (six out of ten) showed to derive their core imitation barriers from cooperation with either customers or suppliers. By establishing exclusive contracts with suppliers or raising user switching costs for customers, these resource providers can effectively be pre-empted. Thus, smaller firms would do well to engage in open innovation and should not only seek to establish imitation barriers based on internal firm factors.

Secondly, analysis shows that imitation barriers are only seldom created randomly or unconsciously. Basically only willingness barriers and some forms of causal ambiguity originate from other factors then deliberate resource orchestration. Managers are therefore advised to come up with a clear strategy for the creation of imitation barriers, at the start of the development trajectory. As most resource orchestration actions simultaneously affect both process development and barrier creation, both strategies should be made to fit with each other. Ideally, imitation barriers are in place at the point of implementation or market entry of the process innovation.

Finally, cross-case analysis shows that certain types of imitation barriers are more likely to be created in case of a particular process innovation types. Moreover, the company's meso and macro context often enables the creation of certain imitation barriers and in some cases also facilitates a particular type of process innovation. Managers should be aware of the particular type of process innovation they are commercialising and search for compatible imitation barrier configurations with this typology. They need to analyse their meso and macro environment for factors, like the presence of participative users, suppliers or certain windows of opportunity that might offer possibilities for the creation of strong imitation barriers. Compatibility between the process innovation type and imitation barriers is key, because creation of imitation barriers can also backfire, for instance through filing of weak patents (disclosure without protection), being too dependent upon a user community or suppliers, or losing the balance between secrecy and not involving enough employees in the development process.

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Although this study was partially performed within PwC Public Services, it was not commissioned by them. Managerial implications therefore do not particularly apply to this company. PwC does, however, advise the European Commission on matters involving innovation, and how innovation can be stimulated among European companies, which partially dependents upon the degree to which companies are able to appropriate their investments. Imitation barriers contribute to a large degree to the appropriation regimes of companies. Some implications can be derived from the results of this study, with regard to how governments might facilitate better appropriation for innovative companies.

As was the case with one of the companies in the sample, especially smaller companies face severe challenges with intellectual property law. They often do not have the financial resources to acquire and legally protect a patent. This puts them at a great disadvantage compared to industry incumbents. Moreover, many government subsidies and grants, require a company to disclose the inventive step in its innovation in order to be eligible for the grant. Without having a patent on the innovation, disclosing such information would be commercial suicide. The combination of both facts can hinder small companies significantly and therefore policy makers should make changes to either IP law or subsidy requirements (of which the latter is more plausible).

Furthermore, from the perspective of enhancing the European Union's competitiveness compared to Asia and America, based on the finding of this report, the European Commission should further promote all forms of open innovation. Especially start-ups and SMEs in this study (six out of eight cases) were involved in some form of open innovation, which was largely responsible for both development of the innovation and creation of imitation barriers. Obviously, not only the innovator benefits from these open innovation initiatives, but also customers and suppliers that contribute to the development and diffusion of the innovation. This way, the success of one process innovation diffuses to several stakeholders. By supporting these initiatives, the effects of EC funding can be enhanced.

6.4 Limitations and further research

First of all, it is unknown whether the current research's chosen context to explore the relationship between resource orchestration, imitation barriers and process innovation context can be generalised to innovation in general. Although the theoretical resembles is evident, practical proof still needs to be established.

Because of the clear focus in this research on the research to market trajectory, as the dominant phase to facilitate imperfect imitability, only imitation barriers that can possibly be build during this phase were considered. Furthermore, the focus lied on barriers to imitation that are in a certain degree influenceable by the innovator firm. Future research might contribute to this by focusing its efforts on the imitators perspective and how he perceived the effectiveness of created imitation barriers.

Certain imitation barriers are very hard to identify, due to the manner of data collection. Managers or founders do not always fully understand their innovation, or falsely comprehend certain elements. Future research might focus on developing better measurement methods for concepts like causal ambiguity. It is, however, unlikely that these factors can ever be accurately measured, because due to their nature they are not perceived by respondents (causal ambiguity) or are associated with future developments (uncertainty regarding the future)

Concerning the conflict of interest, interview questions for data collection were predetermined and limited this thesis in its data collection opportunities. Arguably, it would be better to ask respondents directly for their opinion on the created imitation barriers, but this did not comply with the scope of the larger research project. This particular research therefore aimed to derive relevant information concerning imitation barriers from the data provided on resource orchestration during development and diffusion. However, due to the ambiguity surrounding many types of imitation barriers it would have been unlikely that respondents would have been able to answer these questions directly.

Finally, as this research is a cross sectional study, not longitudinal, it cannot be checked whether the observed imitation barriers are indeed preventing imitators from imitating on the long term. Focussing on older innovations, for which these issues are already clear would endanger the reliability and accuracy of recollections among stakeholders concerning the innovation, and was therefore not an option. Due to the timely limitations, a longitudinal research approach could not be pursued. This would, however, be a sound recommendation for further research.

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8 Figures and Appendices

Appendix A:

Detailed Questionnaire

General information

Nr	Question item
0.1	Name
0.2	Organisation
0.3	Position
0.4	Role in the case: • Actor of the market (i.e., representative of a key company of determined segments having implemented the technological innovations studied, e.g., CEO/Director, R&D, human resources and marketing manager, head of project, research etc., and customer if appropriate); • Actor of the value chain (e.g., supplier); • Partner in research projects or manager of research programmes having contributed to the development of an innovation; • Investor (business angel, venture capitalist etc.); • Public actor (European, National and/or Regional government representative); • Other (please specify).
0.5	History of involvement in the case: how and at what stage this stakeholder became involved in the case (initiator, was invited by the initiator etc.)

Dimension 1: Innovation Cycle

Nr	Questions	
1.1 General		
(1)	1.1.1 What were the main steps of the innovation trajectory starting from its technical source of origin to its introduction to the market (implementation to practice)?	
(2)	1.1.2 What is the duration and sequence of those steps?	
(3)	1.1.3 What key activities were involved in each step?	
(4)	1.1.4 How was the innovation funded throughout the whole commercialisation process? (internal company funds, public funding, business angels, seed capital, venture capital etc.)	
1.2 Step 1: Initial system design and synthesis according to the specified objectives and constraints		
(5)	1.2.1 What is the technical origin of the innovation (technology push: university research, public laboratory research, private company research, collaborative university-industry research; demand pull: advice of industry consultants; market research, competition analysis etc.)?	
(6)	1.2.2 At what point of time the decision was made to adopt the innovation? Who made that decision?	
(7)	1.2.3 Who was involved in the design of an advanced production system (e.g., internal technical specialists, external production system designers, technology managers, top management etc.)?	

Nr	Questions
(8)	1.2.4 What kind of specific activities were carried out at this stage?
(9)	1.2.5 What were the key barriers at this stage? How were those overcome?
(11)	1.2.6 What were the key success factors at this stage?
(12)	1.2.7 When designing an advanced production system, was there enough freedom for system designers to select among different physical implementation alternatives? Were system's objectives separated from the means of achievement?
(13)	1.2.8 When designing an advanced production system, were low-level activities and decisions linked to high-level goals and requirements? If yes, how was it achieved (e.g., multi-competence team with active involvement of top management)?
(14)	1.2.9 When designing an advanced production system, was there a good understanding of interrelationships among the different elements of a system design (focus not only on local elements, but on the whole system)? If yes, how was it achieved?
(15)	1.2.10 How was the information on the design of a new production system communicated within an organisation?
(16)	1.2.11 Were production system designers provided with a roadmap or mental model of how to achieve the strategic objectives of a firm?
1.3 Step 2: Modelling, analysis and simulation	
(17)	1.3.1 At what point of time modelling, analysis and simulation of a new production system took place?
(18)	1.3.2 What kind of activities were carried out at this stage?
(19)	1.3.3 What were the key barriers at this stage? How were those overcome?
(20)	1.3.4 What were the key success factors at this stage?
(21)	1.3.5 What type of tools and simulation models were used for this exercise (e.g., classic simulation models, data-driven simulation models, CAD etc.)?
(22)	1.3.6 How did simulation analysts determine whether the simulation model is an accurate representation of the system being examined, i.e., whether the model is valid, and whether the model is credible?
(23)	1.3.7 Did the following activities took place during the simulation of a new production system? • Stating definitively the issues to be addressed and the performance measures for evaluating a system design at the beginning of the study; • Collecting information on the system layout and operating procedures based on conversations with the "expert" for each part of the system; • Delineating all information and data summaries in an "assumptions document", which becomes the major documentation for the model; • Interacting with the manager on a regular basis to make sure that the correct problem is being solved and to increase model credibility; • Performing a structured walk-through (before any programming is performed) of the conceptual simulation model as embodied in the assumptions document before an audience of all key project personnel; • Using sensitivity analyses to determine important model factors, which have to be modeled carefully;

Nr	Questions
	• Simulating the existing manufacturing system (if there is one) and comparing model performance measures (e.g., throughput and average time in system) to the comparable measures from the actual system.
1.4 Step 3: Final design and implementation	
(24)	1.4.1 At what point of time did the final design and implementation of the innovation take place?
(25)	1.4.2 What kind of activities were carried out at this stage?
(26)	1.4.3 What were the key barriers at this stage? How were those overcome?
(27)	1.4.4 What were the key success factors at this stage?
1.5 Step 4: Redesign and reconfiguration	
(28)	1.5.1 At what point of time did redesign and reconfiguration of the innovation take place (if applicable)? What kind of reconfiguration it was (physical or logical)?
(29)	1.5.2 What kind of activities were carried out at this stage?
(30)	1.5.3 Why was there a need for redesign/reconfiguration?
(31)	1.5.4 What were the key barriers at this stage? How were those overcome?
(32)	1.5.5 What were the key success factors at this stage?

Dimension 2: Diffusion of innovations

Nr	Questions
2.1 General	
(33)	2.1.1 How much time did it take before the adoption of the innovation within an organisation could be considered a technical success?
(34)	2.2.2 How much time did it take before the adoption of the innovation within an organisation could be considered a business success: (a) productivity increase alone; (b) productivity increase plus realisation of other benefits (such as lead time reduction, flexibility), (c) transition of the above into real competitive advantage in the market place?
(35)	2.2.3 What are specific examples of competitive opportunities resulting from the innovation (e.g., reduced lead time for new product; faster response to customer requests; reduced order to delivery lead times; faster product modifications; reduced costs; higher quality products; faster response to customer needs etc.)?
(36)	2.2.4 How did the context of the company, its skills, existing technology and managerial attitudes etc. influenced the process of adoption?
(37)	2.2.5 Did the innovation have to deal with the barriers to successful implementation within production (i.e., the innovation was viewed as an individual project)? What were those barriers and how they were overcome?

Nr	Questions
(38)	2.2.6 Did the innovation have to deal with the barriers to successful implementation across functional boundaries (i.e., lack of holistic approach)? What were those barriers and how they were overcome?
(39)	2.2.7 Did the innovation have to deal with the barriers to successful implementation with customers and suppliers (i.e., the need to align their new production systems with customer and supplier relationships)? What were those barriers and how they were overcome?
(40)	2.2.8 Did the innovation have to deal with the barrier of financial justification? If yes, how was it overcome?
(41)	2.2.9 Were the users provided with the opportunity to learn and develop competence in using the production system? What other human resource practices were applied to ensure quicker acceptance of the new system?
(42)	2.2.10 Did users initially show the resistance in using the new production system? If so, how was it solved?
(43)	2.2.11 Was the innovation introduced to multiple production plants of the same company? Did the innovation spread beyond one company?

Dimension 3: Stakeholder analysis

Nr	Questions
3.1 General	
(44)	3.1.1 What key *internal* stakeholders were involved in the adoption of a new production technology/system? • Top management; • Technical /R&D managers; • Marketing managers; • HR managers; • Head of project; • Shop-floor workers; • Other (please specify)
(45)	3.1.2 What was the impact of internal stakeholders (both positive and negative) on the progression of innovation? (*per type of stakeholder*)
(46)	3.1.3 What interest did the key internal stakeholders have in the development of the innovation? (*per type of stakeholder*)
(47)	3.1.4 What resources did the main internal stakeholders invest to ensure the progression of the innovation?
(48)	3.1.5 Who was the initiator of the adoption of a new production technology/system (e.g., top manager, production manager, technical workers etc.)?
(49)	3.1.6 How was the support and commitment of the top management achieved?
(50)	3.1.7 Was a 'technological champion' present during the adoption of the innovation? If yes, what was his or her impact on the progression of the adoption process?
(51)	3.1.8 Were workers involved in planning and selection of a new production technology/system? If yes, what

Nr	Questions
	was their role? If no, why?
(52)	3.1.9 Were new/different workers selected to operate a new production technology/system?
(53)	3.1.10 Did the reorganisation of the workforce take place after the adoption of a new production technology/system (e.g., smaller, more closely integrated work teams)?
(54)	3.1.11 Were specific orientation, training, and education efforts in place to reduce resistance to new technology?
(55)	3.1.12 Has the adoption of a new production technology/system led to the empowerment of technological workers?
(56)	3.1.13 What key *external* stakeholders were involved in the adoption of a new production technology/system? • Other actors of the market: • Actors of the value chain • Partners in research projects • Public actors • Other actors
(57)	3.1.14 What was the impact of external stakeholders (both positive and negative) on the progression of innovation?
(58)	3.1.15 What interest did the key external stakeholders have in the development of the innovation? (*per type of stakeholder*)
(59)	3.1.16 What resources did the main external stakeholders invest to ensure the progression of the innovation?
(60)	3.1.17 Were there any tactical alliances with other organisations? What was the objective of such alliances?

Dimension 4: Factor mapping

Nr	Questions
4.1 General	
(61)	4.1.1 What key *micro-level success factors* apply to the innovation in question? • Top management support and commitment; • Availability of required skills and competences; • Internal management of information; • Structural aspects, including the type of companies involved and the organisation of their relations (e.g. clusters), the positioning in the supply-chain; • Use of efficient channels of dissemination of information; • Involvement of workers at early stages; • Timing; • Planning; • Internal communication etc.
(62)	4.1.2 What key *micro-level barriers* did the innovation have to deal with? How were those overcome? • Technology transfer inefficiency; • Academic need to publish vs. industry need to patent;

Nr	Questions
	• Risk aversion etc.
(63)	4.1.3 What key *macro-level success factors* apply to the innovation in question? • Appropriate normative framework: standards, patents, legislation; • Public policies and support services to foster introduction or uptake of those technological innovations (at European, national and regional levels); • Access to private finance, e.g. business angels, venture capital etc.
(64)	4.1.4 What key *macro-level barriers* did the innovation have to deal with? How were those overcome? • Risk assessment and protocols for industry; • Environmental, health, life cycle analysis and safety issues; • Consumers issues and media and public perception; • Gaps in policy and infrastructure; • Gaps in support mechanisms (finance, IP, etc.); • Gaps in metrology, standards, investment etc.

Appendix B:

Excel sheet facilitating in-case and cross-case analysis

	Case				
Nature of the innovation	**1. Car**	**2. Platform**	**3. 3D printing**	**4. Magnet fluid**	**5. CRT**
Competitive advantage	Benefits naturally flowing from their process structure. The company is applying what the traditional automobile firms already know and applies it to their co-creation initiatives. Crowd sourcing gets all parties involved and Car's platform where everybody can meet and interact immediately. Consequently, it results in design and manufacture engagement. These efforts result in shorter development times, a cost effective development process from the start and more attractive products.	The company developed an online marketplace for everyone to click to make real things. It is where creators, digital fabricators, materials suppliers and buyers meet to make (almost) anything, based on digital design software and innovative fabrication methods such as 3D-printing, laser cutting, and CNC routing. The company allows designers, fabricators, material suppliers and buyers to find one another and co-create in a manner that is efficient, transparent and mutually profitable. The concept allows for many new business models employed by various companies that make use of the concept, from artistic designers, to clockmakers, to architects.	(**open source hardware**) The company was unable to keep up with demand for their 3D printer, so they turned to their customer base and asked them to manufacture some of the parts (pulleys) for them using the existing 3D printers. The owners of the 3D printers were thus helping the company with producing new printers. The concept of crowdsourced manufacturing generally implies that instead of having a centralised factory that produces parts and then distributes them to the people who want them, individuals have the tools they need to build what they want and distribute it without a central hub. In this case, manufacturing was distributed, but distribution still used the hub model.	A joint venture (founded by a company specialising in magnetics for recycling purposes and a company specialising in metals recycling) implemented and sells a process that through a magnet system and iron oxide fluid allows for the separation of various metals based on their material property density. Opposed to its competitors, the new technology allows the company to separate waste input based on its specific material density. Competitors are still using optical separation techniques based on for instance colours or particle size, factors that are not directly related to the material's properties. A large share of material sorting is also still being done manually. If particle size, however, drops below 50 mm, it becomes very hard to manually sort the material. Moreover, sorting material based on its colour is not a reliable method, because many used materials have been treated with either paint or a coating, hiding their material specific colour.	This process innovation allows for the separation and recycling of lead from leaded glass or CRT waste (old television screens). Key benefits of this solution are not only that the lead and glass is separated for reuse in new applications, but that the whole process is designed to be environmentally friendly.
subjectivity of innovation	new to the operating market of the firm	New to the world.	new to the world with regard to crowdsourced manufacturing.	new to the world.	New to the world
process of innovation	Company started from the very first idea, and then did the invention, prototype etc. **rest**	The technical origin of the platform was a combination of different things. At a technical level, the company did the design work and a good part of the implementation all in house. Certain aspects of the system were based on the advice that one of their very first employees gave them, who came fresh from the a New Zealand Design School. The company relied on him for writing design languages and writing software that was based on design language.	The company builds on the early progress made by another project. One of the founders also founded that project, which helped advance early research in the field of open-source 3D printers. The three founders developed the prototype themselves, which was finished in 2009. Three months later they were already able to sell the first printers.	A technical university came up with the first elementary idea for this innovation, based on some old patents. The university passed the idea on to one of the joint venture partners, because the university was not able to develop the technology itself. The joint venture partner developed the magnet system and a substantial part of the facility, before it founded a joint venture together with a metal recycling company. Within this joint venture the technology was eventually commercialised.	The founder and inventor perceived the need for a solution. Through talking with people from the glass making industry he came up with the basic idea. From there onwards, he and his employees developed everything themselves. Currently, the first few facilities have already been sold.
roles of innovation	<u>Customer dominated and demand pull.</u> Open innovation, external stakeholders are key. Customers come up with designs and help with construction. Compay sells an automotive experience. Large players in the industry also contribute.	The innovation was the result of market pull. In the early 1980's New Zealand went through a period of major liberalisation of the economy. This lead to a situation where in the early 2000s there were few manufacturers in New Zealand. Getting an item or a product manufactured was difficult.	The element that makes this process an innovation is the crowdsourced manufacturing. This element of 3D printing is customer dominated. However, by facilitating 3D printing at the customer's home, the company has enabled this through making the technology affordable. The whole process can be characterised as **collaborative.**	Development of this technology has been manufacturer driven. There is no direct demand pull from the market, but increasing resource prices stimulate adoption of this technology. The technology was developed in close collaboration with suppliers of the process. They were key for success.	The development of this innovation was manufacturer dominated, although there was also a clear need from the market for a solution to CRT waste. The founder initated development after he perceived the need for such a process.
degree of innovation	<u>Application Innovation.</u> From a producer's view the technological change is low, although the production process is quite different. From the buyer's view the increased benefit is high due mentioned factors.	Although some functionalities of the quite advanced, the technological change from a producer's point of view is relatively low. The increased benefit from a customer's view, is high. This innovation, therefore, can be characterised as a application innovation.	The technological change from the producer's view is low. It's entails more of a business model change and not technical change. The increased benefit for the customer is high. 3D printing is now available at home. This process therefore can be characterised as an application innovation.	This new process is a radical innovation. The level of technological change from the producer's view is high and the increased benefit from the buyer's view is also considered high.	This process can be considered to be a radical innovation. The technological change from the producer's view is relatively high. Although it's based on existing principles, nothing remotely similar existed. The increased benefit from the buyer's view is significantly high, because the process allows the transformation of hazardous CRT waste into valuable raw material (glass and lead).
success of innovation	Break-even point: not reached	The BEP has been reached. The innovation already generates profit. In four years, the company managed to spread to four continents, featuring manufacturing hubs in various countries, and allowing new businesses to be founded and made profitable based on the platform's concept.	BEP has been reached. The company has been generating profit since day 42. All profits are invested back into the company. The company has sold over 10,000 units as of February 2012. The company has been ranked among the top 20 startups in their city. (among the largest american cities).	The company already earns money through three business models: separation of waste in a self-operated installation and sales of sorted material, sales of facilities against cost price with monthly royalty payments, and cofounding of joint ventures with clients. In May 2011 the first machines were sold and contracts had been signed. BEP has not been reached.	The break-even point has not yet been reached. The company has already sold
Hard/Soft innovation	Soft	Soft	Soft	Hard	Hard
Tighly/Loosely managed	Loosely	Loosely	Loosely	Loosely	Loosely
Internally/Externally commercialised	internally, but based on external interaction	internally, but based on external interaction	externally	externally & internally (clear preference)	externally & internally (clear preference)
Firm characteristics					
firm size	SME (20 employees)	SME (<10)	SME (50 employees)	The joint venture employs 15 people, the joint venture partners respectively 100 and 750.	SME, 6 employees

firm maturity	Founded in 2006	The company was founded in 2008.	The firm was only founded in 2009. It is still very young.	The joint venture was only founded in 2008. The joint venture partners, however, were already established players in their respective markets.	The company was founded in 2001, although developments have progresses slowly. Still considered a start-up.
organisational structure	Innovative/Adhocracy	Innovative/Adhocracy organisation?	Innovative/adhocracy organisation	During development the joint venture company resembled an adhocracy/innovative organisation.	Entrepreneurial organisation
sector of origin	C Manufacturing, 29.1 Manufacture of motor vehicles	C - Manufacturing, a very wide variety of products.	C - Manufacturing, a very wide variety of things can be printed using the new process.	E Water supply; Sewerage, Waste Management and Remediation Activities, 38.1 Waste collection, 38.32 Recovery of sorted materials.	38.1 Waste collection, 38.2 Waste treatment and disposal, 38.3 Materials recovery
country of origin	USA	New Zealand	USA	Netherlands	UK
current availability on market	Global, although proximity to micro-factory is recommended.	Global, the user platform is accessable all around the world.	Global market (more than 10,000 units sold so far in North America, Europe, Australia, New Zealand, Argentina etc.)	The technology is available on the global market. Sales of the machine are however limited to certain customer companies and are preferably conducted in a joint venture structure, which licenses the technology from the developing company.	Worldwide availability. Currently the technology is already being operated in the UK and USA.
ownership structure		Founders and angel investors???		The joint venture is owned by the respective holding companies of the joint venture partners. A small share of the joint venture is owned by its commercial manager.	The firm is wholly owned by the founder/inventor.
manner of funding	Prize money from competitions (very small), investment money from another person in the industry (1 million), angels investor funding (4 million)	Mainly money from the founders (from previous business endeavours, some money from friends and family and specific angel funders, who have been strong supporters of the innovation.	Seed capital was provided by three individiuals (75,000 dollar) and lateron a VC firm invested 10 million USD in the company and joined its board. The particular process innovation, did not require any specific funding.	The innovation was funded with cash reserves present within the holding company of one of the joint venture partners. This joint venture partner was largely responsible for development of the technology underlying the process.	The firm was almost completely funded with the founder/inventor's private savings, money from friends and family.
Success factors and barriers					
micro succes factors	• The founder originates from an entrepreneurial family and has unique multi-disciplinary skills to innovate; • Car got Support from a company which operated a similar business model and in a similar industry, provided valuable resources. They would provide relevant operational and manufacturing information. In addition, it owner would provide access to engineering, design talent and the time and advice of the company'ss senior management team; • The use of blogs and websites are efficient means of communication. These channels are fast means of communication and are able to reach a large crowd.	• The time pressure of being first to market. • The financial pressure due to a resource scarcity. • A strong desire and a feeling among the company's founders that they could and wanted to build the company. They were creating a system that solves a personal itch. • They were working on a story that grabbed peoples imagination.	• The company's ability to quickly design alternative pulleys that they needed for their machines; • Team's openness towards out-of-the-box solutions; • Small number of people in the team at the time of development (no internal arguments); • High flexibility of the production process: adaptable and temporary production facilities (each 3D printer is a production facility) located close to the market (actually even owned by users) instead of centralised factories with a high vertical range of manufacture; • Differentiation embedded in planning and control systems: ability to integrate both own and user-manufactured pulleys due to detailed specifications for the units (standardisation) and the ability of users to produce exactly the same type of pulley that the company's team produced themselves; • Production and assembly methods considered both local and global conditions.	• The underlying technology for the development of this new process innovation is the patented magnet system. This technology was created by one of the joint venture partner's internal R&D team. This company is a technology leader in the magnet systems market for recycling purposes. Possessing the knowledge and intellectual property rights for the development of this technology, provided the company with a strong bargaining position and made them an attractive party for partnerships; • Experience with intellectual property management, and financial resources to protect intellectual property at the joint venture partner was key to successfully commercialising this technology; • By sorting waste based on its material properties, the joint venture opened up a new market for recycling. Metals and plastics with very small particle sizes can now be reused, instead of incinerated. Conventional techniques like manual sorting or optical identification cannot be applied to small particle size waste material, which means that this technology does not have any substantial competition.	• Highly (intrinsically) motivated founder and team members; • High commitment/involvement of team members ensured constructive discussion; • Team members' perception of the nature of the work is very positive/rewarding; • Multidisciplinary team facilitated original, creative thinking.
micro barriers	• The hiring process of personnel for Car went step-by-step, as capital restrictions determined the number of people they could afford at each stage; • In order to establish large scale diffusion of micro-factories Car needed access to resources such as funding and an employee pool; • Product customers are generally different people then those involved in the design competitions. To resolve this drawback, Car aims to also develop the customer side of the community; • In some cases production drawings needed re-design or refinement. Thus, the community is going to be provided with the right tools. The quality increase of this initiative should make redesign unnecessary.	• A strong tension between the need to just do software development and be a manufacturer at the same time. • The company is a capital-scarce firm which causes a some anxiety in the decision making process.	• The only challenges were related to the internal organisation of the process, but those were quickly solved. • Generally, supply chain management is reported to be difficult. It is full of delays, shipping challenges, and people who do not return calls. The company handles delays by investing in inventory so that they have extras on hand and keep shortages to a minimum. The supply chain is reminds a Tetris-style operation to make sure they have enough of everything to ship quickly.	• Because the innovation was solely funded internally, it was decided not to conduct several development steps in parallel. The development process, therefore, took more time; • The lack of practical experience within one of the subcontracters, hired for facility design, concerning the operation of a recycling facility caused many problems once the theoretical ideas needed to be translated to a full scale facility; • The designs that the external engineering company made were hard to translate to practice. Hiring this agency was considered to be a fault. The joint venture partner should have decided earlier on in the development process to look at the process from a practical perspective.	• Resource scarcity, especially in terms of financial support; • The required secrecy of the newly developed technology, needed because the company did not have the financial resources to defend a patent; • Information disclosure concerning the technology required for the EU funding application procedure, which would have been commercial suicide without the protection of a patent. Therefore the company was unable to participate in certain EU funding programmes.

meso success factors	• Car is able to produce vehicles for niches to which big car manufactures are not able to offer vehicles; • Following from the customer intimacy and availability of drawings and CAD files, it would not be interesting for other companies to copy their business model; • In addition, the community is Car's most valuable asset and because of the **lock-in** and loyalty of users, their community is difficult to replicate; • Car is able to tap into the community's desires and learn from them before they actually start developing a car; • The first end-product uses 90% of off-the-shelf parts, which increases their availability and simplifies maintenance or repairs on the automobile.	• The emergence of a reasonably strong angel-funding network in New Zealand. • Strong support from one of the design schools of an New Zealandish university. • The geographic location of the company (in Wellington) was also important, as it is a relatively affordable city to live in. • Living and working in Wellington's 'relaxed' environment allows people to achieve some balance in their work-life combination.	none were mentioned	• The numerous successful collaborations with suppliers and joint venture partners have been crucial for the development and commercialisation of this technology. These collaborations were successful, because the partnering companies provided the joint venture partner with knowhow and expertise required for development of the technology, which was not internally available at the company; • The general opinion among manufacturing companies towards waste has positively changed in the last few years. These companies no longer perceive residues of production as waste, but as valuable concentrations of scarce resources. Keeping these production leftovers clean and separated, enables easier recycling and reuse. These companies are more and more willing to cooperate in providing a cleaner waste stream to recycling companies. A cleaner waste stream provides higher returns for both the recycling and waste producing company, because less pre-treatment is required.	• Funnelled thought process within large companies in the recycling industry, concerning new business opportunities; • Operational success of the facility at the first customer's site should convince other industry players of the value of buying a furnace.
meso barriers	• Although the product is relatively affordable, the distribution channels and large scales of economy of the automotive industry make it difficult to disrupt the industry; • Assembly and maintenance are performed at micro-factories, they also provide a physical place to meet and to build relationship with customers and the community. The barrier flowing from this approach is the scalability of the business model. As the micro-factory builds a connection with the local community, employees are difficult to transfer; • The local and niche strategy will limit the customer pool and reach of the micro-factory. This follows from the 120 deposited customers, from which 50% would live in a 4-hour radius. The solution is to open up micro-factories all over the world; • No financial scale advantage common to mass production was overcome through adding owner experience value and reducing labour costs through customer involvement; • The automotive industry is such a hard industry to break in because size and isolation, the team overcame the barrier through the use of modern technologies and production possibilities.	• When doing business internationally, there is a geographical barrier that comes from being located in New Zealand. • There is a lot of coordinating overhead involved that comes on top of doing business in New Zealand. • Limited access to growth capital is the most significant meso-level barrier. • A cultural barrier between doing business in New Zealand and doing business in the United States.	none were mentioned	• Significant levels of industry scepticism exist towards the technology, because many companies in the recycling industry claim to have revolutionary technologies, which in fact are not. This technology receives scepticism in particular, because it uses a process liquid to sort the metal. In general, recyclers are not font of processes using liquids for metal recycling, because this stimulates oxidation of the metal; • Many potential customer companies are still operating relatively new recycling facilities. They are therefore not eager to already replace these with the company's MDS installation, which delays the rapid diffusion of this innovation.	• Risk averse behaviour by potential customers in the recycling industry prevents them from buying a furnace.
macro success factors	Car thinks its crowdsource derived co-creation will not likely work for all industries. Crowdsource derived initiatives are more suitable for appealing consumer products such as housing, electronics and obviously the automotive industry. Customer enthousiasm works two-fold, personalised product and automotive experience of co-construction.	• The shift in macroeconomic policy with respect to off shoring manufacturing. • One of the roots of the company's origin is related to aggressive neo-liberal policies in New Zealand, including the dropping of all tariffs, abandoning all protectionism, and loosing large chunks of New Zealand's manufacturing capability. • Westerners fear the complexity of getting stuff done in China. This makes it relatively easy for the company to get traction in the Western world. • Another important success factor has been the emergence of the make culture in the United States, which touches upon the sustainability culture. • The make-culture in the United States was always the critical customer base of the company.	• Supportive customer base (technology enthusiasts): The company heavily relies on the existence of strong, competitive and well-connected user-community composed of operators, engineers, hackers and "ordinary" users; • Using standards to facilitate the adoption of the advanced manufacturing system by end-users (open source design).	• The higher return offered by this technology, opens-up new possibilities for recycling. In combination with subsidies from national governments the company's technology makes recycling of new types of waste not only technologically possible, but also economically attractive for the first time in history. • In Europe, both industry and government have a significant interest in the recycling of rare metals, because of China's growing monopoly position as a supplier of these materials. The stronger China's position in this market is, the stronger their influence on prices will become.	• Worldwide decreasing sales of CRT TVs, means that more and more leaded glass is ending up at landfills. Closed-loop recycling is no longer a possibility and demand for a more sustainable solution is increasing; • Worldwide trend towards higher recycling targets for all companies, demand for more sustainable business processes and increased commodity prices due to resource scarcity.

macro barriers	• Restrictive government rules and regulations covering the automotive sector; • Lack of government subsidy made project funding much more challenging. As a result of the economic recession, start-up capital funding for manufacturing companies was difficult to obtain. Capital requirements were different. Technology venture capitalists look for proof of each development and then gradually release more capital. Car however needs financing in larger doses to roll out several micro-factories. • A third barrier that Car was facing is building and maintaining the community, which is capital intensive. To decrease its costs, LM opened up the community to other companies that desire to tap in LM's talent pool and collaborate on hosting a design competition.	None identified	The company's technology is mostly patent-free. Recently, they designed a component that they could not bring to the market because, even though they developed the idea themselves, their design was too similar to a patented design. They have received letters from companies with patents who have lete them know that they are "watching their every move". If the company decides to invest in patents as a defensive measure, they will need to figure out how to license them so they protect themselves, but do not block innovation in the open hardware community. It is going to be challenge to figure out how to be an open hardware company that lives in the open source future while protecting themselves from the proprietary ways of the contemporary patent system.	None were identified	• Demand for information disclosure in the (worldwide) patent legislation in combination with the high costs associated with legally enforcing it. This enables competitors to imitate, without small companies with low cash reserves to really fight infringement; • The financial crisis that hit the global economy in 2008; • The delayed UK introduction of the EU WEEE directive, active in the UK as of January 2007. Other EU members had already introduced this legislation in August 2005.
Resources					
physical capital resources		The developed an online 'file checker' that checks uploaded design files to see if they can actually be used by producers to fabricate what is designed. Also, the platform features an online pricing system that prices a design based on its complexity and the materials used for fabricating the designed item. This pricing system has broad support amongst the platform's user community. Most of the technology required for the company's system was already in existence. Only specific software had to be developed relating to the design language. There was nothing fundamentally new to the technology that was developed by the company. By opening up a fabrication hub in San Francisco in the United States (the second company's hub after the original one in New Zealand), and afterwards an manufacturing facility in Europe, the company could use and provide the benefits of a distributed manufacturing [illegible]		*The company had the financial resources required for development internally available. *Being one of the technology leaders in its industry of magnet system application for recycling purposes, the mother company already possed the required facilities for modelling, analysis, simulation, testing and constructing magnet systems.	The founder came up with the funding for this innovation together with family and friends. No significant external funding was acquired.
human capital resources		One of the most important and extensive human capital resources is the expertise residing in the platform's user community. The good relations with this community are key. The company's support team is staffed among others by two individuals with a background in design, which focus on support on 3d matters. One of these individuals is also a fabricator within the platform's community. The key characteristic the company looks for in its support staff is the attitude of the staff member, as an attitude is very difficult to teach, while most other relevant traits can be trained for. The attitude of a support staff member is important, as they are talking directly to customers, which is a huge responsibility. As far as the customer is concerned, these staff members are the company.	The company's founders were the key human capital resources. One of the founders was already involved with a foundation he founded, aimed at advancing research in 3D printing. By cooperating with its user base of technology enthusiasts, the company got valuable feedback early in the design cycle and got supports who would influence other buyers in the marketplace.	Being one of the technology leaders in its industry of magnet system application for recycling purposes, the mother company already employed a skilled workforce with regards to magnet system R&D capabilities.	The company's founder had connection in the wineglass manufacturing industry. Through networking with people struggling with the same issues, he learned the basis for the solution to CRT recycling. The first customer did a due diligence on his company. The customer received a substantial reduction in the purchasing price of the facility, and in return they had to pay a monthly contribution to the company for its construction. A team of 5 employees was assembled in 2007, when the founder started to employ people through his company. These persons have been almost solely responsible for the uniqueness and design of the advanced separation system. The team that worked on the project can be considered multidisciplinary. People with chemical, electrical engineering and glass artistry backgrounds were all involved in the development of this technology. The team applied themselves to the job exceptionally well, and demonstrated their passion for their work.

organisational capital resources		As people start working with the platform concept, they submit feedback on issues and matters of understanding previously out of scope of the information content, which is of great benefit to the company's support team responsible for the information content. This feedback processing systems is key. The company's communication system towards its community base is also key. It is important for the company to communicate to its community what is possible within the platform's concept and how to achieve this.	After the company's demand was increasing and they started the crowdsourced manufacturing. The company had to develop new organisational procedures, being: labor requirements planning, evaluation of change in product volume, production scheduling and quality control prodecures. The company setup a good cooperation with schools to acquire new employees through internships.	The mothercompany, having a permanent R&D department and conducting regular R&D activities had an established legal department for IPR issues and R&D procedures with regard to simulation and testing. The mother company's swift decision making process contributed to the early stages of development.	When a discovery was made, or a potential improvement was stumbled upon, communication was mostly face to face or through email. Frequent review meetings, in which everyone came together, made sure that all team members were up to date and on the same page concerning developments and the future focus.
structuring					
acquiring		The platform allows for a lower cost for small production volumes than outside of the concept. This is especially attractive for people that for instance want to have a prototype built, and for hobbyists and small business owners that are in the market for the manufacturing of small volumes of sellable objects. Governmental research labs also use the production serviced through the platform. The designs that are produced through the platform can also become available to other customers this way. Four months into the development phase the company brought alpha customers in. The people at the company felt it to be natural to bring these customers into the development, as they themselves profess this was by and large baked into their DNA. Analysis and simulation of the concept has taken place to the extent that early in the development potential users and customers of the company's system were involved in the development, to analyse how these individuals would interact with the company's system, and to gain their early feedback and practical insights on how the system was developing. The company had a good relationship with TechCrunch. There was no money involved with the platform's presence at Tech Crunch. It was the early beginning of Tech Crunch, and Tech crunch wanted to establish themselves and be interesting to a broad audience.	Because of the open source nature of the 3D printer, th existing user base provided the company's team with many suggestions for improvements, and printing upgrades and replacement parts both became popular projects for learning to operate the units.	The mother company which developed the magnet system, acquired significant amount of resources from external players. The fundamental idea came from a technical university, along with a phd student. For design and construction of the facility incorporating the magnet technology, expertise and test facilities were acquired from several suppliers of components and parts. Design and engineering expertise regarding the facility layout were acquired from another design agency. Finally, the mother company partnered with an established player in the metal recycling industry in order to acquire its expertise and experience in operating/constructing and implementing a recycling facility.	Before the founder started searching for a solution, he operated a small electronic waste take-in firm. He had no substantial technical skills. Throughout the process, through learning and employing different people he acquired the capabilities of glass heating, chemical treatment and manipulation of molten glass flows. Most important of all, was to get exactly the right balance of parameters. After a sale has been made, the company either operates the facility itself or install it at a customer site and trains the customer's staff. Access to funding has been problematic throughout the product's development. In fact, the company has been on the brink of bankruptcy several times. The company acquired some useful resources and capabilties from external partners. A british university helped with developing a process results measurement tool. Through it's first customer, the company got access to computer model simulations and expertise with electronic waste recycling from an Finnish university and the customer's mother company.
accumulating		It was important to have at least part of the concept ready as soon as possible, so that the company could interact with customers. The customers then could shape the company's understanding of how the concept was received, and the company could shape the customer's understanding of the concept.		After the magnet system, underlying technology for the process innovation was developed, all resources were sort of accumulated in a joint venture, which was founded with the purpose of finishing the final design of the facility and initiate commercialisation.	Accumulation of resources and capabilities was initiated 18 years ago, when the founder decided to come up with a solution to CRT recycling. Besides expertise with entrepreneurship and electronic waste take-in, he possessed not particular technical skills. All required capabilities and assets were accumulated during development and were brought together in the company specifically founded for developing and commercialising this technology. At that point in time, 2001, the intellectual property that the founder had created was put into a newly founded company. Within this company, further developments were pursued. During the final design and implementation, the company ran the installation for a full year, to optimize the technology and increase it's understading of the process in practice.
divesting		The company did not have the financial resources to go over things again and again. The company had to stick to what they had in order to drive revenue. The company's management acknowledges this was far from a perfect scenario, but it was good enough to get people (customers and users) involved quickly.	The company divested in laser-cutting technology which was initially used to produce pulleys.	The company divested in its relation/contract with the external design/engineering agency. This agency did not deliver the wanted results. Drawing board ideas could not be translated to practice. The company also broke its relationship with one of the five key suppliers during development. This suppliers also did not make up to its promises.	No particularly important divestments were made during development. Trial and error implies that with every test, some parameters turn out to be wrong, and can be disregarded or omitted from future test. This can be seen as divestment.

governance & organisational structure.		The company can be characterised as a innovative organisation.	The company can be characterised as an innovative company.	the joint venture has an innovative structure. The mother company which did most of the development work is characterised by a divisional structure.	the company has an entrepreneurial structure, with the founder/owner clearly leading the company conduct.
business model			The company's business model is to sell 3D printer kits that customers assemble themselves at home. From their online store they also sell printer upgrades, accessories and plastics used for printing and even assorted open source hardware.	The joint venture has adopted three different business models for commercialising the technology. Currently, however, it prefers to either operationalise the technology internally or opt for a joint venture construction with interested customer companies. The joint venture then gets access to the technology through licenses.	The initial business model the company used to diffuse the technology among customers entailed a simple transaction of the plant, which would then be operated by the customer company. The furnace package is a turnkey item, but the company cooperates with the customer to make sure their glass preparation process will produce a glass feed that is acceptable. Due to the substantial length of time it takes for a customer to make the decision to adopt and implement the whole installation, the company decided to offer another possibility to interested parties. By opening and operating the furnaces at sites across the world themselves, the company offers recycling customers the opportunity of getting rid of their leaded glass waste, without having to invest a lot of time and money in the implementation of the technology themselves. This new approach should make sure that the innovation diffuses in time before the window of opportunity closes.
bundling					
stabilizing		Getting user feedback and using it to further develop the system is a practice that is very natural to the company and they have never stopped deploying this practice.		The mother company's capability of magnet system engineering was anchored within the joint venture by taking over some employees into the joint venture. Development and manufacturing capabilities of suppliers were anchored/tied to the JV by promising them preferential supplier contracts once the technology was launched. The mother company's capabilities with regard to communication and coordination in R&D projects was deployed almost on a daily basis.	The whole process of developing new capabilities and eventually the process innovation was done through trial and error and learning by doing. It has been a collection of thousands of tests. Each time, only one component or variable could be changed (changes to the chemical process, heating, etc.). A test would then be conducted and the results evaluated and analysed. Using these results as new input for certain parameters, the process of testing would start all over again.
enriching		A lot of the software and technology that the company used was open source, and what was not available they built themselves. However, the company did combine existing technology in a manner that was new to the world. Reconfigurations take place constantly, as the design language software needs be updated and improved constantly, based on the feedback the company receives from its user community.	After the company had asked its customers to produce pulleys, it needed to enhance its quality check procedures, to see whether the customer manufactured parts were proper. The user community enhanced its own production skills through learning. Productivity was increased tremendously.	The joint venture partner's capability of constructing and operating recycling facilities was improved by conducting reallife tests with the facility setup, incorporating the magnet system en fluid (a unique combination they hadn't used before). Two additional facilities will be implemented this year at their sites in the Netherlands. Although the mother company already had commercial expertise with selling magnet systems for the recycling industry, it has never sold such a innovative process. The JV had to enhance its sales/commercial capabilities to sell the facility. The joint venture had to enrich the customer relations capability because approaching potential customers is a delicate matter. It requires a balance between motivating the customer and leaking as little knowledge as needed.	Throughout the years, breakthroughs achieved with small scale setups were elevated and reproduced on larger scale setups, untill eventually a full industrial scale working facility could be constructed. This trial and error approach took many years of work to execute.

pioneering		Most energy, in building this process innovation, was not spent on the technology for the platform, but on who would use the system and why. So the capability of community building and shaping, was key, and developed during the research to market trajectory. Analysis and simulation of the concept has taken place to the extent that early in the development potential users and customers of the company's system were involved in the development, to analyse how these individuals would interact with the company's system, and to gain their early feedback and practical insights on how the system was developing. The management says to have always known their endeavour would be a market building exercise. Building up the user community and getting them to learn using the concept was key. The manner in which the company educated its user base, was a key capability that needed to be developed. The company decided to redesign and redevelop their entire concept information package, explaining the how and why of the platform concept and disseminating the new information through channels such as blogs, forums, social media, YouTube, and webinars. Result of this are that designs are easier to convert to physical products, are more sophisticated, and are in general better than earlier designs.	The company pioneered with crowd-sourced manufacturing, born out of necessity. The pulleys used in their own design would break down after 100 hours of usage. The customer could print their own replacement pulleys based on a digitial design distributed by the company. Lateron these customers also helped to anticipate stock shortages of pulleys, due to increasing demand. The company really pioneered with this new capability of crowdsourcing. Through this CSM the company was able to convert "black PR" into product improvement.	By combining the magnet system which was developed internally, and the process liquid as developed by the suppliers, and testing their functioning, the joint venture company developed the capability of manipulating the perceived density of process fluid, enabling the sorting of a large variety of metals with the same facility. The joint venture developed a new purchasing capability. It has to buy suitable waste material in an international context, to keep its own facilities running. An industry veteran was recruited for this purpose. The mother company also formed a joint venture with a different partner, focused on plastics recycling. The company sees a lot of potential in the innovation and tries to exploit many different application fields. This product differentiation capability is another skill under development.	The company did not have any significant capabilities to start with. All developed capabilities with regard to the process and its commercialisation where basically created from scratch. These were however created very gradually. Initial wanted results with small scale tests were stabilised, improvement points were enriched through changing parameters. This combination of stabilising and enriching eventually led to the creation of completely new capabilities.
leveraging					
mobilizing		The step of initial design and synthesis was very much dependent on the objectives of the platform as initially set by the founders of the company at the start. The founders of the company started looking at means for digital production, but found little possibilities. They then thought up the platform as a means to connect the different parties involved in digital production, specifying the objectives of the company's system.		The plan or vision, which described the required capabilities needed to form the vital capability configuration was developed at the very beginning of the project, by the workgroup. This workgroup existed of 7 persons including top management, commercial management and the R&D manager. (The organisation expected to have the capabilities needed to design the facility layout itself, this turned out to be wrong. It lost time during development of the facility due to this and eventually choose to start a joint venture with a recycling company.	For the company, creative thinking was needed to circumvent the use of high-cost material, which eventual brought them to use stainless steel instead of for intance platinum. This turned out to be more cost efficient while performing just as well. The company was bascially forced to perform frugal engineering. The design of the process was focused solely on finding a solution to recycle CRT glass present in TV and PC screens. Within this focus, all possible aspects of getting the lead out of CRT screens have been considered. The company has been very open minded to all possible solutions.
coordinating		The platform itself connects a network of people with design skills, people with access to manufacturing devices such as 3d printers or laser cutters, people with the skill to operate these devices, people with access to specific materials, and people that are in the market to buy specific designs or specialty items. A very important piece of software technology, that is pivotal in bringing all parties together through the company's website and digital storefronts, is the online file-checker and pricing tool. This tool allows design files to be checked automatically to see if it is actually possible to fabricate a product based on the design, and to determine the fabrication price.	Most of the design capability of the community is integrated and exchanged through the digitial design community.	The integration of the different capability configurations was largely done within the joint venture. Here the underlying technology was combined with the process fluid, the operational capability and market knowledge of the joint venture partner and the expertise of the various component suppliers.	The different capability configurations were integrated during the full year of test runs that were conducted to show that the technology was both technically and economically sound.

deploying strategies		The company wanted to both be a software provider as well as a service provider that connects individuals that want to have a specific items produced, to individuals that can fabricate that item, and individuals that can supply the needed materials.		The formed capability configuration was exploited by making use of a resource advantage, market opportunity and entrepreneurial strategy. The resource advantange was established by combining expertise of key players in different fields (patents/exclusive contracts). The market opportunity of the ever increasing raw metal prices makes recycling a more interesting option. The entrepreneurial strategy of forming joint ventures with interested customers, to which licenses are sold, makes the venture both attractive and controlable.	The company made use of its resource advantage, the knowledge created during the years of experimenting and testing, arising because the rest of the recycling industry was ingnoring the problem of CRT recycling. The market opportunity that is there, is only temporary, because the production of new CRT waste is decreasing and will completely stop in the near future. The entrepreneurial spirit and vision of the founder/inventor made sure that the venture persisted during years of failure and industry criticism.
nurture innovation		Analysis and simulation of the concept has taken place to the extent that early in the development potential users and customers of the system were involved in the development, to analyse how these individuals would interact with the company's system, and to gain their early feedback and practical insights on how the system was developing.		Innovation was nurtured and protected througout the process by, not limiting the designers and engineers in any way, choosing for the best possible solution, by closely collaborating with suppliers and letting every player focus on its core competence. Finally, by moving the technology into a new joint venture, it was not hindred whatsoever by customary business routines, and optimal usage could be made of the two partners' combined knowledge.	
Imitation barriers					
cognitive barriers					
uncertainty regarding the future	no, the automotive industry has not radically changed over the past decades.	At first nobody understood the concept. A big hurdle to take was the proof of concept, as the company was first to organise production in this way.			trend in the industry goes towards electronics recycling, because these contain high amounts of metal which require sophisticated techniques to separate. Diffusion of the process was initially aimed to start in 2008. Due to the economic crisis hitting the global economy, the approach for diffusing this innovation process was altered. In the near future, when the production price of flat screen technology will drop below that of CRT screens, the whole industry is expected to disappear and the total quantity of screens that need recycling will start to decline every day.
complexity and interplay of resources				yes, different components in the facility layout have to closely function with the core technology, the magnet system and fluid, underlying this process innovation.	The final solution runs a very thin line between everything that has been done before. A chemical effect is induced under a heated environment, which eventually results in the extraction of the lead. The company makes use of many different technologies. This is actually one of the reasons why the process was successfully developed and so difficult to imitate.
inter-organisational conflict					
complementarity in valuation			A potential competitor clearly would have to had access to a consumer base with 3D printing or similair enabling technology that would allow customers to engage in manufacturing, to conduct crowdsourced manufacturing.		
ong time lags between cause and effect	yes, between investments in the community through event hosting and online-tool building and the eventual customer co-designs that it would produce.				
causal ambiguity	no				

secrecy	no				To keep the process a company secret, the company uses a very thick non-disclosure file. This became especially important when in 2007, the founder started to employ people within the company. Five employees together with the founder would form the development team. Everybody that has ever seen the process, e.g. customers, universities, employees etc, had to sign an NDA that lasts for six years. It is expected that by the time this contract expires, any player that has not already implemented this process will be too late to benefit from the window of opportunity.
Willingness barriers					
institutionalised norms	The car industry is very conservative and has not radically changed over the past decades. It would ve very unlikely that traditional car manufacturers would copy this approach.			Industry opinion towards liquid separation in general, however, still is negative.	Traditional glass manufacturing processes, not concerned with separating lead from CRT waste, would incorporate the use of platinum, a very expensive resource, of which the use in similar processes was thought to be inevitable. Those companies did not really perceive the need to drop this old habit, because they had plenty of financial resources. For the company, creative thinking was needed to circumvent the use of this high-cost material, which eventual brought them to use stainless steel instead of platinum. This turned out to be more cost efficient while performing just as well. The company was not bound to business-as-usual, unlike companies that specialise in chemical processes or businesses that do smelting only. "This process is the result of pure, independent original thinking". According to the owner of the first customer company, in the recycling industry big players generally buy small existing companies with a running facility as opposed to purchasing a bit of innovative engineering
political and cultural institutions		In the early 1980's New Zealand went through a period of major liberalisation of the economy. This lead to a situation where in the early 2000s there were few manufacturers in New Zealand. Getting an item or a product manufactured was difficult. The community will give voice to any potential disappointment in a very public fashion, such as through Twitter, Facebook, and blogs. A university professor from a University Design School was also involved. The company has a strong relationship with the school, which is due to the neo-liberal restructuring in New Zealand of the late 1980s. The school needed to work out how to teach industrial design without having access to factories. The University has evolved into a direction that teaches fabrication not as a separate part but of an integral part of the curriculum. This view really helped to work out the platform concept. This stakeholder participated in the option scheme of the company.			UK environmental agencies were also somewhat involved during the process because of their frequent visit and contact about amendments in environmental law. Finally, the local municipality was involved in a purely financial manner, because they provided a small grant for employing local residents in the region.
environmental stability					The window of opportunity for this technology is closing, because the industry that supplies this technology with its inputs (CRT screens) is completely going to dissapear in the near future.
availability and price of IPR licences		Yes. As the platform concept grew and developed further, an addition type of stakeholder emerged from the fabrication hubs that the company organised on different continents. This stakeholder licenses the concept and storefront from the company for a start-up and a monthly fee. Then, for each platform order this stakeholder processes, both he and the company get a share of the revenue.		Licenses are aviablable at a reasonable price for interested parties. Indeed, this is the business model the company preferably opts for. Create a joint venture with the customer company and sell licenses to the newly founded JV.	
Ability barriers					

Intellectual property rights					
patents/utility models		yes, but only on the online web-store front which was licensed to one particular vendor. Not on the core element making the process innovation novel.	no	yes, on the magnet system underlying new process. This magnet system was developed internally and indepently by the JV's mother company.	**No,** Although this process innovation is new to the world, the technology is not patented. It is a company secret. An IP lawyer, who had been with the company during the developing years, stated that applying for a patent would be commercial suicide. If the company were to apply for a patent, disclosure of the invention would be required. The disclosed information would enable a person skilled in the art to create a similar product. Disclosure would thus allow people to copy the invention. Furthermore, according to the company a patent is only as strong as the amount of money there is to defend it. Moreover, a patent would still not enable the company to really defend the invention in foreign countries.
trade secrets/NDAs					To keep the process a company secret, the company uses a very thick non-disclosure file.
path dependency					
irreversible investments	investments made mass production models and production lines for mass production models first need to be earned back by traditional car manufacturers.	At that time the company defined a careful narrative and it took great patience to bring about the change that the market required for the company to succeed. They are sceptical about the idea that a market by itself would have evolved without them. They have observed other markets, and these markets were shaped by participants very heavily.			Competitors did not invest in this technology in the past, due to which they will not be able to commercialise the technology before the window of opportunity closes, in case they would attempt imitation.
time compression diseconomies		It was important to have at least part of the concept ready as soon as possible, so that the company could interact with customers. The customers then could shape the company's understanding of how the concept was received, and the company could shape the customer's understanding of the concept.	Each batch of new units would be slightly upgraded as time went on.		Yes, according to the founder, competing companies are not able to come up with a similar technology in a short period of time, because it takes substantial time to figure out how all the different parameters must be setup in relation to each other.
asset mass efficiencies	Yes, through snowball effect in the form of network externalities or communication good effects.	Yes, through snowball effect in the form of network externalities or communication good effects.	Yes, through snowball effect in the form of network externalities or communication good effects.		
experience economies	how to build a community	It was important to have at least part of the concept ready as soon as possible, so that the company could interact with customers. The customers then could shape the company's understanding of how the concept was received, and the company could shape the customer's understanding of the concept.		yes, the JV first ran the facility internally for a year to make improvements and see whether the technology functioned properly.	Retaining the molten lead after extraction was the biggest problem that could not be calculated. Experimentation was needed to see how it would react and how it could be best contained.
social complexity					
presence of socially complex resources	yes, the community mechanism	More specifically, the platform allows designers, fabricators, material suppliers and buyers to find one another and co-create in a manner that is efficient, transparent and mutually profitable. A large number of flexible business cases can be made to work based on the platform's concept of digital transportation of design files and local fabrication of items in production hubs throughout the world.	Crowdsourced manufacturing not only helped the company to solve the technical issues with falty parts, lack of production capacity, but it also helped the company to build and strengthen its user community base.		
social engineering required	yes, takes a lot of time and effort.	yes, takes a lot of time and effort.			
resource interrelatedness					

balancing of resources	yes, takes a hard balance in which actions have to be performed by the engineers of Car and of the design community. Futhermore the balance between creating an interesting automotive experience and necessary but boring construction work.				The process itself is a novel combination of already existing processes and theories. For example, the method of getting the lead to separate from the oxygen is called a reducing process, already stemming from the 19th century. Combined with relatively basic technologies, originating from electrical engineering, glass arts and chemistry in a very specific balance, this allows for the extraction of lead from CRT waste. There are many different factors involved, and if any parameter is set-up wrong, the process will not work. The process demands exactly the right combination of temperature, chemicals, molten glass flow and timing, which have to be present in a very specific way. The final solution runs a very thin line between everything that has been done before. A chemical effect is induced under a heated environment, which eventually results in the extraction of the lead. The company makes use of many different technologies. This is actually one of the reasons why the process was successfully developed and so difficult to imitate.
economies of scope			yes, the product the company sold, enabled the customers to help in manufacturing.	yes, through combining knowledge of both JV partners, the two suppliers of the process liquid and the other four key suppliers of facility components.	
causal ambiguity					
two sided ambiguity					
single sided ambiguity					
deterministic nature				yes, through secrecy	
stochastic nature					with regard to trial and error, learning by doing. Always encompasses a good share of luck.
information impactedness & secrecy				yes, process and info on process were kept isolated from the rest of the organisation.	To keep the process a company secret, the company uses a very thick non-disclosure file. This became especially important when in 2007, the founder started to employ people within the company. Five employees together with the founder would form the development team. Everybody that has ever seen the process, e.g. customers, universities, employees etc, had to sign an NDA that lasts for six years. It is expected that by the time this contract expires, any player that has not already implemented this process will be too late to benefit from the window of opportunity.
preferential market access					
communication good effects	In addition, the community is Car's most valuable asset and because of the lock-in and loyalty of users, their community is difficult to replicate;	The platform becomes more attractive to both producers and buyers with increasing user numbers.	Community members benefit from an increasing community, because of the exchange of 3D printing designs. The company also benefits from an increasing community, because it has more potential co-manufacturers available.		

buyer evaluation cost	Process is aimed at automotive enthusiasts, which will probably form the opion leaders.	Still it was hard to reach a good level of understanding among the general public, and a lot of people still don't understand the company's concept and the benefits it offers. A large technology event, however, found the platform interesting enough to have them present. It was one of the early key validation moments of the company. The launch is considered by the company's management to be very valuable, and is seen as a very early validation that changed a lot of things for the better inside the company, settling in the image of being an international company with the first overseas market being the Unites States. The community will give voice to any potential disappointment in a very public fashion, such as through Twitter, Facebook, and blogs. The most unhappy community members are those members that send emails expressing their unhappiness. When these individuals notice that their problem is solved in a way that is meaningful, they will spread the positive word on the platform, generating a great word of mouth.	At the start, the company shipped a product that would eventually fail (faulty pulleys). Most companies would recall those products. This company however saw it as a challenge, and as a problem that could be turned into success through crowdsourced manufacturing. The company saw the importance of keeping production and shipments high, to enlarge the community. At that time, the company's customers were mainly so called technology enthusiasts and engineers, who were open towards challenges and found it exciting to be able to work on the solution together with the company. By cooperating with its user base of technology enthusiasts, the company got valuable feedback early in the design cycle and got supports who would influence other buyers in the marketplace.		
advertising & channel crowding	first co-creation crowdsourced automobile manufacturing platform.	The opening of the European fabrication hub proved that the concept works. The proof of concept generated a lot of press and public attention for the company. Still it was hard to reach a good level of understanding among the general public, and a lot of people still don't understand the company's concept and the benefits it offers.	Existing research shows that the best way to reach technology enthusiasts is to place a message on the internet. Direct email with factual information will also work. This is exactly what the company did, and applying the appropriate communication means can partially explain the success of the whole exercise.		
product complementarities					
buyer switching costs	In addition, the community is Car's most valuable asset and because of the lock-in and loyalty of users, their community is difficult to replicate;	The platform concept incorporates a tool that requires a specific level of skill for people to engage with it. It doesn't naturally occur to people and it requires a new type of thinking. Users need to learn specific things and they need to make an investment (spending time and energy) before they can use it. This allows for drawing a parallel to the early computer market, where people would need to learn computer language to use computers. The market in which the company operates is similar to the 1978 computer market, where sellers need to invest in up-skilling potential buyers. The management says to have always known their endeavour would be a market building exercise. However, they consider themselves to have been naïve on the time it would cost and amount and types of messages to convey for people to "catch on and get it".	To be part of the community and make use of the growing collection of designs etc., a customer first has to purchase a 3D printer. It then takes some learning to get used to the system. These two factors create substantial buyer switching cost, in case a rivaling system would arise.		
pre-emptive actions					
inputs	yes, investments made by customers into the car designs and community platform. Enthousiast are already bound to this community. They won't likely switch to another platform due to switching costs/lock in : "the community is Car's most valuable asset and because of the lock-in and loyalty of users, their community is difficult to replicate"	preemption of technology enthousiasts, innovators, and manufacturers with production capacity, which have already been tied to the community.		the two suppliers of the liquid developed a custom-made fluid for the joint venture. The properties of the liquid substance are of high influence to the success of the process. The joint venture established exclusive contracts with the suppliers of this fluid.	
market positions	no, many customisable, carkit kind of car manufacturers out there.				
know-how	no, no exclusive contract whatsoever with regard to knowledge acquisition.			yes, see patents	partially, by having personnel, customers and other persons that have seen the innovation, sign a NDA.
distinct managerial capabilities					

cific knowledge possessed by managers	yes, on of the founders worked for McKinsey & Co's automotive practice. Besides his father used to own a motorcycle company.			The commercial manager (and partial owner of the JV) and technical manager possess substantial combined knowledge of both the recycling and magnet systems industries, through their employment within both mother companies.	Many people who tracked the development of the process stated that if the founder had had a chemical or glass manufacturing background, he would have never pursued this solution. Many critics of this approach have claimed that what the company was trying to achieve, was impossible. Proving them wrong obviously has been very rewarding for the whole team.
d team-specific experience of managers				The commercial manager (and partial owner of the JV) and technical manager possess substantial combined knowledge of both the recycling and magnet systems industries, through their employment within both mother companies.	yes, the manager knows exactly which tasks to give to which person. Clearly involved with coordinating the whole team.
entrepreneurial vision of managers	yes, one of the founder had a mental model or roadmap in mind, which formed the development process.	A strong desire and a feeling among the company's founders that they could and wanted to build the company. They were creating a system that solves a personal itch.	The three founders are clear proponents of empowering customers and other people around them. They were already involved with open innovation in the past and had a clear vision to develop this innovation.		This lack of a solution to this problem was a source of motivation for the inventor to develop this process innovation. The founder can be considered a persistent leader with a clear vision, who keeps generating diverse solutions. He came up with a list of tasks that other people needed to carry out. Employees were left with their tasks and goals.
development strategy complexity					
distinct organisational capabilities					
producer learning			producer learning was not only present at the company, but also at the customer base, which was able to improve its productivity itself.		The process was run for a full year to improve it and enhance technological understanding.
organisational learning			Business development and technology development were both done in a DIY or "learning by doing" process.		The core development successes have mainly been achieved through trial and error and learning by doing.

	Cases				
Nature of the innovation	**6 CO2 dye**	**7. Copper**	**8. Biofuel**	**9. In-cell**	**10. CFL**
Competitive advantage	The company is the world's first supplier of industrial CO2 textile dyeing equipment. By replacing water with pressurised CO2, the process of dyeing textile becomes more economically and environmentally friendly. It is a complete water free dyeing process with considerable lower operational costs compared to the conventional dyeing processes. Other advantages include: elimination of wastewater discharges; wastewater treatment process eliminated; elimination of drying and dryer effluent; reduction in energy consumption; reduction in air emissions; reduction in dyeing time; surfactants and auxiliary chemicals in dyes eliminated; dye utilization is very high with very little residue dye; unused dye can be recaptured; approximately 95% of used CO2 will be recycled; fewer red dyes are required; and colour correction is easier compared to aqueous dyeing.	The company developed a recycling technology for separating copper rich parts from metal scrap. The goal of the clean scrap machine is to extract non-contaminated ferro parts from a mix stream of scrap. By getting ferrous scrap completely clean, while concurrently doubling the quantity of copper that can be extracted from the ferrous scrap stream, the company ensures that scrap continues to serve as a vital source of raw materials for both the steel and copper production industries. New separation technique; using the concept of magnetism combined with velocity and material density, they are able to separate copper from metal scrap; (material is sorted based on density, shape and magnetic properties). Advantages are: • Higher copper revenues; • Higher scrap quality; • Less hand sorting; • Consistent quality of outputs; • Simple and robust recycling system.	The company has developed an advanced fermentation process through its cutting edge research in advanced microbial technology. The company has a large library of biocatalysts and has developed a fermentation process that produces low cost and renewable butanol from waste and agricultural by-products. It delivers high performance with strains and sustainable feedstocks at the lowest cost, and with minimum negative environmental and social impact. The company provides fermentation technology to customer's facilities in various countries to enable low cost biobutanol production from sustainable feedstocks for the chemical market. Furthermore, the company's novel process has the potential to reduce cost so that biobutanol can compete in the biofuel market.	The company specialises in printers, scanners, and photography machines. It has replaced its fixed conveyor belts with push carts that allow for a flexible in cell production process. As a practical implication of the cell-based process, the cart pulling method uses carts as a transport tool. The unit to be assembled is loaded on a cart, and the cart is then pulled or propelled along different work stations for different assembly operations .The company reports that the transition from a belt conveyor production process to a push cart production process has lead to electricity savings of 99%, a 67% reduction in square footage needed for the process to operate, a 99% saving on initial investment, the obliteration of maintenance costs, and a 99% reduction of carbon-dioxide emissions.	The company, the world leader in rare earth-based formulations, has developed a new process for the recovery and separation of rare earths contained in used low-energy light bulbs. Rare earth elements or rare earth metals are a set of seventeen chemical elements in the periodic table. Six of these elements are used variably in CFLs, of which the five most common are yttrium, europium, terbium, cerium and lanthanum . In the past, rare earths contained in CFLs were considered waste and ended up in landfills. By use of the company's new recycling process, these materials can now be extracted for reuse. Due to their scarcity and unique application benefits, these metals are highly valuable.
subjectivity of innovation	new to the world	The separation technology is new to the world.	The innovation is new to the operating market of the firm.	The innovation is new to the world.	New to the world.
process of innovation	A consortium of three partners was responsible for developing the first working prototype (the company's mother firm, a technical university and large machine builder), based on 25 year old patents. The mother company's founder/owner together with the company's commercial director/owner founded the company as a spin-off of the mother company. Within this new company, the prototype was further developed. Initial prototype development took 7 years. Development from the initial prototype until a full implemented machine took approximately 4 years, from 2008 until 2011.	The company is a spin-off of a technical university in the Netherlands.The technology underlying the process innovation was developed by the university. A university professor assembled a team and found a solution. The result was an advanced prototype in 2009. This is where the technology for the process innovation was developed. After the technology was derived, the idea was spun off in 2009. Together with a VC, the university started a company that would exploit the innovation.	The idea developed by the company was to improve microbial performance of the fermentation. It did extensive work on genetic manipulation of microbes to improve solvent yield, concentration, and improvement of fermentation productivity. The founder established the company from scratch by offering contract research services. The butanol fermentation process, however, is not new. Its development could be traced back to the year 1912, when it was first developed and commercialised in the UK. Subsequently, it spread around the world	In the last few years a new production system has emerged in Japan's manufacturing industry, showing both economic benefits and environmental advantages compared to the factories using conveyor belts. In some Japanese factories, this old system has been replaced by a new 'cell'-based process, wherein a small number of workers assemble units from start to finish. ---- It took the company three months to get from initial concept to final design, and three months to get from final design to implementation. The cart line process originated from within the company itself.	The development process for this innovation was initiated in 2007. Implementation of the process started in April 2012. The whole development process took approximately five years. The technical origin for this idea came from the company's internal R&D department, as the result of a large market analysis.
roles of innovation	(Manufacturer dominated) The development and diffusion of this technology can be considered a combination of demand pull and technology push. The technology was pushed by the company by offering such significant performance improvements relative to conventional textile dyeing techniques, that industry players could just not ignore its existence. Market pull was created by partnering with large fashion labels.	An industry giant indicated that copper contamination in ferrous scrap was increasingly becoming a probem, in 2007. The industry giant argued that there was a need for a robust solution to solve this problem (non-robust solution existed).	The founder of the company noticed a huge demand for biobutanol in the chemical market in the last three or four years.	This innovation was clearly manufacturer dominated. No customers or other external parties were involved. The innovation is the result of technology push.	The development process for this innovation was manufacturer dominated. It is the result of technology push and market pull. There is a clear need from the market for additional suppliers of rare earth material, due to China's clear monopoly position in this market.
degree of innovation	This process innovation can be considered a radical innovation. The technological change from the producer's view is high. The increased benefit for customers is also very high.	The technological change from a producer's view is rather limited, because it mainly uses existing principles in the recycling industry. Eddy current separators are known to use both velocity and magnets to separate ferrous and non-ferrous material. The increased benefit from a customer's view is high. Steel industry giants have highlighted the increasing problem of copper contimination in steel production. This requires more robust techniques that can deliver a clean, copper-free scrap input for steel production.	The technological change from the producer's view is relatively high, due to the advanced use and development of microbes, which improves fermentation productivity. Because this advanced technology allows for the reopening of idle existing fermentation platns, the increased benefit from the customer's view is also high. This therefore is a radical innovation.	The technological change from the producer's view is limited, because it merely encompasses a logistical change in the production line of the producer. The increased benefit for the customer is also low, because it only entails incremental improvements in quality, flexibility and price. This innovation therefore is incremental.	This innovation can be considered an application innovation. The technological change from the producer's view is relatively low, because most of the capabilities required for this process were already present within the company. The company already knew the forward approach. The increased benefit from the buyer's view is high, because waste is transformed in a valuable resource.

success of innovation	The cost, energy, and polution saving realised through using this technology. The first machines have already been sold to a launch customer. BEP, not yet been reached.	The recycling process has been implemented at a number of external companies. Moreover, the company expects to close more large deals in the near future. It also already won an innovation price in its home country (2010). The break-even point has not yet been reached.	No, the company has not reached the break-even point yet. The company already has customers for the process in China. It is in the process of rolling-out full-scale commercialisation of the process. The resulting product of the new production process will be on the market somewhere in 2012.	The company reports that the transition from a belt conveyor production process to a push cart production process has lead to electricity savings of 99%, a 67% reduction in square footage needed for the process to operate, a 99% saving on initial investment, the obliteration of maintenance costs, and a 99% reduction of carbon-dioxide emissions. BEP=YES	The innovation is only going to be implemented and operated internally. The innovation is a market success in so far as the company considers it to be a technical and business success. The technology allows the recycling of rare earth material that otherwise would end up at landfills. BEP, not reached.
Hard/Soft innovation	Hard	Hard	Hard, but elements of Soft, due to the close cooperation with existing butanol plant owners (customers).	Hard	Hard
Tighly/Loosely managed	Tight	Loosely	Loosely	Tight	Tight
Internally/Externally commercialised	Externally	externally & internally	Externally	Internally, but company helped to spread the innovation to other large Japanese manufacturers (without commercial aims)	internally
Firm characteristics					
firm size	SME, the company currently has 10 employees, of which 9 have a technical background.	SME (<250 employees)	SME (40 employees)	Multinational, globally operating and employing over 100,000 employees	The company has over 14,000 employees.
firm maturity	The company was founded in 2008 as a spin-off. The spin-off's mother company, however, already had plenty of experience in commercialising liquid CO2 based technologies.	The company was only founded in 2008. It is thus still a relatively young start-up.	The company was already founded in 2003. The first years were mainly focused on research. From 2007 onwards, the company started focusing on commercialisation. (start-up)	Established, incumbent company.	The company was created in 1998, as a spinoff resulting from a merger between two established players. The company is already established in 25 countries around the world.
organisational structure	Innovative/Adhocracy organisation	Innovative/adhocracy organisation	Innovative organisation	Machine organisation (bureacratic)	Divisional organisation
sector of origin	C Manufacturing; 13. Manufacture of textiles; 13.3Finishing of textiles.	C Manufacturing: 28 Manufacture of machinery and equipment	C Manufacturing, 20.59 Manufacture of other chemical products n.e.c.; M Professional, Scientific and Technical activities, 72 Scientific research and development	26.30 Manufacture of consumer electronics; 26.20 Manufacture of computers and peripheral equipment; 26.70 Manufacture of optical instruments and photographic equipment.	20.1 Manufacture of basic chemicals, fertilisers and nitrogen compounds, plastics and synthetic rubber in primary forms, 20.6 Manufacture of man-made fibres, 20.59 Manufacture of other chemical products n.e.c., 20.41 Manufacture of soap and detergents, cleaning and polishing preparations. 20.20 Manufacture of pesticides and other agrochemical products.
country of origin	Netherlands	Netherlands	UK	Japan	France
current availability on market	Global market: Currently the technology is only operated in Thailand, but the company aims to penetrate the global textile dyeing industry next year.	Global market	The first plant deploying the company's fermentation process is expected to become operational in China in the summer of 2012. The company has a few early stage commercial prospects running in India, Brazil and the United States.	The firm that developed and implemented the process innovation is a global company, hence the innovative production process touches the global market. It is however, not globally for sale.	The technology is only being operated internally, at two of the company's sites in France.
ownership structure	The company is partially owned by its former mother company, its manager and some investors. The mother company no longer owns more than 50% of the shares. The company is independent now.	The company was founded as a partnership between a technical university and a venture capitalist firm. The university owns 30% of the shares, the VC 70%.		Public company (Tokyo Stock Exchange)	The firm is a member of a large global business conglomorate.
manner of funding	The initial prototype was funded by three partner organisations, two companies and a university. The final version of the technology was funded by private investors and the Dutch national government.	• Venture capital / private equity • Grants and subsidies	• 'Friends & Family' • High net worth individuals ("Business Angels") • Venture capital • Grants and subsidies • Service contracts	The development and implementation of the cart lines was financed out of operational profits.	The innovation was completely funded internally, with cash reserves available within the company.
Success factors and barriers					

micro succes factors	• Availability of a working prototype from the spinoff's former mother company; • Access to the mother company's broad base of knowledge concerning liquid CO2 technology; • Smart application of patents, which provides the company with broad protection of its technology without disclosing crucial process features. This is enabled by the spin-off's very specific knowledge of liquid CO2 dyeing.	• Skilled and motivated team with the right background (i.e. a PhD student who was involved was doing his PhD study in the field of magnetism); • The professor mainly involved with this project from the technical university is an experienced researcher and had tackled other challenging projects before; • The university was very supportive of developing the technology and gave the research team room to do extensive research and come up with their solutions; • Restructured management did a great job on changing the company and its corporate culture; • Restructured management understood that complex innovations require time and was able to convince the VC of this; • Thanks to the restructured management, the process was improved and successfully sold as a result.	• Deep understanding of the technology – The company has rich expertise in the fermentation technology. In addition, it has strong technical capabilities in advanced fermentation technology; • Agility – The Company has the ability to move more quickly than its competitors. This is due to its strong technical competence and its relatively small size which helps it to speed up any decision making; • Customer-centric approach – The company has developed close linkages with their customers. It very well understands the customer needs. They provide solutions tailored to customer requirements rather than pushing their own thoughts on the issues; • Innovative business strategy – The company's low risk and lower capital strategy of first restarting the existing facilities with their technology helped to speed up the time to market. Also, this low-risk strategy increases the chances of securing deals with potential customers.	• Availability of required skills and competences – Being a large company, the firm has been able to draw upon the vast pool of skills and competences available within their staff. This has been helpful as it has minimised the need for sourcing, procurement or alliance building, which may have taken valuable time away from the development of the line carts; • Use of efficient channels of dissemination of information – The existing information infrastructure within the company also has been a helpful factor in designing, testing and implementing the cart lines. The company has made use of email listings, e-learning modules and video tutorials to disseminate the new production process to all stakeholder within the company; • Involvement of workers at early stages – The development of the cart lines has benefited from early-stage user involvement. Shop-floor workers were involved in the planning of the implementation of the cart lines and were involved with testing the cart lines and the individual carts as well as evaluating their performance. This has allowed for timely feedback to the engineers on issues that might not have occurred to them otherwise.	• The company has a fulltime R&D department and substantial amounts of experience with managing large R&D projects and constructing industrial scale facilities. This contributed to efficiency and the timely realisation of this innovation; • The company possessed adequate internal financial resources to fund the development project independently; • Experienced legal staff engaged with the patentability; FTO and patent application procedure contributed to securing the required intellectual property rights for this innovation; • Synergy between hydrometallurgy chemists and pyrometallurgy chemists contributed to the development of the technology; • Synergy between experienced operators and new employees at plants contributed to a more fluent implementation process; • The company being a producer of several phosphor precursors and luminescent powder precursors, already had significant experience and knowledge concerning the production of rare earth material. This knowledge and experience could be deployed for developing a reverse-production or recycling process.
micro barriers	• No were explicitly mentioned.	• The venture capitalist pushed for short-term returns, putting a lot of pressure on the old management (management changed during the process) to pursue sales too early; • As a consequence, all resources were channelled into marketing and sales activities, even though potential clients argued that the product was not fully developed. Despite all these efforts, no subsequent sales were made; • This push for sales led to deteriorating relationships with manufacturers and research partners, which needed to be overcome by the restructured management in order to take the process to a new level; • In addition, the technology needed to work under rough conditions. This put some constraints on the design, because if it did not fulfil that requirement, it would lose one of the key characteristics that could make it a successful innovation; • Coming up with the design took a lot of time and used extensive resources from the manufacturing company. The initial design they come up with was of approximately 80% of the desired quality. The remaining 20% needed to be fine tuned. As they agreed on a fixed fee, the manufacturing company struggled to stay within budget.	• Perceived technical risk and customer inertia – Most of the customers are hesitant to adopt any new technology. They are cautious of implementing new processes. People perceive technical risks. The root cause of the hesitance lies in implementing new technologies which have a history of failures. Customers do think of alternative uses of capital; • Technical difficulties – The Company did face a few technical barriers while moving to feedstock. However, the team overcame those.	• Risk aversion – The design and implementation of the cart lines has suffered somewhat from risk aversion, as initially some resistance was shown towards the new production system.	• Difficulties with finding suitable partners for commercialisation; • Time pressure on the redesign and reconfiguration process, due to early implementation decision; • Acquiring the permit for recycling materials at one of the company's sites in France from the EPA was difficult. This caused the delay of the implementation process; • Communication between chemistry specialists and recycling specialists was difficult because the latter were not familiar with chemistry jargon.

meso success factors	• The launching customer for this process innovation generated market exposure for this technology and provided the company with valuable input for reconfiguration; • A partnership between a big sports fashion label and the company creates market pull for the adoption of this innovation. By putting pressure on its suppliers and creating incentives for adoption, the fashion label stimulates the diffusion of this process innovation.	• Owing to the close cooperation between researchers from a technical university and a manufacturing company, two well functioning demonstration models were developed in a relatively short term; • The technical university used its network to gain feedback and make the first sale. By approaching a close contact, they not only received feedback on the design, but made their first sale quickly.	• Increased demand of renewable chemicals – In the last three or four years, there is a huge demand from the chemical industry for green and renewable chemicals and alternatives to conventional petrochemicals. The company noticed the demand for biobutanol in the chemical market. The market forms a perfect breeding ground for the company's process; • Availability of market opportunity – There is a presence of ample idle ethanol and butanol production plants whose owners are in search of solutions to restart those production plants. The company is providing the technology, improved microbes for fermentation, to Chinese companies which will allow them to restart their plants on alternative, lower cost feedstocks.	none were mentioned	• The collection circuit for light bulbs was already in place at ecological organisations across France. This enabled the company to focus solely on the actual recycling process; • The nature of this process, recycling of scarce resources, matches with the company's vision and CSR values, which it wants to communicate to its customers, unions and the general public. This match made it easier for the R&D department to accomplish the project's predetermined goals, because conflicting requirements between different dimensions were absent.
meso barriers	• The textile manufacturing industry is considered to be very conservative. The industry is mainly cost driven and does not care much about sustainability; • The spin-off being the first company to enter the market for liquid CO2 textile dyeing technology, faces a significant challenge in developing all peripheral equipment and products supporting this technology.	• Designing the machinery was challenging at times and required help of a technical university and an external manufacturing company to closely cooperate to come up with a fitting solution;	none were identified	none were mentioned	• The company's subcontractors that are tasked with the collection of CFL waste material are faced with stringent French legislation regarding the transport of hazardous waste. This legislation increases the cost of transportation for subcontractors and consequently has effect on the price that the company has to pay for procurement of CFL waste.
macro success factors	• The global trend towards sustainability forces large fashion labels to adopt a more "green" image towards its customers. A partnership with an environmentally friendly technology company like the spin-off adds to this; • Water scarcity is becoming a serious issue in most textile manufacturing countries. Most textile treatment and manufacturing facilities are located in Asian countries. Adoption of the company's technology could drastically decrease water pollution in these countries.	• The company had access to a venture capitalist right from the start, which provided well-needed funding at the beginning of the innovation cycle. As turned out, this also defined some of the challenges the company has faced; • The technology helps with current environmental problems by providing a recycling solution for copper contaminated metal scraps. This puts the innovation in a positive perspective.	• Rise in the price of substitute - The economics of the fermentation process relative to the petroleum alternative is sensitive to oil prices and feedstock cost. Now that oil prices have recovered, fermentation looks to be a more viable option.	• The presence of an appropriate normative framework of standards – The company aims to integrate a focus on their environmental impact with their product lifecycle, through sustainable environmental management, production processes, and products. This connects well both to the global trend towards more green and sustainable products and processes, and to the development of the cart line production process, which is expected and has shown to deliver tangible (energy) efficiency benefits.	• The volume of rare earth materials exported by China is dropping, even though world demand is increasing. Resulting supply deficits and increasing resource prices can be considered a window of opportunity for this particular technology; • Increasing prices of rare earth material allows the company to make a healthy return on investments made into this project.
macro barriers	• Acquisition of funding was hard in 2008, due to the financial and economic crisis.	• The recycling business is a very conservative world and you often get only one chance to prove your product's worth; • Lack of local member state support for potential business activities in riskier countries (i.e. Turkey) was indicated to hinder the possible commercial success of the innovation. In these countries there is demand, and the company is in contact with interested potential clients, but it has proven to be difficult to raise capital in these countries.	• Operational and management issues working in foreign country - There are a number of challenges in working at different countries. The company has experienced a few barriers on the site, consisting mainly of operational and management issues.	• The need for risk assessments and protocols within the industry – The manufacturing industry's practice of risk assessments and process protocols has somewhat slowed down the design and implementation of the cart lines.	• It is hard for the company to convince a company that collects low energy light bulbs to sell their waste to them. Chinese companies for instance are able to offer better prices due to less stringent environmental standards, health policies and labour laws.
Resources					
physical capital resources	The company had access to a working prototype (using the same principles as the current technology), which was developed by three influential partners based on significant funding. Within this consortium, the university faciltated the working environment and graduate students. The large industry player mainly contributed financial resources, together with the government. The consortium developed the required experimental setups and testing equipment.	The prototype that was developed by the university. By 2009, there were also two demonstration models ready. These were developed by an external manufacturing company, with the help of the university. The venture capital firm invested 1,7 million EUR and the university supplied the necessary human capital and inputs.	The company has an extensive research facility and a laboratory in the UK. In December 2011, the company acquired another U.S. based biobutanol technology company. It adds engineering and operational skills to the company as well as a pilot plant facility, and serves as an operational base for the firm to address market opportunities in North America. Through contract research the company generated revenues right from day one. After the first three years, the company received investment from friends and family, business angels (high net-worth individuals), and more recently, venture capitalists and institutional investors.	Tools and simulation models used to develop and test the cart line and the carts included computer-aided design and commercially procured machines and electrical parts. These were either developed in-house and were already partially present within the company. --------The company verified the technology by constructing a prototype cart line and tested it in a controlled setting.	The process of separating and extracting rare earth material starts with a used CFL as input material. These light bulbs first need to be collected, which is done by ecological organisations. These organisations then send the collected material forward to sub recyclers, who crush and separate the light bulbs down to metals, glass, plastics and mercury. The company then takes in the glass containing the luminescent powders from sub recyclers at their plant. The project tried to reuse a lot of existing equipment to keep costs down. Today, more than 90% of the main equipment that is being incorporated is previously used equipment. This is part of the whole business philosophy of the company.

human capital resources	The company had access to the mother company's liquid CO2 technology. Within the consortium responsible for the first prototype, the mother company mainly contributed technological expertise through its employees. It also employs nine technicians itself, specialising in either engineering, technical design, process development and laboratory skills. Those engineers are highly skilled machine construction, especially with regards to 3D rendering and component integration. Their commitment and motivation eventually led to the development of this innovative process technology. Relationships/partnerships with both a launch customer and large fashion labels were key. The first for final development and diffusion, the latter mainly for diffision.	By focusing on fewer potential clients, but investing more time in the relationship with them, the company managed to make extra sales. One of the key successfactors was the skilled and motivated team with the right background (i.e. the PhD student who was involved was doing his PhD in the field of magnetism), the professor from university with a lot of project experience, and finally the good relationships with the technical university, which was very supportive.	The founder holds a PhD degree in biochemical engineering and a BSc in Microbiology. In 2008, the current Chief Executive Officer (CEO) joined the company. He leveraged his rich experience in the sector of energy and renewable to help commercialise the fermentation technology of the company. The company promotes its process largely on a relationship basis. The company usually engages in dialogue with the potential beneficiaries of the process, such as people with existing butanol and biobutanol plants in China, entities with sugar mills in the company's key markets, ethanol plant owners in the U.S., and also end-users of butanol. -----------The company already had links in China.-------------The company has about forty employees, including management, with a background in science, management and production engineering. The people have experience primarily in the field of fermentation and renewable chemicals. There are six employees working each on the commercialisation side and in engineering and operations. About twenty five employees are engaged in research activities, development and technology transfer. The research team has skills in microbiology, molecular biology and fermentation.	Design and development of the process was entirely performed by the company's internal equipment engineers. They were responsible for designing, prototyping, testing, implementing and redesigning the cart lines --------• Shop-floor workers were involved in the planning of the implementation of the cart lines and were involved with testing the cart lines and the individual carts as well as evaluating their performance.	There was plenty of freedom for system designers during the development process. They played a key role in identifying, defining, patenting and industrialising the process. Furthermore, development employees participated in selection of the site to implement the technology at. During all of these steps, employees had a significant influence. Recruitment of the operators started at the end of 2011. These persons needed to be trained in order to teach them how to operate the plant. R&D personnel was active at the plants for more than two months, in order to support the operators. More than 20 new people were recruited. In new projects, the company always makes a mix between new employees and experienced employees. New employees were recruited and linked to the correct workshops for training purposes.
organisational capital resources			The company has deployed a digital communication protocol that ties into the flexible cart line. Anywhere in the world, a company's salesperson can forward orders digitally to the company's plant in Japan, including customised features negotiated with the client. The information is then processed within the plant, instantly initiating the required manufacturing process with the production cell tailored to the specific manufacturing requirements, while allowing the company's manufacturers to flexibly change the volume of production on a weekly basis and maintain production speed and efficiency even when faced with considerable fluctuations in demand.	To complete a transition from conveyor belts to pull carts is seen as a very complicated decision-making process, entailing the choices of how many cells should be deployed, the number of workers assigned to each cell, and how to evaluate the performance improvement expected from the transition.---------The company developed a control measurement system. During the deployment of the carts it turned out that implementation of proper control measures made it possible to omit the originally designed functionality of cart overload detection. As this detection system would be redundant in relation to the implemented control measures, the design of the carts could be additionally simplified.	The information on this new technology was communicated using the company's public relations departmetn, through many speeches and presentations to unions, the safety groups of the unions, the media, the involved plants and the company's R&D community. The company's effective and experienced legal department was responsible for swift acquisition of patents. The company's marketing department contributed substantially to the commercial dimension of the project.Four employees within this GBU are working on strategic marketing. They conducted a marketing analysis to check whether the company was approaching the right markets and companies for acquiring powders to recycle and for selling the recycled material.
structuring					

acquiring	After conceptual design was completed, the company broke down the machine into its most key components. Based on the precise 3D drawing the company made, component suppliers were found and instructed. The suppliers then drew up the designs of the separate machine parts.For outsourcing the development of machine parts to supplier companies, clear requirements, parameters and design layout needed to be established. By combining all design codes (restrictions due to certain design rules) a certain optimal design arose, which determined what the final machine should look like. The launch customer, the innovator or early adopter of this technology, can be considered to be a real success factor for this phase of development. This company was willing to accept a machine that was still not perfect, but had the potential of changing the textile dyeing industry in the near future. The launch customer provided the company with a real-life industry test-environment.	The university provided preliminary designs and offered support, but the external manufacturing company was left free to come up with the final design of the demonstration models. One of the demonstration models was tested at a close contact of the university and was subsequently sold. Based on feedback they had received and based on additional research, the design was further improved. This increased the efficiency of the innovation. The venture capital firm invested 1,7 million EUR and the university supplied the necessary human capital and inputs. The government also provided 300,000 euros of capital. Through the university's relations with a key launch customer, the company was provided with feedback and was able to sell its first large demonstration model.	During the initial years, various key activities such as finding and funding lab space, acquiring research equipment, attracting talented people and advancing the butanol technology were undertaken to set up the company. Customers are mostly well informed about the availability of different feedstock in their area. The company cooperates with them through regular conversations to decide on the feedstock option. After diligently evaluating all the possible feedstock options, the company selects the most economic feedstock.-----It has partnered with diverse institutions and companies across the globe such as research labs of various universities, with pre-treatment technology companies and a range of companies for cellulosic feedstock. Upstream entities consist of companies with pre-treatment technologies. Midstream entities consist of companies with production facilities such as ethanol plant or sugar mill. Downstream entities, consisting of users of the product such as paints, chemical companies that wish to replace petro-based chemicals with the renewable long-term sources of feedstock, and agriculture players that are willing to look for a new market for their product	As these advantages have been expected from the start of the design of the cart line, internal financial justification has not been a barrier for the development of this innovation, also because the design and implementation could be financed from the company's operational revenues.-------• Suppliers have helped the company's engineers to select the most appropriate components for the design of the cart line as well as the individual carts.	One of the main reasons for choosing light bulbs was that the circuit for collection of these products, in France and many other European countries, already existed. This was considered crucial because, according to the company, collection is one of the key activities in recycling. The company wanted to outsource this activity to partner companies, because it is not their core competence. Other external stakeholders have supported development of this innovation to a lesser degree. This involved support with design activities and optimisation of a few process steps. These were not key, however.
accumulating	The development team of approximately ten employees grew over the years. It started with just two members, but gradually complemented with chemists, process technologists and high pressure specialists. At the beginning of the development process the company conducted clear goal setting, machine design and technical drawings. This was very important for communication with supplier companies and eventual accumulation of capabilities during the integration and assembly phase.	The substantial resources invested by the VC and the technology of the university were accumulated in the spin-off company.	All resources are basically accumulated at the customer's plant, where the first step of implementation (of the less advanced technology) is executed. This is were both the customer's resources and experiences come together with the company's technology and expertise to generate competitive advantage.	All resources were accumulated in the R&D team of the company. All capabilities required for developing this innovation were present within the company. Apart from some publically accessible technological knowledge, all resources were also internally available.	Two of the company's plants in France were eventually chosen as the most suitable places to commercialise the technology. One of the key reasons for selecting these two sites was that they had substantial amounts of existing, usable equipment already available. To keep implementation costs down, reuse of existing equipment was set as one of the development goals. These plants, were final implementation and redesign were conducted, can be seen as the places where all resources for this process were accumulated.
divesting	No particularly important divestments were made during development. Trial and error implies that with every test, some parameters turn out to be wrong, and can be disregarded or omitted from future test. This can be seen as divestment.	This early sale led both top management and the VC to believe that the innovation was ready to be sold on the market. As a result, the process was marketed aggressively and many potential clients on a global scale were approached. The results, however, were disappointing; while they were burning most of their budget on market and sales activities for the next 1-1,5 years, no sales were made. This led to great dissatisfaction of the investor. Moreover, further development of the process came to a stand-still in this period. Due to the pressure that was put on the management team to make sales, they detoriated their relationship with both university and external engineering company, which eventually led to a change in manufacturing company. They again, had to start from scratch. The VC also divested in the top management, and attracted a new, interim manager. It even considered to pull the plug on the company.		The company divested in its old manufacturing logistics, namely conveyor belts.	After the patents applications were filed, the company decided that it wanted to commercialise the technology in collaboration with a partner. After one year of partnership, however, the company decided to continue on its own. The partnership was not as beneficial as was expected.
governance & organisational structure.	Both the mother company and the spin-off can be considered innovative organisations.	Innovative/adhocracy organisation	innovative/adhocracy organisation	The company can be characterised as a bureaucracy or machine organisation.	The company can be characterised as a divisional organisation.

business model	The launch customer is a very innovative company and also became a minor shareholder in the company. It did not pay for the first machine that was implemented in Thailand. the company installed this facility as a sort of R&D project. The second machine, the 0-series model, was paid for by the company.	The business model of the company is to sell machines/facilities to interested customers worldwide. Especially large steel manufacturers and recyclers are interested in the technology.	The company deploys a capital light commercial model. The commercialisation strategy of the company centres on two possibilities. It either licenses its technology to the plant owners and other customers or forms a joint venture with the facility owners by investing in the existing facilities. If it's licensing – the better the technology performance is, the more the company can charge in terms of royalties. If its equity participation, the company gets direct benefits as they too participate in the project. The company earns a small part of revenue from research and engineering services but it is not a full scale commercial operation.	Their is no particular business model for this innovation on itself. It basically helps the company to optimise its existing manufacturing capability through cost and time savings and offering higher flexibility.	The business model for this process innovation is purchase CFL waste and recycle the rare earth material contained in this waste. The raw material acquired through this process can either be reused in company production processes, or can be sold on the market. The price of this rare earth material is substantial and has increased significantly in the last few years.
bundling					
stabilizing	The process of scaling up this prototype to a full working industrial machine was based on trial and error.This means that successful machine parameters were anchored and stabilised, while non-functional parameters were changed and enriched.		The company's core skills are in microbiology, molecular biology and fermentation.	The company's engineers could draw upon existing academic work on cell production and the transition from line to cell production.	Being a large multinational, technology leader and producer of several phosphor precursors, the company already possessed knowledge about the processing of rare earth materials. This knowledge could also be used for the extraction and recycling of this material. According to the BU manager, it is easier to apply reverse chemistry if you are already familiar with the forward approach. The company was already skilled in laboratory testing, managing innovation development, IPR management, construct industrial scale facilities, use of stage-gate procedures Some steps were considered self-evident and did not need a lot of testing. A process step that did not need any testing involved liquid separation, with which the company already had substantial amounts of experience.
enriching	The machine was then run for about 10 to 11 months, to check whether it functioned properly. After these tests had been completed, the facility was shipped to the launch customer in Thailand, were additional modifications and changes were made in a real-time production environment. Reconfiguration to make the machine completely error free will take place over the coming years. The process of scaling up this prototype to a full working industrial machine was based on trial and error.	In the beginning way too much effort was put into improving the marketing and sales capability of the young firm, especially in comparison to development and research work. Lateron, this caused serious problems. The company drastically improved its marketing and sales capabilities, by focusing them on a shortlist of 20 interesting potential customers globally. This eventually paid off in the form of sales of approximately 3 million EUR.	The idea developed by the company was to improve microbial performance of the fermentation. It did extensive work on genetic manipulation of microbes to improve solvent yield, concentration, and improvement of fermentation productivity. The company is performing research on the next generation of feedstock. The company does testing of the process both in its own laboratory and in the other testing facilities. The advanced fermentation process of the company has been successfully tested in a laboratory. Now, the key to success lies in the scaling up of the process. One of the company's strengths lies in its capability to tailor the technology to specific customer requirements regarding feedstock and plant configuration. However, it must be noted that it does not fully customise the technology, but instead makes adjustments to suit the customer's requirements. It does leverage its existing technology to some extent. The company aims to continue technical advancements with time. It has a capability to improve its technical capability quickly after each customer acquisition.	The company's engineers verified the technology by prototyping a cart line and testing it in a controlled setting. Important result of the tests was that the motion control of the carts was in need of improvement. In some occasions the carts would tip over or even collide with a worker that would stand too close to the rail. In order to prevent worker injuries, the chance of this type of mishap occurring was significantly reduced by installing spans, railings and girders alongside the cart line.---------The company kept on improving the technology through redesigning elements of the process twice, especially with regards to the pull principle responsible for progressing the carts through the line.	At steps where there was a lot of uncertainty, extensive tests were conducted in 2010. The R&D department did several tests with regard to pyrometallurgy, sieving, and hydrometallurgy. For sieving, several technologies were considered. At the beginning there was a large variety of possibilities. After testing, only two options remained viable. Initially the one that was adopted for use in the process did not turn out to function properly, so eventually the development team had to switch to the other solution instead.

pioneering	Clear 3D drawings of the conceptual design, performance measures and other parameters made sure that these suppliers knew what to develop. This way the company facilitated the acquisition of external capabilities from machine component suppliers.The company possess the specific knowledge on how to combine chemistry, pigments and liquid CO2 to enhance textile dyeing and eventually came up with the capability of using CO2 in a super-critical state to dye textile. Only the company possesses the required knowledge for the final assembly of these components.	One of the professors of the university decided to pursue a less complex technology that would result in the extraction of copper from steel, because existing technology were to delicate. Together with a PhD student in the field of magnetism, they came up with an idea to use magnetism to sort out copper from (melted) steel. At this stage they conducted many experiments and tests to understand how this could work. Different materials for instance have different densities. Combining magnetism with velocity and material density provides a theoretical basis to extract specific materials, e.g. copper from steel. By doing research, lab experiments and prototyping, they came up with both a theoretical framework and a practical solution for sorting copper from metal scrap in a fully automated way.	To illustrate, it takes sugarcane as feedstock and converts it into butanol through an ABE ('Acetone Butanol Ethanol') clostridium based fermentation process. Subsequently, it plans to do two things for improving the performance further – firstly, to convert the feedstock to cellulosic feedstock which would include a front end process of hydrolysis of the feedstock which would then feed to ABE fermentation facilities. The second part of the plan would be to upgrade the existing process to advanced fermentation process. Advance fermentation process implies upgrading existing production process to continuous production, and advancing recovery and other aspects of fermentation. These advances facilitate more efficient conversion of sugar to the product and transform the economics of the fermentation process. The company also developed key marketing capabilties. The company considers a number of factors to decide on what markets to enter, namely prices of the feedstocks, the operational costs and the chemical market for butanol and whether there is a commercial drive at the customer end for finding a technology in order to restart existing closed plants.		The company perceived the need to identify new sources of rare earth material, because traditional sources like mines are not easy to find. This is why the company adopted the new practice of urban mining. Urban mining is the practice of reclaiming compounds and elements from products, buildings and waste. There is a lot of rare earth material to be recycled from existing applications like consumer electronics. In 2007, throughout the whole group, an in-depth analysis was made to see which applications were most interesting to reclaim rare earth material from. Low-energy light bulbs were the source selected. The balance that the company struck between, pyrometallurgy, hydrometallurgy, sieveing and liquid separation, which eventually leads to extraction, can be considered the new capability that was created during development.
leveraging					
mobilizing	Right from the start, the company's commercial director and founder had the vision to diffuse the technology through the use of partnerships with influential fashion labels. This strategy enabled leveraging of resources and capabilities. With regards to development, the necessary process and chemistry knowledge could be anticipated, but apart from that the development process just required significant amounts of research and attempts. The development trajectory was process driven, meaning that the means to achieve the project's goal were already anchored in the early stages of development. The technical drawings and 3D model in particular formed a kind of roadmap for the development trajectory.	The university's vision/plan to commercialise this technology within a newly founded company with the help of a VC was good. However, it seems that this is were the plan stopped. The VC got to influential and their plan was too much focuses on quick return on investment. All the budget was spend on marketing and sales, although the process still needed further development and finetuning. Lack of a clear/succesful vision was very detrimental to the innovation. Furthermore, the marketing efforts were not focused enough.	The company's vision or plan to apply/diffuse its technology among idle fermentation plans follows an incremental approach. Investments from external investors and customers need justification through technical credibility. Therefore, the company is first implementing the first generation fermentation process which is relatively easier to commit to. Once the plant starts running smoothly and profitably, it would be easier to retrofit the advance fermentation process onto it. Advanced fermentation consists of continuous extraction, fermentation and cellulosic pre-treatment. The retrofitting will be incremental.	Important design parameters were cost optimisation of the manufacturing process and a low maintenance need for the components to be used. Especially the latter point was an important factor in electing to pursue a very simple structural design. A limiting factor in designing the process was the prerequisite of using existing carts in the process that would require limited to no modification before being deployed.	Clear goals and requirements were stated at the beginning of the project. The main goals of the project were that it had to be able to treat all types of powders from florescent lamps, and the new process had to fit with the existing technology at the company's existing plants and other downstream technologies.One of the goals of this project was to implement and commercialise the technology very quickly, because a head start on competitors is considered key in this industry. After initial testing and comparisons were finished, a certain "development route" was created that further determined the pursued development trajectory for this innovation. Use of roadmaps is very common in the development processes of the company and this was also the case for the current technology. A roadmap was developed for all possible scenarios of commercialisation, whether through partnerships or through independent commercialisation e.g. development of several scenarios in parallel, before selecting the best solution within a couple of months or years.
coordinating	Integration of the different supplier capabilities was done at the company's site in the Netherlands, by testing and experimenting with different component configurations, to eventually come to a fit. This can be considered one of the core competnecies of the firm, machine component integration and assembly.	The idea of integrating all acquired resources and available capabilities in the newly founded company did not work out properly in the beginning. The VC's interest of getting quick returns on investment were too influential and made the project focus too much on its marketing and sales capabilities, instead of research and development. All required capabilities were successfully integrated for the first time, after the interim manager had formed a new management team around him. Development capabilities were further conducted and the marketing and sales activities were largely enhanced.	All capabilities and resources are basically accumulated at the customer's plant, where the first step of implementation (of the less advanced technology) is executed. This is were both the customer's resources and experiences come together with the company's technology and expertise to generate competitive advantage.		Integration of different capability configurations was done during the fore-last stage of development, implementation, during which the different technical capabilities and organisational capabilities (communication, training, recruitment, permit acquisition etc.) were integrated.

deploying strategies	By partnering with large fashion labels, the company improved its resource advantages by gaining access to the fashion labels network, office space and marketing power. It took advantage of the market opportunity that large fashion labels are eager to communicate a more green label to their customers, and are thus very much willing to adopt this technology. The power of these labels in the industry, means that they will force the adoption of the technology upon their suppliers. This entrepreneurial strategy really allowed the company to leverage its technological advantages into a market advantage.		The company is exploiting its capability configuration by making use of its superior fermentation technology (resource advantage), build through extensive research, and makes effective use of the market opportunity of idle lying fermentation factories in for instance China. The entrepreneurial strategy of first offering contract research to generate cash flow for further research, and tying idle plant owners to the firm, preempts valuable production capacity.		The company's resource advantage, as a technological leader in its industry, in combination with the market opportunity of ever increasing rare earth material prices was used to exploit the capability configuration established during the development phase.
nurture innovation	Innovation was nurtured in a sense that the company allowed all players to play to their strengths. The company itself only focused on its core competency of system design, integration and assembly. It led key suppliers develop key machine components, like the pressure vessel, valves and software.	This appears to have been not well done with the current innovation. When the technology got put into the newly founded company, too much emphasis was put on commercial objectives, and innovation was not nurtured at all. Before, within the university-manufacturer relationship, this was better facilitated and development and research were more emphasised. After management had changed, the interim manager demanded that more resources needed to be channeled to technology development instead of business development.	Innovation is nurtured, because the company first took plenty of time to completely develop the technology, without pushing for commercialisation. Furthermore, the company works together with customers, and makes use of the existing resource base at the customer location. By first applying a less advanced version of the technology, it keeps customer interest and lowers the barrier for adoption. This way, the customers can get used to the innovation.	Innovation was nurtured by getting production floor workers involved in the process early on. They could provide the developers with valuable feedback from practice and this additionally lowered their resistance to the technology.	
Imitation barriers					
cognitive barriers					
uncertainty regarding the future	New legislation even threatens to endanger the continuity of textile dyeing companies in the near future.				
complexity and interplay of resources	During development, some miscommunication occurred between employees skilled in different disciplines. By having these different employees communicate frequently and informally, chemists and mechanical engineers could however overcome this problem. Chemists for instance had to be notified of the restrictions of the process, which dictated their freedom to operate. Because the team was relatively small, just ten employees, this did not pose significant problems. No resistance was experienced among the company's employees regarding the liquid CO_2 technology.		The company has complementary resources, which allows it to make full use of the new fermentation process. This increases the perceived value of the innovation. The company closely inspects the existing facility at the customer site. Next, it tries to understand the possible engineering solutions that could be implemented at the site. It might involve the consideration of factors such as fermentation reconfiguration, provision of utilities, waste water treatment, the water recycling approach, and the ability to integrate ABE butanol with existing logistics in place. These factors provide evaluation criteria to choose an optimal engineering approach. The firm aims to maximise the use of existing facilities rather than changing everything. This approach, in turn, leads to a more economic outcome.		Throughout the whole development process, there was a good understanding of the interrelationships among the different elements of the system design. The development team had some hydrometallurgy chemists, and some pyrometallurgy chemists who worked together, under the supervision of a project leader. This collaboration did not cause any problems. On the contrary, there were some synergies on both sides. Recycling of hazardous waste requires employees from different disciplines to cooperate, like chemists and recyclers. Chemists are familiar with encountering barriers in communication with other specialists. When chemists communicate with recyclers, they are faced with problems that the recyclers are not familiar with like the chemical names of certain materials and processes. When they have to talk to an external design institute, they again have to adapt their language and jargon. This all implies that the process entails a lot of complexity, of a technical, administrative and coordinative nature.

inter-organisational conflict	During development, some miscommunication occurred between employees skilled in different disciplines. By having these different employees communicate frequently and informally, chemists and mechanical engineers could however overcome this problem. Because the team was relatively small, just ten employees, this did not pose significant problems. No resistance was experienced among the company's employees regarding the liquid CO2 technology.	There was substantial conflict or friction between the company and university's interest to first improve the technology, and the VC's interest to commercialise the innovation as quickly as possible.		Initially some resistance was shown towards the new production system, as it proved to be very challenging to design an optimal manufacturing layout. However, repeated practice runs and trial-and-error tests allowed the company's engineers to resolve all encountered issues. The company did not employ the practice of appointing a technology champion to be present during the implementation of the cart lines.	Recycling of hazardous waste requires employees from different disciplines to cooperate, like chemists and recyclers. Chemists are familiar with encountering barriers in communication with other specialists. When chemists communicate with recyclers, they are faced with problems that the recyclers are not familiar with like the chemical names of certain materials and processes. When they have to talk to an external design institute, they again have to adapt their language and jargon. This all implies that the process entails a lot of complexity, of a technical, administrative and coordinative nature.
complementarity in valuation			The company closely inspects the existing facility at the customer site. Next, it tries to understand the possible engineering solutions that could be implemented at the site. It might involve the consideration of factors such as fermentation reconfiguration, provision of utilities, waste water treatment, the water recycling approach, and the ability to integrate ABE butanol with existing logistics in place. These factors provide evaluation criteria to choose an optimal engineering approach. The firm aims to maximise the use of existing facilities rather than changing everything. This approach, in turn, leads to a more economic outcome.	Due to the particular market demand and nature of the product being manufactured, the current process inovation turned out to be more efficient than the old conveyor belt technology. Without these particular complementary factors, a technology change like this might not prove useful for competitors.	The company already performed the forward process of manufacturing phosphate precursors. The resulting rare earth material from the current process can be used as input material for some of the company's other production processes. Furthermore, 90% of the technology is made out of recycled components and tools.
long time lags between cause and effect					
causal ambiguity					
secrecy					The process is only implemented internally. It will not be diffused to customers. This facilitates secrecy. Furthermore, it was mainly developed internally, which makes secrecy easier.
Willingness barriers					
institutionalised norms	Currently, the textile market is at a point where it is realising that this technology is very valuable and might become the next standard in the industry. Both a productivity increase and cost reduction relative to conventional techniques has been realised in practice now. There was some initial resistance from industry among for instance pigment and dye suppliers. These companies lose some of their margin due to the new technology. Liquid CO2 dyeing requires less pigment and chemicals, both supplied by these companies. It therefore indirectly decreases their sales. These companies have however dropped their resistance and are now open for change.The textile processing industry has historically been very conservative. The industry is cost driven and does not like change.	The recycling business is often considered to be highly conservative when it comes to new technologies, which can partially be explained by the high investments that are required for the machinery.			The tools used during the simulation of different setups were unlike normal petro chemistry, where calculations are generally used. In fact, simulation was done by executing pilot tests. This experimental process was based on trial and error. For the selection of the most appropriate filter size, a multitude of different sizes were tested, in order to see which delivered the highest productivity. Some small calculations can be made to support this process, but practical tests were considered a necessity. The company also had contact with a HSE committee and Unions, who had to give their advice on whether they would accept the process. This is due to French law, which states that if you develop a new process it has to be approved by unions, which represent the workers operating the new technology.

political and cultural institutions	New legislation even threatens to endanger the continuity of textile dyeing companies in the near future.	The recycling industry is typically rather conservative. This also has a direct impact on your ability to sell new recycling processes to the industry. It has been a tough business to pitch new ideas in, and stakeholders noted that it has only appeared to become tougher the last few years. As Turkey is not part of the EU the company faced problems to acquire the necessary funding to built a recycling machine there. The European banks that the company approached found this kind of an investment opportunity in Turkey to be too much of a risk. Moreover, the Dutch government refused to support the investment instead, making it hard for the company to conduct business in riskier countries.	The sustainability too is a value proposition of the process. It is noted that the customers and end-users are enthusiastic about adopting a sustainable process. The sustainability of the process offered by the company does improve its marketability.		The company encountered several other challenges. At one of its sites, the company, was not allowed to process waste, because of the lack of a permit. A new permit needed to be applied for at the Environment Protection Agency (EPA), which required a lot of communication. One of the key challenges was to acquire authorisation in time. Another problem is currently still one of the key challenges remaining. It is hard for the company to convince a company that collects low energy light bulbs to sell their waste to them. Chinese companies for instance are able to offer better prices due to less stringent environmental standards and ethics.
environmental stability					
availability and price of IPR licences			On the commercial side, the company selects appropriate instruments for how to deal with royalties, development programmes, investments, and provision of long term support. The company either licenses its technology to the plant owners and other customers or forms a joint venture with the facility owners by investing in the existing facilities. If it's licensing – the better the technology performance is, the more the company can charge in terms of royalties.	No applicable, because no patents.	no
Ability barriers					
Intellectual property rights					
patents/utility models	Currently, The company possesses seven patents to protect different parts of the machine. Parts of patented process components are manufactured by external suppliers but are assembled at the company's plant. Some of the patents required adjustment during final design and industrial tests, to offer better protection of the process.	The university professor is an experienced researcher. Aside from the company's technology, he has patented several of his other innovations. His experience as a researcher and his connections both within and outside the university have helped the innovation to not only exist, but also to take its initial steps.	The company has several patents that are strain-specific, covering genetically modified strains such as clostridia, and also thermophilic microbes for butanol production. Currently, it has filed one patent for each of these processes in the U.S. and in Europe. The patents have not been granted yet. Both the patents broadly cover the fermentation process.	No	The legal department checked the freedom to operate and patentability of the technology. The initial patent that was applied for turned out to be unsuitable for the protection of the process, therefore the company applied for a second patent.
trade secrets/NDAs					
path dependency					
irreversible investments					
time compression diseconomies	There were no significant success factors for development in this phase of the project, except for adequate time for testing and trial and error.	The company was to quick to market the new process. It should have taken more time to develop the innovation.			The company chose speed over quality and went for the methods that were available and that delivered a sufficient result. These results, however, are still not optimal. It takes time to generate optimal solutions, which is done in parallel to the implementation process.
asset mass efficiencies	yes			yes, through the permantly active R&D departments in the firm. The company already developed and implemented several process innovation internally.	yes, through the permantly active R&D departments in the firm. The company already developed and implemented several process innovation internally. Furthermore, the company already had experience with the formward approach of manufacturing phosphate precursors. As the manager stated, it is easier to develop the
experience economies	The process was run for 8 months to improve it and enhance technological understanding. This was done by conducting simulation, testing and analysis.				
social complexity					

presence of socially complex resources	The group of employees and its manager considered themselves to be a sort of family. All employees were fully involved in making development decisions and conducting selection procedures. The whole project followed a clear team approach. Communication was very informal, frequent and continuous. For communication and coordination of the project a good project manager was particularly important. No protocols or procedures were used to guide communication and coordination.	The interim manager, after the screw-up of the VC firm, had to put a lot of effort into changing the culture of the firm and reestablish the relationships with the development team at the university.	The company promotes its process largely on a relationship basis. The company usually engages in dialogue with the potential beneficiaries of the process, such as people with existing butanol and biobutanol plants in China, entities with sugar mills in the company's key markets, ethanol plant owners in the U.S., and also end-users of butanol. -----------The company focuses on establishing long-term partnerships with customers by working closely with them. It transfers its technology through licensing and also offers customer support onsite.------One of the company's core values centres on its ability to collaborate with their partners. It is very well reflected in the company's partnership initiatives spanning across the whole value chain of the process.		In new projects, the company always makes a mix between new employees and experienced employees. The team has to get familiar with each other as well as the facility, in a fairly short amount of time. This can be very challenging, but also one of the key success factors, because of the potential synergy between new and experienced employees.
social engineering required					
resource interrelatedness					
balancing of resources					Throughout the whole development process, there was a good understanding of the interrelationships among the different elements of the system design. The development team had some hydrometallurgy chemists, and some pyrometallurgy chemists who worked together, under the supervision of a project leader. This collaboration did not cause any problems. On the contrary, there were some synergies on both sides.
economies of scope	yes, by combining the knowledge of suppliers of several of the key machine components, and the company's own design and assembly capabilities.		The company closely inspects the existing facility at the customer site. Next, it tries to understand the possible engineering solutions that could be implemented at the site. It might involve the consideration of factors such as fermentation reconfiguration, provision of utilities, waste water treatment, the water recycling approach, and the ability to integrate ABE butanol with existing logistics in place. These factors provide evaluation criteria to choose an optimal engineering approach. The firm aims to maximise the use of existing facilities rather than changing everything. This approach, in turn, leads to a more economic outcome.		The company already knew the forward approach.
causal ambiguity					
two sided ambiguity					
single sided ambiguity					
deterministic nature	with regard to the filing of patents.			yes, because the process is only commercialised internally	yes, because the process is only commercialised internally
stochastic nature	with regard to trial and error, learning by doing. Always encompasses a good share of luck.				
information impactedness & secrecy	The content of the filed patents was deliberately done in a very vague manner, to not enable competitors of discovering the crucial details about the process.			no, the other way around. The company actually helped to diffuse the technology to other companies, through several partnerships. These companies are however not active in the firm's own product market.	
preferential market access					
communication good effects	only with regard to pheripheral products, which are currently still largely under development.			no	no

buyer evaluation cost	The company lowered the launch customer's buyer evaluation cost, by providing the first installation for free. Successful implementation at the launch customer, subsequently lower's the buyer evaluation costs for other players in the industry.		The company first installs the first generation fermentation process which is relatively easier to commit to. Once the plant starts running smoothly and profitably, it would be easier to retrofit the advance fermentation process onto it. This way, buyer evaluation costs are lowered, because they can first get used to less radical technology.	The company willingly helped four other major Japanese manufacturing companies to introduce this concept to theri own plants. The company did not engage in a commercial cooperation or partnership to this end.	
advertising & channel crowding	As an important player in the textile processing industry, implementation of the innovation at the launch customer's site also functioned as a showcase for the new technology, generating significant amounts of exposure. Exposure would not have been so high if the technology would not have been new. The same goes for the partnership with Nike, which also leverages this novelty to generate extra exposure.	The demonstration model was initially meant to show the basic capabilities of the technology.		The innovation saves a lot of energy and CO2 emmission and also allows for the whole manufacturing process to be run on photovoltaic energy. In combination with being the first company to adopt this technology, this provides the company with positive public exposure.	The current facilities at the two company's sites in France, are demonstration units. In the near future, they will be further developed into full scale, fault free, industrial units. In terms of communication to the public, implementation of this technology would show that the company is using its knowledge to achieve good things. This contributes to the sustainable image that the company wants to communicate to the general public.
product complementarities	The last phase of development not only entails constant fine-tuning of the process, but also the development of peripheral applications like textile dyes and pigments. The initial assortment of dyes only consisted of 18 different colours. Expansion of this assortment and further development of peripheral equipment and products is done based on market demand. Development of new dyes is done in cooperation with large chemical companies.				
buyer switching costs			Substantial switching costs arise when a customer plant has the first technology of the company installed. It has to learn how to use it, adjust its purchase competencies and other pheripheral plant layout features. Moreover, the prospect of having the more advanced technology installed at the plant, provide significant opportunity costs, in case of switching.		
pre-emptive actions					
inputs	yes, exclusive contracts with the suppliers of certain key components, like the pressure vessal and software programme.		The company selects a specific engineering approach for each particular site. It then establishes a commercial deal with the host site. This way the company is preemting existing production capacitiy, which other competitors can no longer access. It provides the technology, improved microbes for fermentation, to Chinese companies which will allow them to restart their plants on alternative, lower cost feedstocks the company's microbes ferment a wide range of sugars including ones derived from cellulosic feedstocks).		Pre-emption of inputs, through establishing contracts with CFL waste collectors, the company effectively pre-empts the input material for this process, at least in its own operating region.
market positions					The company is the first in the world to have this technology available on the market. Normally, the research to market trajectory for this type of innovation takes over 7 to 8 years, whereas the company reached the phase of implementation within five years. The technology will be further optimised during the implementation process.
know-how	The company has established exclusive contracts with several of its key supplier companies, for instance the software developer and pressure vessel manufacturer.	yes, through patents	yes, see patents		(preemption of know-how through patents) The company is the first in the world to have this technology available on the market. Normally, the research to market trajectory for this type of innovation takes over 7 to 8 years, whereas the company reached the phase of implementation within five years. The technology will be further optimised during the implementation process.

distinct managerial capabilities					
firm-specific knowledge possessed by managers	The mother company's founder and owner has extensive experience with liquid CO2 research and market applications. He did a PhD study on this topic and is closely connected to a Dutch technical university.	The VC therefore hired an interim manager, who had 10 years of experience in the waste industry, to assess the situation. After careful consideration, it was concluded that the innovation first needed to be further developed. This manager changed the company's culture and demanded changes from the VC company.	The founder holds a PhD degree in biochemical engineering and a BSc in Microbiology. He has worked on various aspects of the butanol fermentation process for past twenty years.		
shared team-specific experience of managers	The developers had plenty of freedom in designing the process. According to the founder and commercial manager, technicians have the tendency to keep on developing a concept until it is perfect. Some restrictions were therefore needed to keep the development pace up to speed. The group of employees and its manager considered themselves to be a sort of family. Communication was very informal, frequent and continuous. For communication and coordination of the project a good project manager was particularly important. No protocols or procedures were used to guide communication and coordination.				
entrepreneurial vision of managers	The commercial manager's vision of diffusing this technology through partnerships with large fashion labels and a large influential launch customer was key to the swift commercialisation of this technology.			The transition within the company is part of the company's long term vision, by the company referred to as the 'very long term' vision, and its associated targets. The company aims to integrate a focus on their environmental impact within their product lifecycle, through sustainable environmental management, production processes, and products	
development strategy complexity		The company developed a new and complex strategy to foster more sales with a highly focused marketing and sales strategy. By short listing approximately 20 potential clients and subsequently only approaching 5 of those, sales are much more focused. It is much easier to grasp the needs of 5 companies than it is of as many as 70 at the same time, which is the number of clients they used to approach.	Around 2007, the company realigned its commercialisation strategy to focus on re-commercialising existing ABE fermentation technology. It speeded up its efforts in taking its butanol fermentation process to the market. The founder sold the business case to venture capitalists and thus raised funds to focus on the commercialisation of biobutanol. ----------------The initial strategy adopted by the company is to commercialise the first generation fermentation process at a scale and then retrofit the advanced fermentation on to it. This is a low-risk strategy for customers. This strategy will help customers turn their unprofitable plants such as an ethanol facility to profitable ones. The company will then target improved performance and the production of higher value derivative products. The process leads to lower cost of production and saves a substantial amount of capital. It allows more profitable measures at the customer's end. Customers could directly witness the gains.		The company has tried to put clear emphasis on sustainability which is highlighted by its clearly formulated Corporate Social Responsibility (CSR) regime. The company's standard code of conduct had a significant influence on the way that the company conducts its business and the way in which it pursues innovations. The development process of this innovation has followed the company's standard R&D procedure. This standard procedure consists of five different phases of development.
distinct organisational capabilities					
producer learning	The process was run for 8 months to improve it and enhance technological understanding. This was done by conducting simulation, testing and analysis.			An established player like the current company already has substantial experience with manufacturing high quality product in very high volumes. This experience was beneficial to the development of this innovation.	Yes, the company already acquired substantial experience with chemical processes and phosphate precursor production in the past.
organisational learning	The process of scaling up this prototype to a full working industrial machine was based on trial and error. "To create something which is not already existent cannot be done using predetermined steps and frameworks", according to the company's founder/owner.				