Abductive reasoning as strategy to develop business growth

Executive's cognition and business performance

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1. Executive summary

The study presented in this work investigates the impact of forms of logical reasoning on company performance. Under changing market conditions and uncertainty, executives too often fail to foresee strategic options that lead to superior company performance. One reason for this is that executives tend to rely on deductive/inductive logic in order to reduce the risk associated with decision making under uncertainty. Deductive/inductive logic relies on general rules or prior observations. This means, rules or observations must be known prior to the decision. However, during early-stage innovation and strategic planning, future conditions are usually unknown. Therefore, it is unlikely that one will have made all observations necessary for such an explanation. As a consequence, executives often become risk averse and make predictable decision errors.

In order to successfully foresee strategic options—despite changing market conditions and uncertainty—executives need to change their approach and particularly the reasoning they apply. In the area of design and concept selection, scholars promote the use of abductive reasoning. This type of logic forms plausible hypotheses about future outcomes and events instead of deducing/inducing what is known from the past. When using abductive reasoning, thinking becomes more future orientated, and the potential of yet-not-existent concepts and outcomes can be better recognized despite the present uncertainty. This is important not only for design and concept selection, but also for other processes such as strategy development.

Building on prior studies and literature from the field of cognition, strategizing, opportunity recognition, design and abductive reasoning, I hypothesized that abductive reasoning should positively influence company performance. Under the umbrella of a larger research project funded by the Australian Research Council (ARC), I conducted a study investigating this link both qualitatively and quantitatively. The research was conducted at the University of Sydney in cooperation with Delft University of Technology under supervision of Dr. Massimo Garbuio, Dr. Boris Eisenbart and Prof. Andy Dong, and with Prof. Petra Badke-Schaub as chair of the graduation committee.

The study is based on secondary data of 30 US companies in the Software and Development Industry that went public on the US-stock market (NASDAQ) in the period between 2013 and 2014. The data was derived online via the US Securities and Exchange commission database. For the assessment of abductive reasoning, a framework was developed that expands existing frameworks used for the assessment of (abductive) reasoning during concept selection (see section 6.1). Financial data were acquired via COMPUSTAT.

Results of the study confirm that abductive reasoning leads indeed to significantly greater company growth performance. Furthermore, abductive reasoning positively influences company profitability when used in conjunction with deductive/inductive logic, and was found to 1) introduce new business or revenue models 2) identify market segments 3) define a product

or service offering, 4) invent technical solutions 5) revise and form beliefs/missions, and 6) explain observations such as (market) behavior.

Qualitative analysis suggests that specific observations made prior to or during early-stage venturing—referred to as *observation sets*—stimulate abductive reasoning. Three different categories of these observation sets were identified: analogy, anomaly and paradox. Observations about technological developments are suggested to enable innovation, i.e. the technical component of a new venture idea, while demographical and organizational observations are often the source of new strategic options.

Up to this point, the most commonly accepted view has been that strategic decisions are made rationally. Therefore scholars advise the use of tools which rely on deductive and inductive logic to assess and create strategic options. Results of the presented research, however, suggests that companies should instead make an effort to complement their strategy development with abductive reasoning approaches. In this paper, the results are discussed, managerial implications and contributions to literature are presented, and future research is suggested.

2. Introduction

It is a fundamental human tendency to try to avoid complexities and ambiguities associated with risks in almost every respect of life (Doerner, 1990). This is particularly true in business venturing, where vast financial resources are at stake that can sway success or failure of an organization. In order to reduce risks in business venturing, research has shown that executives rely on quantifiable metrics and deductive/inductive logic to foresee new strategic opportunities (Zacharakis & Meyer, 2000). Such approaches, however, show strong limitations when it comes to coping with dynamically changing user needs and global competition (Garbuio et al., 2015; (Assink, 2006); Tsoukas, 1996). This is because, on the one hand, quantifiable metrics like financial forecasts and SWOT analysis, the quality of a design, and formal analytics, such as actuarial modelling, Net Present Value (NPV) or Internal Rate of Return (IRR) require very detailed, quantitative information about the opportunity in question (Zacharakis & Meyer, 2000) which is often unattainable under changing market conditions (Assink, 2006; Vanhaverbeke, Berends, Kirschbaum, & De Brabander, 2003). Despite the tendency to use such approaches, under conditions of uncertainty, executives tend to have little confidence in formal analysis when making decisions (BCG, 2010) and instead rely more on their intuition (Huang & Pearce, 2015). Indeed, research has shown that executives start screening ideas for patterns that have been successful in the past and then try to replicate these patterns (Baron, 2006). This approach is based on deductive and inductive logic which use known or observable factors from the past or present, such as societal and technological trends, to predict future developments. As such, the approach is prone to decision myopia—importance of the future is reduce in order to minimize uncertainty which often results in short-term decision making—(Lovallo & Sibony, 2010) and entails predicable errors due to bounded rationality (Tversky & Kahneman, 1986). Moreover, opportunities which result from this type of logics are designed for a context which is foreseen to change according to past developments. However, under dynamically changing conditions also the context is hard to foresee. As consequence, executives need to change their approach in order to foresee new strategic opportunities.

In design scholarship, prior research has emphasized the use of abductive reasoning, in particular at the conceptualization stage (Dorst, 2011; Roozenburg, 1993). Different from deductive/inductive logics, that aim to produce logically true conclusions, abductive reasoning forms hypotheses to explain an observation or data (Dorst, 2011; Peirce, 1932). Abductive reasoning proposes the most plausible and parsimonious explanation for observations, this means the hypothesis may or may not be logically correct (see also Dorst, 2011; Garbuio, Dong, Lin, Tschang, & Lovallo, 2017; Peirce, 1932). In a strategic setting, when generating options under conditions of uncertainty, decision makers will first produce a scenario under which a specific option will be successful, and then generate plausible hypotheses how the result could

be most likely achieved. In other words, this approach tries to apprehend future rather than current (or projected) market potential and is, thus, more forward-thinking.

In the area of concept selection on innovation, prior research has found that abductive reasoning can help increase the decision-making accuracy, specifically, it was found to reduce the likelihood of projects with high market potential to be falsely rejected early (referred to as Type-I-error) (Dong, Lovallo, & Mounarath, 2015; Guenther, Eisenbart, & Dong, 2017; R. Mounarath, D. Lovallo, & A. Dong, 2011). This means that when thinking abductively, decision makers build mental models to test whether an innovation concept will be successful in the future under yet unknown circumstances and thereby improve their decision-making accuracy. As abductive reasoning helps to build and test future scenarios in which different applications, products, or outcomes can be tested, this type of logic should also be helpful to test the plausibility of future events and developments. It thus stands to reason that executives engaging in a higher ratio of abductive reasoning are better in recognizing options for innovations before they are proven by the market. In other words, they should perform better in opportunity recognition. Thus far, scholars have argued that opportunity search and recognition are dependent on an individual's professional background, the familiarity with a market, how to serve a market, and the associated needs (Shane, 2000), prior knowledge (Fiet, 1996, 2007; Shane, 2000), divers social networks, and pattern recognition abilities (Dyer, Gregersen, & Christensen, 2008). Gaglio (2004) emphasizes the importance of individual's readiness for reaction to dynamically changing circumstances and proposes that cognitive processes, such as counterfactual thinking and mental simulations, help entrepreneurs to identify opportunities. This is because both "facilitate the reassessment process and may (but not always) indicate that it is necessary to radically alter the contents or the relational dynamics" (Gaglio & Katz, 2001, p. 99). This means, these cognitive processes—similar to abductive reasoning—build and test new mental models (or means-and-chains) in which changed circumstances become a plausible cause or effect. More observed opportunities, in turn, increase the potential for the adaptation of new innovations. Innovations are intended to increase company's performance (Damanpour, 1991; Hult, Hurley, & Knight, 2004).

The similarities between the cognitive processes emphasized in Gaglio's research and abductive reasoning support my prior argumentation that abductive reasoning may help to identify superior innovation opportunities. Extending this line of thought, executives who engage in more abductive reasoning should then also be able to yield substantially higher performances for their respective organizations. However, this very relation between the use of higher ratios of abductive reasoning in opportunity recognition, strategizing and a company's performance has not been investigated thus far.

In this study, I therefore aim to shed light on how a higher ratio of abductive reasoning used in opportunity recognition and strategizing affects companies' performance. Based on the above considerations, I expect that abductive reasoning and a company's performances are

positively linked. If abductive reasoning and performance are indeed linked, I further expect to find a positive correlation between the ratio of abductive reasoning used in the development of a business and a company's performance. I conduct a study using data from 30 companies in the Software and Development Industry. In this work, I will also describe how observations can encourage abductive reasoning and lead to the creation of new strategic options. The developed concept is referred to as 'observation sets'. In the following, I first review literature on abductive reasoning, opportunity recognition and firm's performance, then I present the study and the obtained findings. I conclude with a discussion of the results and their implications.

3. Cognition and growth creating strategies

3.1. Forms of reasoning

In order to be innovative and to introduce new products to the market, one needs to create something new. Abductive reasoning is said to be the only form of reasoning which creates new knowledge. Therefore, it is the only form of logical thinking which creates something new. The theory of abductive reasoning was developed by Pierce and first published in the 1930's. In his work, Peirce introduces a total of three reasoning types: deductive, inductive and abductive reasoning, respectively. In the following I present these logics and show examples of their applications.

3.1.1. **Deduction and induction**

Deductive reasoning, or deduction respectively, forms conclusions based on general laws and fundamental principles which are known to be true (*if* this, *then* that). Induction, in contrast, is based on observation of a phenomena, which can be both either effect or outcome. The observations (cause or effect) that form the explanation (or hypothesis) of a cause or mechanism are dependent on the context (that, *because* of this). Deductive and inductive reasoning, conversely, build upon existing knowledge and established rules (see, e.g., Fischer, 2001). For both induction and deduction (nearly) all relevant parameters and contingencies must be known to draw reliable conclusions.

An example can better illustrate deductive and inductive logic. We all probably know the law of specular reflection, this is the mirror-like reflection of waves such as light or microwaves from a surface where all incident ray angles equal the angles of their reflection (incident angle equals reflection angle). The environment, e.g. clouds and trees, reflected on a still lake is one example of specular reflection. A deductive way of predicting the position of the reflection is by knowing the general laws that apply. Without seeing it, if we know the incident angle and the shape of the reflected object, then we can predict the reflected result. In case we don't know these rules, we can apply inductive reasoning and recall the last 20 instances where we have observed a tree being reflected on water. Based on these observations we can induce that when light is reflected on water, the produced image is reflected in same angle on the water as the surface reflected. In case of the tree, we will see a mirror-like vertical image of the tree reflected

in the water. The reliability of this rule is, of course, strongly dependent on the variation of external conditions during our observations in the first place. For example, flat water is a better reflector than a mat black surface as this absorbs more light. Hence, the results will not only vary depending on the angle of incident but also on the reflecting surface. When making predictions on future markets or product success we face similar problems. We don't know all parameters nor their impact. Under uncertain conditions, deductive/inductive logics fail in providing a correct result.

3.1.2. **Abductive reasoning**

Different from these logics is abductive reasoning. Abductive thinking introduces hypotheses and theories to explain a given result (or observations, respectively) or how a not yet existent outcome could be achieved when both context and means are unknown at the given moment in time (Dong et al., 2015; Peirce, 1932). In contrast to the other two forms of logical reasoning, the formed hypotheses are based on information available at a given time, thus connecting the realms of 'what is' and 'what might be' (Kroll & Koskela, 2014). While deduction can be understood as logical construction of a hypothesis and induction as the confirmation of a deduced hypothesis through multiple observation (Queiroz & Merrell, 2005), abductive reasioning forms explanations by reasoning from cause to effect (Paul, 1993). This means, while deduction relies on logically correct interference rules and induction uses classified observations for an interference, abduction *synthesizes* explanations. Synthesis is defined as an abductive sensemaking process during which an individual produces knowledge and information (Kolko, 2010). During the synthesis, an individual first manipulates, filters, and organizes data, thereby identifies implicit and explicit relations to, then, build new connections between before seemingly unrelated information. During this process, the abstraction of an idea is more important than to be 'accurate' (Kolko, 2010, p. 18). While sensemaking is a purely internal process, synthesis can also be an external, i.e. collaborative, process. The result of a synthesis can be seen as an 'induction axiom' which, in a later step, is verified by induction to test whether the explanation is plausible (Queiroz & Merrell, 2005). More simply stated, the process of abduction is a two-step recursive process and can be divided into hypothesis generation, and selection (see also Roozenburg, 1993).

3.1.2.1. Hypothesis generation and selection

Abductive interference has two goals: it generates a hypothesis which 1) explains all present manifestations (covering goal) with 2) the least complexity (parsimonious goal, 'minimize complexity') (Pagnucco, 1996, p. 54). Different to hypothesis *assembly*—a process that relies on induction and basically selects predefined hypotheses (Paul, 1993)—hypothesis *generation* creates new knowledge. Therefore, this process is seen as the most essential part of abductive. Note that also generalized rules that result from an inductive process can be used as input for such an abductive interference. In this case, induction generates *facts* for an abduction.

In contrast, when multiple, similar abductive hypotheses are used during inductive reasoning, then the abductive hypotheses serve only as *examples* for the interference *(Abe, 2000)*.

The result of this first phase, the generation of an abductive hypothesis, is a *set* of possible explanations of an effect (or cause). In the second part of abduction, the most plausible hypothesis is selected. For this process Peirce (1932) proposes three criteria which can be summarized as: *valuable, verifiable,* and *applicable*. First, the hypothesis needs to explain the facts and have an intrinsic value; second, the hypothesis must be verifiable through the use of induction, i.e. through recall of similar of same effects (or causes). This is not only important to see whether a hypothesis is plausible, but also to estimate the consequences of potential failure. Lastly, the selected hypothesis must be broad enough yet specific. An abductive hypothesis is the simplest and most intuitive way to arrive from cause to effect. In the field of computer science and artificial intelligence (AI), Ng and Mooney (1992) introduced the notion of 'explanatory coherence', which is the plausible relation between observation and explanation. Other scholars stress that for the selection of the hypothesis one should focus on the analogical (rather than plausible) relation between observations or between explanations. They propose that 'explanatory coherence' is less the 'explicit correctness' between observation and explanation but rather the analogical relationship between similar interferences. In that line of argumentation, Abe (2000, p. 5) "adapted the notion of explanatory coherence as analogical mapping and proposed Abductive Analogical Reasoning (AAR)". While the process suggested by Ng and Mooney (1992) uses only a simplicity criterion, in AAR the success of previous abductive hypotheses for similar observations is used as coherence criterion. Thus, prior abductive hypotheses that have shown to be successful (or unsuccessful) are used as examples to, then, induce whether the new hypothesis is plausible or not. This means, as the example causes were plausible, also the induced rules are plausible.

In design cognition, the process of the *creation* and *testing* of an abductive hypothesis is referred to as *generative sensing* (Dong, Garbuio, & Lovallo, 2016a). Generative sensing is a 'design thinking pattern' that allows not only to find a plausible, logical solution for a problem, but it also to reframe the initial problem itself. Generative sensing its thus an interactive testing of propositions for both the solution as well as the problem frame. This shows that abduction is not only used to create an explanation which could not be found relying only on inductive logic; but abduction is also used to adapt initial problems. Two different abductions can thus be distinguished: explanatory and innovative (or creative) abduction (Dorst, 2011).

3.1.2.2. Explanatory and innovative abduction

Explanatory abduction is the synthesis form effect to cause. During the synthesis, often incomplete, contradictory, and complex information are used to arrive at a plausible cause for an effect (see also Kolko, 2010). Explanatory abduction can be understood as 'interference to the best explanation'(Dong, Garbuio, & Lovallo, 2016b). In an explanatory abduction, two variables are used: *effect* and *cause*. This process is similar to induction, as argued by many

scholars in the field of computer science (Abe, 2000; Pople, 1973), yet it shows important differences (see above). Explanatory abduction is used to interfere an explanation when deductive or inductive logic cannot provide a logically correct answer. This is the case e.g. when not all parameters are known or when the observation does not fit within the existing belief model.

Innovative abduction predefines unknown variables to explain how these will affect a given parameter. This means, innovative abduction helps to define *what* needs to be created in absence of a rule for *how* it should be created (Dorst, 2011). In design, this form of reasoning is used to create a design concept (explanation) with a specific function (what) and form (how) (Kroll & Koskela, 2014). This reasoning from *function to form* is similar to Sullivan's design credo 'form follows function' as noted by Dong et al. (2016a). However, not only the form (how) is unknown at the beginning but also the concept (explanation). Dorst (2011) refers to the 'design concept' as *value*, wherein value is not equal to purely economic value but also to broader benefits that a designer aspires, e.g. through the design of a product or service. Innovative abduction adds another layer of complexity. Different from two variables used in explanatory abduction, innovative abduction uses three variables (what, how, and value) of which two are not (or ill) defined. In strategy development, the intended value is usually the only known factor (Dong et al., 2016b). However, for the process, it does not really matter which of the variables is known. I will give an example to illustrate the use of abduction.

Let's say a designer, Tony, is ask to design a furniture for a co-working space that allows an optimal use of space. The value is thus the only known factor. At the given moment, Tony does neither know 1) how this furniture is going to look like (what) nor 2) how it might work. As consequence, Tony has to invent concepts which combine both aspects, how and what, and then select the best one. Kroll and Koskela (2014) propose for this 'matching' a two-step-recursive process, where, in some sense, two hypotheses are created. In the example, a first hypothesis about the *what* would be proposed, and then another one which is generated to explain *how* the first hypothesis can become true. In our example, Tony believes that when he designs furniture that allows flexibility (hypothesis 1), the space could be used more efficiently. For this, Tony needs to find a design. He decides that the best option is to make some lightweight furniture with wheels as people can then easily rearrange the space (hypothesis 2).

Hypothesis 1: IF flexible (option) THEN space used optimally (value).
First conclusion: Make furniture flexible.
Hypothesis 2: IF on wheels (mode) THEN flexible.
Second conclusion: Make furniture on wheels.
Overall conclusion: Furniture on wheels to use space optimally.

This example illustrates a two-step-recursive process as described above and illustrates three components as suggested by Dong et al. (2016b): the intended (observed) value, the strategic option, and its mode of operation (how).

The next example will illustrate that the same process can also be used to solve more complex problems, i.e. with three or more unknown variables. This means, an abductive interference is not limited to *one* two-step-recursive process (Kroll & Koskela, 2014), instead, abduction can be understood as an iterative interference process (see also Dong et al., 2016a, pp. 4-5).

Let's say, Tony was only told to design some new furniture for a co-working space. It is required that this furniture creates some sort of value. He now not only needs to hypothesize the concept and the function, but also the value. In this example, Tony believes that for co-working spaces it is valuable to use the space depending on demand and situation (hypothesis 1). Therefore, he wants to design furniture that allows flexibility (hypothesis 2). For this, Tony needs to find a design. He thus decides that the best option is to make some lightweight furniture with wheels as this makes it easy for people to rearrange the space (hypothesis 3).

Hypothesis 1: IF space used optimally (option) THEN value creates (value)
First conclusion: Make furniture that optimizes use of space.
Hypothesis 2: IF flexible (option) THEN space used optimally. (new value)
Second conclusion: Make furniture flexible.
Hypothesis 3: IF on wheels (mode) THEN flexible.
Third conclusion: Furniture on wheels to use space optimally.
Overall conclusion: Furniture on wheels create value.

Abduction thus creates new means-end-chains which are only plausible if all hypotheses are true. As the example showed, also value can be an unknown variable. In the following, I therefore use *desired outcome* instead.

The two examples show that the first hypothesis generates a plausible *option* which is then used to substitute an unknown *fact*. The second hypothesis is built on the premise that the option is true, hence it becomes a fact. Different to deductive and inductive logic, abductive logic can become very complex as it creates various relations and dependencies. In order to still be able to verify the means-end-chains created, abductions should thus be the simples reasoning from effect to cause (explanatory abduction) or from desired output to mode of operation (innovative abduction), as described in *3.1.2.1 Hypothesis generation and selection*. Note that Schurz (2008) further divides creative (or innovative) abduction into three types, namely 1) factual abduction 2) law-abduction, and 3) second-order existential abduction.

3.2. Reasoning and application

3.2.1. **The use of deductive and inductive logic**

Under circumstances of high complexity, humans strive for certainty (see Teece, 2007). In general, humans often rely on relatively simple rules to categorize previously unseen stimuli (Vermaercke, Cop, Willems, D'Hooge, & de Beeck, 2014) instead of creating new hypotheses to explain unseen stimuli. It seems that deduction and induction just feel more natural to people then abduction. Also Peirce (1932) noted that for abduction to take place, one must experience

a surprise. This means, usually people *automatically* apply known rules and reason deductively/inductively. Deduction and induction help to build routines and thereby reduce cognitive effort. Therefore, it is not surprising that these are the dominant logics used in research, teaching, business, and our daily life.

Decisions, forecasts, explanations—all these usually rely on rules or observations made in the past. The predilection for deductive/inductive logic is reflected in the tools used to make decisions and to evaluate outcomes. As example, metrics such as financial forecasts, SWOT analysis, Porter's Five Forces, and formal analytics, such as actuarial modelling, Net Present Value (NPV) or Internal Rate of Return (IRR), all rely on detailed, quantifiable data (Zacharakis & Meyer, 2000) to steer decision makers towards the 'best' option. Such analyses reduce complexity and have shown to reduce the number of human errors (Zacharakis & Meyer, 2000). Also during concept selection, people have shown to dominantly use deductive/inductive logic (Cornelissen & Clarke, 2010). Furthermore, in this work I show that during the development of strategies and business ideas, individuals tend to rely on these two logics too. For example, when making decisions about market expansions, executives often chose strategies that have shown to work in the past, and choose to either expand their presence in a market or go to a market that shows similar characteristics.

The problem with deductive and inductive logic

Despite being *easier* and making thinking faster, deduction and induction show important limitations which I briefly discuss in the following (see also example in *3.1.1 Deduction and Induction*).

As deduction and induction rely on general rules or prior observations, one must either know the rules or have made similar observations. This means, interference from *cause to effect* and from *effect to cause* cannot produce any new knowledge when reasoning deductively or inductively since everything that leads to a deduced or induced explanation is already known. However, as it is unknown what needs to be explained in the future, it is unlikely that one will have made all observations necessary for such explanation. Thus, if one would only rely on deductive/inductive logic, many problems (causes or effect) could not be explained. This does not only affect individuals but also tools that are designed for deductive and inductive reasoning (see *3.2.1 The use of deductive and inductive logic*).

For example, quantifiable metrics, as mentioned above, rely on detailed information in order to e.g. forecast future events. However, for early-stage innovation concepts or for new market entry strategies, many of these information are not available, nor can they be substituted by other financial forecasts or trend analyses (Vanhaverbeke et al., 2003). This is because many innovations and strategies are too different and novel, and do not show similarities to prior products or patterns which would be observable. Furthermore, when thinking of a new innovation, not only the innovation will be new, but also the context will have changed by the time it is on the market. Therefore, in such situations inductive and deductive logic have strong

limitations when it comes to coping with dynamically changing user needs and global competition (Assink, 2006; Garbuio, Lovallo, Porac, & Dong, 2015; Tsoukas, 1996). However, humans predominantly rely on deductive and inductive reasoning in processes such as concept selection (e.g. Cornelissen & Clarke, 2010). Deduction and induction are both associated with risk aversion. As result, projects with large potential are often rejected (Type-I-Error) while bad projects are supported before they fail later (Type-II-Errors). I will this with an example.

Let's say, a company developed a tool to analyze radiographs (images from radiology) automatically using image recognition and machine learning. Based on the studies they conducted, the company predicts that results could be ready within a tenth of the normal time. As consequence, hospitals using their tool could employ less radiographers, thus saving not only time but also money. They believe to have a valuable business case, but how to market it? The company conducts research and finds out that hospitals are the largest market. Hospitals usually buy software (licenses) instead of using platforms, i.e. Platform as a Service (PaaS) or Software as a Service (SaaS), because of data security issues. The contracts for such software last over several months or years. Contracts over a longer time span allow them a guaranteed income. In other industries, however, SaaS with a pay-per-use-model have become more and more popular. Furthermore, they find out that radiographers are not only responsible for the analysis of the images but also for the preparation of the radiology. Relying on inductive logic, they come to the conclusion to offer a software with a two-year subscription-model for hospitals and to train the radiographers in managing the input/output of the software. The resulting product and business model do not offer something new. Furthermore, the context in which the software is used is assumed to be the same as at the time they conducted the research. However, since their tool uses machine learning, processing a lot of data would be beneficial. Therefore, a PaaP or SaaS model would have improved the tool. Also, a pay-per-use or per-client might have been interesting for hospitals and potentially opened the market to individual practitioners that currently do not buy any image processing software. As this example shows, relying only on deductive/inductive logic does not help to prove future success of innovations. Therefore decision makers all too often become risk averse. As the product is new to the world, decision makers cannot rely on 'best practice' and, instead, revert to scanning ideas for potential similarities to patterns that are believed to be successful (Baron, 2006). As innovation concepts, such as the example above, often show dissimilarities to such patterns, truly innovations are often rejected or not even considered. Also, such reasoning makes it easy for competitors to predict a company's steps and reaction.

3.2.2. **Application of abduction**

As deduction and induction are more *natural* forms of reasoning, abduction only takes place when a surprising observation is made, i.e. when humans 1) cannot explain something relying on former experiences or general rules they know or when 2) inventing something new to the world. The use of abductive reasoning has shown to benefit various fields such as

scientific discovery (Dunne & Dougherty, 2016) and particularly design, such as design synthesis (Lu & Liu, 2012), design evaluation (Dong et al., 2016a), and concept selection (Dong et al., 2015; Guenther et al., 2017; Mounarath, D. Lovallo, & A. Dong, 2011); as well as strategy development (Calabrese & Costa, 2015; Dew, 2007; Dong et al., 2016b).

In many of these fields humans are confronted with complex problems. In their work, Dunne and Dougherty (2016) identified three challenges innovators face which are associated with complex systems (or problems); these are: 1) the amount of information, 2) to become stuck in local optima, and 3) the decomposition of nested problems. This means, innovators must base decisions on incomplete, yet diverse information while getting little to no direct feedback. Only if a sequence of steps is executed, some feedback is available. However, this feedback is often not on the final outcome but only on an intermediate step. Furthermore, uncertainty often increases the amount of information which needs to be processed (Tsoukas, 2005), which in turn increases the complexity. Complex systems include various independent problems which create "vast and multipeaked spaces of potential alternatives" (Baumann & Siggelkow, 2013, p. 129). People tend to decompose complex problems into smaller chunks (multipeaked spaces) and evaluate these separately by scanning them for known patterns. This process often entails proximity biases and leads to the selection of local optima. As consequence, when assembled as set, these local optima risk to create low performance (Baumann & Siggelkow, 2013). To counter this 'problem-solving oscillations' (Mihm, Loch, & Huchzermeier, 2003), researchers promote an integrated problem solving approach, rather than decomposing the problem into smaller chunks. To deal with this complexity innovators use mental models to make predictions, and adjust their model based on experienced conditions (Denrell, Fang, & Levinthal, 2004). Abductive reasoning is suggested to help during this process (Garud, Gehman, & Kumaraswamy, 2011) and in viewing complex problems as a whole. This form of reasoning should therefore be of particular value to scientists as their research is based on discovery rather than prediction, and many problems are usually of high complexity (see Dunne & Dougherty, 2016).

3.2.2.1. Example of an abductive scientific discovery process

Most literature on abductive reasoning is conceptual (Fischer, 2001; Gonzalez & Haselager, 2005; Peirce, 1932, 1998), therefore providing little insight how people actually use abduction in particular situations. Dunne and Dougherty (2016) developed a framework based on 85 interviews with scientists that introduce three social mechanism that enable the use of abductive reasoning, and thereby the development of new products in complex systems. These mechanisms are: 1) the use of clues, 2) elaborating and narrowing around imagined interactions of configurations to build intermediate models and alternatives, and 3) "iteratively iterating across disciplinary boundaries to reframe the configuration of interactions" (Dunne & Dougherty, 2016, p. 143). The first category reveals that individuals often rely on clues to hypothesis a pattern or interactions between parts of the problem. The content of search (or

search domain) influences pattern recognition, and the ability to embrace ambiguity and active and structured engagement in the search process facilitates the recognition of clues. This finding is in line with research in the field of entrepreneurial opportunity recognition. Shane (2000) for example found that opportunity recognition is dependent on the background—and also *pattern recognition* plays an important role (e.g. Dyer et al., 2008; Gaglio, 2004).

In the study of Dunne and Dougherty (2016, p. 143), scientists used "clues to imagine a configuration of interaction" which enabled them to "jointly optimi[se] the various links". The imagined configurations are abductive hypotheses which might not be the final ones, but they function as 'intermediate models' which are essential to figure out the next steps (Denrell et al., 2004). Clues also give meaning and help to invent 'worlds' in which these clues make sense (Weick, 2005). Thereby they help to synthesize otherwise noisy information and to narrow the search process. Dunne and Dougherty (2016) found that clues are also used to make analogies (see also Dunne & Dougherty, 2016). While different people found different clues, and the amount of abductive reasoning used differed among people, how abductive reasoning was used along the process did not depend on discipline or role.

The second category emphasizes the importance of constantly elaborating and narrowing around imagined interactions of the configurations. This process enables the contextualization and improvement of interactions in complex systems. Using abductive reasoning, scientists were able to focus on details while continuously searching systematically for related facts (Dunne & Dougherty, 2016).

The last category illustrates that innovators from different disciplines work across experimental situations and share their knowledge among each other. By 'iteratively iterating' scientists reframed initial problems, improved configurations, and were able to develop new performance parameters and find new interdependencies. Thereby they "accumulate[d] the insights generated by the discovery process into a revised hypothesis about the configuration of interactions" (Dunne & Dougherty, 2016, p. 148).

The model described above shows how abductive reasoning is used during the process of the development of products within a complex system and underlines its significance for innovation. Next, I present how abductive reasoning can be used in other fields, starting with design evaluation and concept selection.

3.2.2.2. Abductive reasoning during design synthesis

The aim of most product development processes is to develop products which are new to the word. If relying on inductive logic, innovations are likely to be incremental as they try to replicate known principles. As designers are often confronted with wicked problems—this are problems that are ill defined or of which not all variables are known—scholars promote the use of abductive reasoning (Dorst, 2011; Roozenburg, 1993). As abductive reasoning creates new knowledge and plausible hypotheses rather than proven facts, it is considered vital for the design process (Dorst, 2011), and particularly for design synthesis (Lu & Liu, 2012), design evaluation

(Dong et al., 2016a), and concept selection (Dong et al., 2015; Guenther et al., 2017; Mounarath et al., 2011).

In their work, Lu and Liu (2012) illustrate three situations in which designers use abductive reasoning and develop an 'abduction-based synthesis process' (see Figure 1). They suggest that designers use abductive reasoning during 1) the definition of 'implicit design targets', this are steps (or functional requirements) necessary to achieve the 'design intent' (or customer need); 2) the ideation process, and 3) the diagnoses of 'bad' design concepts.

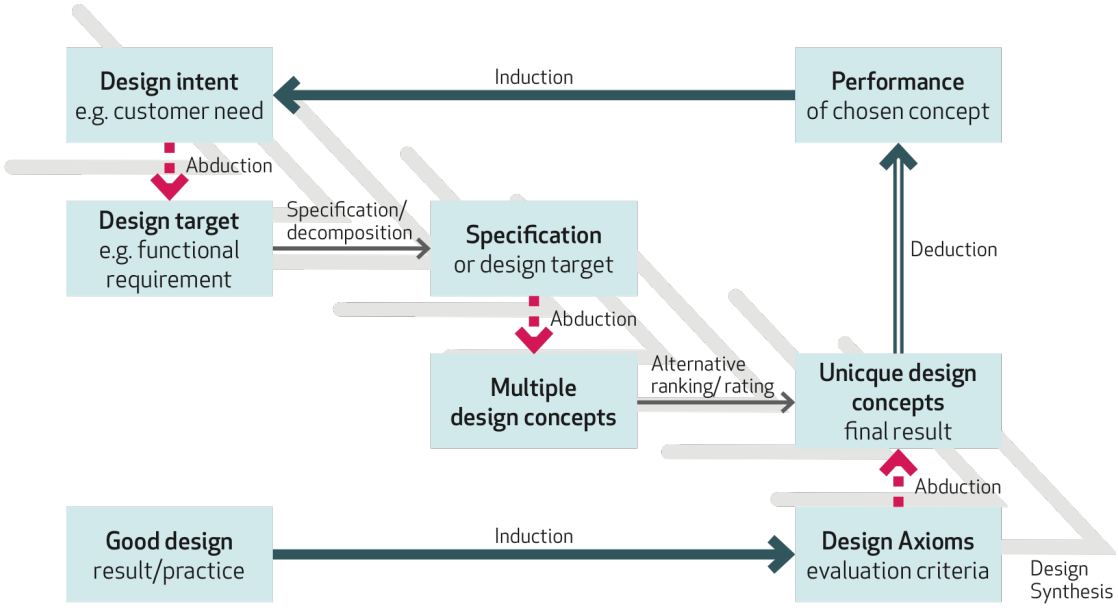

Figure 1: Abduction-based synthesis reasoning process, adapted from Lu & Liu, 2012, p. 145

Similar to the first example given in *3.1.2.2 Explanatory and Innovative abduction,* the design intent (or value) is the only know variable which functions as starting point for the abduction. Building on the classification Schurz (2008), Lu and Liu (2012) argue that designer use two different forms of 'abduction' during ideation. These are 1) *factual abduction* and 2) *law-abduction*. In the former both the outcome and the proposed hypothesis are described as singular facts, whereas in the latter the desired outcome and the "possible hypothesis are expressed as certain laws" (Lu & Liu, 2012, p. 144). Lu and Liu (2012) provide the following example for factual abduction:

> *Initial design intent: to preserve food.*
> *Background design knowledge: keeping food at low temperature can preserve food.*
> *Possible design concepts: refrigerator, freezer, ice, etc.*

This example is indeed similar to the ones given earlier. Here the designer starts with the intended outcome and formulates a hypothesis (low temperature) under which food would be preserved for a longer period. The 'possible design concepts' is somehow equivalent to the *mode of operation* which I used earlier. However, I argue that the following example which

illustrates ‘law-abduction’ does not make use of abduction as defined earlier, but uses induction to generate new ideas. This is because all factors are known at the given situation. The idea is thus induced and not abducted.

> *Initial design intent (empirical law): car must move.*
> *Applicable design knowledge (background law): all objects with wheels can move.*
> *Proposed design concept (new law): car should have wheels.*

The authors note that when employing “law-abduction to ideate new design concepts, the chance of success of the proposed concepts becomes higher, because the entire reasoning process consists of multiple chaining laws. However, the novelty and diversity of ideated concepts are likely to be less. This is due to the fact that laws always contain much more tangible information and rigid frames than singular facts, which will limit designer’s ideation” (Lu & Liu, 2012, p. 44). These are indeed known limitations of deductive and inductive logic (see in *3.2.1 The problem with deductive and inductive logic*). Though their examples might not be the best, I agree with them that abduction plays a vital role in the design synthesis. Furthermore, their conceptual model (Figure 1) is, so far, the only representation of logic used during the design process in literature. However, the model entails some fallacies e.g. use of deduction during concept selection. I address these issues in the following and show that abductive reasoning should also be used during evaluation and selection, respectively.

3.2.2.3. Abduction in design evaluation

A large body of literature comes to the conclusion that the evaluation of concepts should be based on deductive reasoning as ‘evaluation’ means to determine the “quality (value or worth) of a design concept against established objectives as a function of one or more its attributes” (see Dong et al., 2016a, p. 16). However, as many design concepts are new they entail a lot of ambiguous evidence which is hard to evaluate at the given moment. This is especially important during early development stages when market conditions are likely to change. Relying solely on deductive and inductive logic would therefore lead to project rejection because merit-based evaluation uses current working principles and patterns to evaluate product success, however many of these may not work in the future. To counter this fallacy, abductive reasoning should be applied as this allows to mentally expand the given idea from a concurrent state to a likely future situation (Dong et al., 2015; Mounarath et al., 2011).

In their study, Dong et al. (2016a) analyzed design review conversations of third-year industrial design and entrepreneurship students. They found that during the evaluation all types of reasoning were used (including abduction). Therefore, design evaluation does not only use convergent, analytical thinking, which necessarily entails deductive reasoning and leads to definite conclusions, but also include design thinking practice (see Dong et al., 2016a). This results support findings from studies of concept selection which also found abductive reasoning instances (Dong et al., 2015).

Furthermore, their coding scheme shows that during design evaluation not only the mode of operation can be subject of an abductive interference, as proposed by (Dorst, 2011; Roozenburg, 1993), but also the context of application. In total, Dong et al. (2016a) canvas five codes for abductive interference; these are: 1) structure, 2) behavior, 3) product, 4) user, and 5) context. The first two describe the interference of a form to a mode of operation, that is by either changing the form of the concept or by changing the way of interaction applied in a concept. The third positions the concepts in a new way so that the initial concept proposition changes, therefore creating a different type of product. The user code is about framing alternative modes of how users operate the concept (interaction) from a user perspective. Lastly, as stated above, also the context can be interfered, which then often results in a new product or a new market.

Their results show a use of 20% logical reasoning during design evaluation with significance differences in the frequencies of each reasoning type. They show that deductive and abductive reasoning occur separately and in the same utterance or episode of evaluation. That is, abductive hypotheses resolving problems "by proposing a solution that may then be assessed through further actions; or, abductive hypotheses that propose conditions that undermine the present concept" (Dong et al., 2016a, p. 12). Building on the instances where both types co-occur, Dong et al. (2016a) describe a 'recursive, hypothesis-driven' evaluation method in which new propositions are invented as means to "explain, resolve, or challenge the evidence in favor or against a design concept", and thereby test the propositions (Dong et al., 2016a, pp. 15-16). They define this co-occurrence of reasoning as a pattern of design thinking and call it 'generative sensing'. Their results suggest that abduction can direct to both divergent and convergent thinking. During design evaluation, generative sensing—and abductive sensing as one of its micro-foundations—can aspire entrepreneurs to avoid single answers and choose familiar solutions. In the same time, it can help designers to reframe their concepts thereby discover new innovations.

3.2.2.4. Abduction in concept selection

Similar to concept evaluation, tools and advocated 'best practice' for concept selection rely on deductive/inductive logic too. However, if only applying these types of reasoning, the same fallacies would occur, e.g. many innovative concepts would be rejected as their success cannot be proven with existing rules and past observations (see also in section *3.2.1 The problem with deductive and inductive logic* and *3.2.2.3 Abduction in design evaluation* for limitations of deductive, inductive logic). As mentioned above, deduction and induction are associated with risk aversion. To cope with this bias, companies often expose themselves to risk. However, explorative processes often lead to the acceptance of bad projects. This type of errors (referred to as Type-II-Error) is also associated with optimism (Lovallo & Sibony, 2010) and hindsight bias (Christensen-Szalanski & Willham, 1991). Therefore, exposure to risk does not lead to better results, in contrary.

Mounarath et al. (2011, p. 2) suggest that the "abductive reasoning frame might be productive in overcoming hindsight bias since abduction requires an explicit relaxation of the prior constraints to 'guess' a new, plausible explanation of a situation". To test the suggestion, Mounarath et al. (2011) studied decision making during concept selection and manipulated groups with different voting rules and either a deductive or an abductive reasoning frame, resulting in four different decision making conditions. The two voting rules were a permissive and a conservative one. Under the first rule, at least one person must vote accept for the project to be accepted for funding, under the latter, the whole group needs to vote accept for the project to be accepted into the final portfolio. The deductive reasoning frame emphasized the importance of technical feasibility and market opportunity and "induces a strong inclination towards evaluating project briefs as they appeared in the portfolios" (Mounarath et al., 2011, p. 6). In contrast, the abductive reasoning frame was of hypothetical nature, aimed to motivate participants to look beyond the facts presented in project briefs, and elicited a 'creative search and idea generation of the possible future [in 2-3 years' time] wherein the product could co-exist" (Mounarath et al., 2011, p. 6). While the voting rules did not significantly affect the decision making across the conditions (deductive versus abductive, permissive versus conservative), individuals in groups manipulated with the abductive reasoning frame selected more projects. However, under the abductive reasoning frame, the number of Type II errors (acceptance of bad projects) arose.

Dong et al. (2015), the group of scholars who's work on abductive reasoning for design evaluation I presented in the prior section (3.2.2.3), also investigated the effect abductive reasoning on concept selection, particularly the direction of decision outcome. The study design was similar to the above presented research by Mounarath et al. (2011) with the difference that only reasoning frames (RF) were manipulated. The data confirm prior findings, i.e. under an abductive reasoning frame the project acceptance is higher, and show that abductive reasoning is associated with project acceptance while deductive/inductive reasoning leads to project rejection (Dong et al., 2015). Dong et al. (2015) argue that by an intrinsic change in the form of reasoning applied—leading to a more thorough future-oriented exploration of the projects' potentials—abductive reasoning reduces pattern recognition biases Dong et al. (2015).

A recent study extends the research of Mounarath et al. (2011) and Dong et al. (2015) by investigating not only the presence/absence of abductive reasoning and the direction of decision outcome, but also the ratio of abductive reasoning used during concept selection and the correctness of the decisions (Guenther et al., 2017). Rather than investigating concept selection in group settings, the study examined individual decision making. Thereby, factors that influence decision outcomes in groups, such as consensus versus single voting rules and group size (e.g. Bardolet, Fox, & Lovallo, 2011), are eliminated. During the study, participants were asked to generate ideas for product extensions (for the next 2-3 years), then to decide whether they want to further fund the project (accept) or not, and to justify their decision. The analysis

of in total 255 decisions made on a total of five projects presented (instead of seven) shows that when individuals applied a high ratio of abductive reasoning, the number of projects accepted increased compared to individuals that used less abductive reasoning. Abductive reasoning was positively correlated to decision-making correctness and decreased the number of Type-I-Errors while the amount of Type-II-Errors did not increase significantly (Guenther et al., 2017).

In addition, the research investigated whether highly creative people use more abductive reasoning than less creative people. Choosing concept selection is crucial during the innovation process and an important component of innovation is creativity (West & Farr, 1990), which has been argued to rely on (or occur in) abductive reasoning (Finke, Ward, & Smith, 1992; Gonzalez & Haselager, 2005; Kapitan, 1990). The findings show that, during concept selection highly creative people used more abductive reasoning for generating extensions, this are follow up products, new market opportunities or modification of the product that lead to a new product category (Guenther et al., 2017). In line with prior findings that abductive reasoning leads to more projects being selected, highly creative accepted more projects, made better selections, i.e. they chose successful projects and rejected bad projects. Abductive reasoning and creative thinking, therein divergent thinking, are thus vital for the selection of innovation concepts and can help to overcome risk aversion.

3.2.2.5. Abductive reasoning in the process of strategizing

A firm's strategy is another field in which innovative thinking is required. The origin of strategy is human cognition. Cognition allows the selection, interpretation and deformation of information. It is essential for decisions which lead to the formulation and implementation of a strategy. The process of strategy development—also referred to as 'strategizing'—is a cognitive or decisional process which is essential for the management of firms (see Calabrese & Costa, 2015). Executives' mental processes and capabilities are therefore crucial for companies, i.e. executives' strategic cognition (SC) allows innovation and the derivation at new value propositions (Gavetti, 2012). SC refers to the relation of cognitive structures and decision making in regards to the formulation and implementation of a strategy. SC is affected by many aspects, thereunder an executive's knowledge, biases, bounded rationality (see Tversky & Kahneman, 1986), dominant logic, and heuristics. Executives often take mental shortcuts in the process of strategic decision making and assess predictions of past events for the assessment of probability judgements (see also Porac & Thomas, 2006, Chapter 8), which negatively impacts executives' strategizing. As shown earlier, mental shortcuts are mainly associated with deductive/inductive logic. In fact, strategizing is generally understood as a rational process (see also Teece, 2007). However, Gavetti (2012) found that superior strategies respond to out-of-the-box ways of thinking and are cognitive distant, i.e. uncommon strategies outside the cognitive bound. Executives that think more visionary tend to be more proactive and open in their strategizing. Refusing and changing the status-quo and existing paradigms often leads to

the emergence of new possibilities. This, however, often requires executives to change perspective (Friedel & Liedtka, 2007).

Though the body of literature investigating the underlying cognition of managerial opportunity recognition capabilities is growing (see e.g. Gaglio, 2004; Gaglio & Katz, 2001; Teece, 2007), comparable few scholars examine the underlying reasoning processes (e.g. Calabrese & Costa, 2015; Dew, 2007; Dong et al., 2016b).

In a recent study, Calabrese and Costa (2015) used a semi-structured laddering technique to analyze the cognitive processes underlying strategizing. Twenty leaders of successful financial institutions were interviewed about the "cognitive paths [they] follow to create innovative and successful strategies"(Calabrese & Costa, 2015, p. 29). As result of interviews and the laddering technique, Calabrese and Costa (2015) propose a model (see Figure 2) representing the cognitive process employed during strategizing. They conclude that strategizing is a dynamic process which entails all forms of logic and is dependent on a leader's knowledge and associations. "Leaders' ability to manage their existing knowledge, applying cross-disciplinary analogies according to strategic principles" is essential for innovation, and particularly strategizing (Calabrese & Costa, 2015, p. 34).

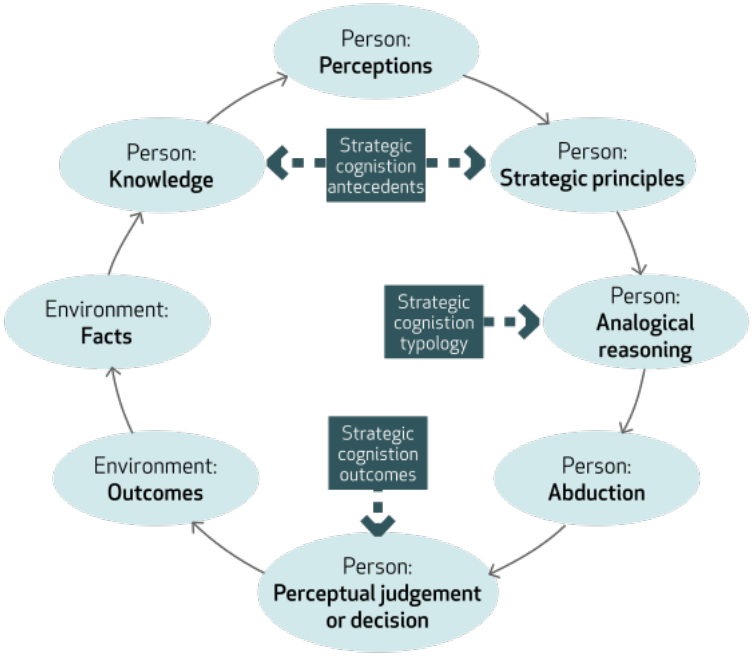

Figure 2: Cognitive process during strategizing, adapted from Calabrese and Costa, 2015, p. 31

Calabrese and Costa (2015, p. 34) argue that, "when leaders' knowledge and analogical reasoning are low, a firm may find itself exposed to competitive risk, and would need to manage its actions in response". This is in line with Dong et al. (2016b, p. 102) argumentation that when "deductive logic [is applied by executives] to understand forces, then [executives'] understanding can only ever reflect thinking that started from a proven template. No further testing is necessary because evidence to support the conclusion already exists. Similarly, if the

understanding is derived from inductive logic, any new evidence consonant with existing beliefs and mental models reinforces the beliefs and mental models, while other evidence is simply considered anomalous".

3.2.2.6. Abductive reasoning for sensing strategic options

Strategy development requires sensemaking of highly ambiguous environments (Hill & Levenhagen, 1995). Deductive and inductive logic are of little help under these conditions. Hill and Levenhagen (1995) suggest that, to cope with these uncertainties, entrepreneurs (and executives alike) build mental models that explain their environment (sensemaking) in order to then communicate their understanding to others (sensegiving). The mental models are developed through a 'double loop' or 'second order' learning process. Metaphors used in the model allow to transfer a larger amount of yet more abstracted information (Astley & Zammuto, 1992). Due to the level of abstraction and incompletion, metaphors enable individuals to make interferences more easily and thereby enhance creative processes (see Hill & Levenhagen, 1995). Metaphors often evoke emotions as they contain emotive content. New metaphors can lead to disruption and contradictions with existing mental models. If a new metaphor is regarded as beneficial and can be controlled, arousal evokes and the disruption is seen as a challenge (Kahneman & Tversky, 1979). Through comparison of existing and new metaphors, individuals can revise their beliefs and cope with ambiguity. However, if the individual cannot cope with the emerging metaphor, i.e. the metaphor is seen as harmful, then stress results (Hill & Levenhagen, 1995). Hill and Levenhagen (1995, p. 1064) suggest that these "cognitive processes of metaphor usage can provide useful heuristics when: (1) the amount of detail overwhelms cognitive abilities, (2) learning is sketchy or incomplete, (3) perceptions seem ambiguous, or (4) problem domains are ill-structured". This all applies to the conditions under which business strategies are developed.

In contrast to Calabrese's and Costa's study which examined the *process of* strategizing, Dong et al. (2016b) focused on the cognitive process and managerial capabilities of 'sensing and sizing' strategic options and opportunities. Sensing capabilities rely on belief revision—the revision of one's beliefs is also essential for abductive reasoning—and are sensible to external dynamism, prior knowledge (as this forms beliefs), and perception (Dong et al., 2016b; see also Teece, 2007). Sensing capabilities should be supported by companies as individuals cannot process all the incoming information due to their limited attention (Teece, 2007).

In their conceptual work, Dong et al. (2016b) identified two microfoundations—the underlying cognitive processes—of sensing capabilities and developed a framework which illustrates the process of 'generative sensing'. Generative sensing extents the current understanding of sensing capabilities discussed in the dynamic capability literature. Generative sensing capabilities are sensing capabilities which focus on *generating* and *testing* hypotheses that result from an abductive reasoning and 'framing' process (Dong et al., 2016b). Similar to a *reasoning frame*, framing refers to the lens through which an individual interprets stimuli. For

example, a *problem frame* is the lens or perspective through which a problem is investigated (see also Garbuio et al., 2015). Reframing refers to the change of a frame, i.e. a problem in another context or a change of the problem itself. In design, framing is often used to draw associations and thereby helps designers to identify new ideas. In the context of strategizing, frames can help to reframe problems, such as losses or customer needs, to derive at new problems or ideas. Through reframing, executives are able to abstract and find associations with similar concepts in other contexts, i.e. business models, product/service solutions, or marketing strategies in other fields. This process allows them to identify novel problem frames and more innovative solutions (for the use of analogies in strategy development see also G. Gavetti, Levinthal, & Rivkin, 2005; Lovallo, Clarke, & Camerer, 2012).

Generative sensing makes use of both explanatory as well as innovative abduction (see *3.1.2.2 Explanatory and innovative abduction*). Dew (2007) illustrates several examples of how abduction is used in the context of strategy development. Dong et al. (2016b) extend this list and allocate the examples to either explanatory or innovative abduction. They propose that explanatory abduction is helpful to 1) identify motives of competitors' actions/reactions, 2) explain market behavior (e.g. consumer behavior), 3) revise belief about environment/trends, 3) explain supply chain behavior, and 4) discern technology developments. In contrast, when companies aim to innovate they will rely on innovative abduction and use this form of logic to e.g. introduce or change 1) their business model or 2) product/service offering, or to 3) identify new market segments. Dong et al. (2016b) also emphasize that executives should scan their environment for anomalies as these require explanatory abduction to derive at an explanation. Furthermore, executives should focus more on understanding and reframing the problem rather than on solutions (Dew, 2007) and embed generative sensing capabilities within an organization (Dong et al., 2016b). The development of generative sensing capabilities is important as these capabilities can improve the pool of strategic alternatives and thereby improve the overall strategy (see Friedel & Liedtka, 2007). Besides cognitive styles—that is how an individual gathers and processes information and includes process such as abductive reasoning and generative sensing capabilities—cognitive content and structures are suggested to affect executives' ability to frame problems (Finkelstein & Hambrick, 1996). Cognitive content refers to prior knowledge and beliefs, cognitive structures to how content is arranged and connected. Cognitive content also affects opportunity recognition, which I explain in section *3.3.3 Opportunity recognition.*

3.3. Growth creating strategies

In order to achieve growth, companies need to innovate and survive among competitors. A large body of literature investigates how different strategic decisions and orientations affect performance of companies, e.g. market and entrepreneurial orientation (Hult et al., 2004), expansion and entry-mode decisions (Shaker A Zahra, Ireland, & Hitt, 2000), and competition

and ownership (Baghdasaryan & la Cour, 2013). Some scholars examine strategies that can lead to competitive advantages (Lieberman & Montgomery, 1988), characteristics of innovations (Ettlie, Bridges, & O'keefe, 1984; Kilic, Ulusoy, Gunday, & Alpkan, 2015), environments which stimulate innovation (Engel & del-Palacio, 2009), characteristics associated with innovative entrepreneurs (Dyer et al., 2008; Hartog, Van Praag, & Van Der Sluis, 2010), conditions influencing entrepreneurial behavior (Brandstätter, 1997; Carsrud, Gaglio, & Olm, 1986), and how managerial characteristics influence decisions (Finkelstein & Hambrick, 1996; Hambrick, 2007; Hambrick & Finkelstein, 1987; Hambrick, Geletkanycz, & Fredrickson, 1993). In the following I talk about two areas which are relevant for companies' performance and the later discourse. I first address the difference between innovativeness and innovations and findings in the field, followed by a section about factors influencing (strategic) decisions. In the latter, I briefly introduce the upper echelon theory and key findings in the field of opportunity recognition. I conclude each part with an example. The first will show that many choices that are believed to be purely rational are in fact influenced by personal and other factors which cannot be captured by rationality based theories. The second example shows how companies that do not follow 'best practice' create competitive advantages. Both examples illustrate location choices. Location has been chosen as example since, different to other resources, such as supply channels and partners, it is defined as generic resource. Generic resources are equally available and therefore do not lead to superior performance. In the second example, I show, however, that also generic resources—when used strategically—can have a major impact on a firm's strategy.

3.3.1. Innovation and innovativeness

Innovation and innovativeness need to be distinguished. 'Innovativeness' has yet to be clearly defined in the literature as its definition has been changing over time (see e.g. Kilic et al., 2015). Commonly, innovativeness is seen as notion of openness to new ideas and rate of adaptation of innovations, measured based on its antecedents after implementation, i.e. numbers of innovations adopted at a given time (compare Damanpour, 1991). The in 2005 published Oslo Manuel (OECD, 2005) extended the commonly used classification of innovations into 1) process and 2) product (or technical) innovation by two categories, namely 3) marketing and 4) organizational (or administrative) innovations. Product innovation are often further distinguished into incremental and radical (or disruptive). Prior studies show that innovative companies (Gunday, Ulusoy, Kilic, & Alpkan, 2011) and innovativeness lead to better performance (Damanpour, Szabat, & Evan, 1989), and that financial performance can be predicted by innovation strategies (Shaker A. Zahra & Das, 1993). Innovativeness can also help to achieve a sustainable competitive advantage as it allows "the firm to preempt competitors with new or improved products, diversify product lines, and generally expand the firm's scope of activities" (Hult et al., 2004, p. 436).

Using a taxonomy based approach, Kilic et al. (2015) investigated whether the innovativeness of manufacturing companies differ among innovation categories (see above), whether this is affected by age, firm size, ownership status, sales, and presence (or absence) of foreign direct investment (control variables), and whether it influences companies' performance. Kilic et al. (2015) divided innovativeness into four clusters: leading innovators, followers, innovators, and laggers. Company performance was assessed through managers' perception of the firm's performance in the last three years compared to the previous years and assessed with three items: financial, production and market performance. Likewise, innovativeness was assessed through a survey. From the control variables, only sales differed among the clusters. The innovative leader cluster outperformed all others on all aspects (process, radical product, incremental product, marketing, and organizational innovations). Kilic et al.'s clusters reveal differences in how leading innovators, followers, innovators, and laggers adopt and develop operations and attain corporate performance levels. The authors suggest that firms should innovate across all innovation categories because "each aspect of the innovative capability is important and offers some degree of competitive advantage. [For example,] Inventors emphasize more the development of radical product innovations, they focus on the flexibility more than do Followers and are the leaders in total sales growth rate and the second best performer in production and marketing performance. On the other hand, Followers do not prefer to develop radical products but give balanced importance to process, organizational, and incremental product innovations" (Kilic et al., 2015, p. 131).

The difference between radical and incremental innovation on a process level has been already investigated in the 80's. Ettlie et al. (1984) found that the 'causal strategy-structure sequence' in organizations differs for both types. While incremental product introductions and process adaptations are supported by more complex, traditional organizational structures and market orientated strategies, radical innovation requires unique strategies, such as a decentralized decision making and a more general orientation, especially for process adaptations (Ettlie et al., 1984). Another type of complexity that affects performance, besides organizational complexity, is competitive repertoire complexity. Competitive repertoire complexity is the set of actions and resources which allows companies to respond to and take advantage of emerging changes, stay ahead of competitors and protect themselves against imitation. Complexity in competitive resources is positively associated with company performance on a long term (Connelly, Tihanyi, Ketchen, Carnes, & Ferrier, 2016; Ferrier, 2001) and its aggressiveness in attacking competitors. However, many firms struggle to deal with such complexity and, as consequence, do not benefit from these effects (Miller & Chen, 1994). The repertoire complexity a company possesses depends, besides others, on the experience and diversity of executives (Ferrier, 2001). One explanation for these effects might be the upper echelon theory, which I briefly introduce in the next part.

3.3.2. Upper echelon theory

Individuals, particularly CEOs and top management teams (TMT) (here called 'executives'), have shown to influence decision making outcomes. The upper echelons theory (e.g. Hambrick, 2007) suggests that the background of executives (e.g. experiences, values, and personalities) influences their perception of a situation in which a strategic decision is made, and that executives themselves are affected by the environment and, besides others, the 'job demand'. This is the difficulty of strategic conditions, performance challenges, and executive aspirations (Hambrick, 2007). Furthermore, Finkelstein (1992) found that the power of executives within TMTs is not equally distributed and that their biases must be taken into account when predicting TMT actions. For example in regards to entry mode decisions, prior research has shown that TMT's international experience and their national diversity affect decision outcomes, and that these factors are yet two distinct characteristics (Nielsen & Nielsen, 2011). In addition, executives who showed a poor performance in the past feel a greater need for strategic change (Hambrick et al., 1993). Similar, strategic decisions made by executives that face high job demands (see above) entail more of the executives' characteristics. Also, executives under these conditions too often take mental shortcuts and screen for properties and patterns which have shown to work in the past (Hambrick, 2007).

Research on competitive action found that team heterogeneity influences the sequence of their reactions and the complexity of their competitive strategy. Ferrier (2001, p. 852) notes that "by way of greater awareness in sensing strategic problems, heterogeneous teams can match complex competitive challenges and uncertain contexts with a requisite level of cognitive and experiential variety". This may enable them to develop more aggressive, complex and unpredictable strategies and sets of alternatives. Homogenous TMTs however tend to develop simpler strategies and to be more committed to status-quo orientated as they do not possess 'conflictual decision-making techniques' (Ferrier, 2001).

A substantial body of literature on the upper-echelon theory exists. However, in many fields, especially economics, managerial differences of individual influences are not included or neglected. In the following example on location choice theory I list findings and show the importance of individual differences on such decisions.

Example: How individuals affect location choice

Individual differences have shown to influence decision making in other areas such as resource allocation, financial decision making, or concept selection. The choice of location, however, is too often seen as a rational and reactive than strategic decision. Two different approaches are frequently named in the location decision making literature. These are 1) the economic approach and 2) the internationalization process model (Buckley, Devinney, & Louviere, 2007). The former assumes that location decisions are made to protect profitability and to seek assets by using a rather rational approach. With other words, this approach assumes equality of all decision makers, thus, it looks at decision makers as an equally behaving group

rather than as individuals. Due to this, the economic approach does not include a lot of managerial discretion (see Hambrick & Finkelstein, 1987). The latter approach is an iterative decision making process in which decision makers are confronted by limited information and risk aversion. Here, the decision is not seen are purely rational but also includes the goal of 'learning to internationalize'. So far, many different variables, such as cultural distance, technology, institutions, and policies, have shown to influence the location choice of companies. Other studies have shown that the level of corporate experience affects location choice, particularly when it comes to uncertainties (Davidson, 1980).

Building on the study of Davidson (1980), Buckley et al. (2007) conducted an experimental study in which they tested the importance of various variables (such as RIO, assets, business line) for 1) the consideration of an investment and 2) the actual investment decision. Their results show differences between those situations and between experienced decision makers compared to those with less experience. Also, whether decisions were made more or less rationally differed depending on the situation.

This shows that decision making and strategic planning are made in a specific context and depended on the individual, i.e. experience or uncertainty tolerance. Strategic decisions are made because they are believed to lead to a superior positioning or some sort of advantage. Therefore, in the following part, I talk about opportunity recognition. That is, how opportunities are found or created and by whom.

3.3.3. **Opportunity recognition**

Opportunity recognition refers to the process a person undertakes to identify potentially profitable ideas for new business venture (Baron, 2006; Kirzner, 1979). Two major theories need to be distinguished when talking about opportunity recognition: the *equilibrium theory* and the *Austrian economics theory*. The former assumes that all resources are equally available and that anybody is equally able to recognize opportunities. The latter, in contrast, assumes that individuals differ in their ability to recognize opportunities. This is because, *if* everyone was able to discover the same opportunity, *then* the opportunity would not exist anymore.

Scholars attribute differences in opportunity recognition to prior knowledge (Shane, 2000; Shane & Venkataraman, 2000), experience (Shane, 2000), personality traits (Ardichvili, Cardozo, & Ray, 2003; Brandstätter, 1997; Dyer et al., 2008), networks (Dyer et al., 2008), and cognition (Cornelissen & Clarke, 2010; Gaglio, 2004; Gaglio & Katz, 2001) including 'entrepreneurial alertness' (Ardichvili et al., 2003; Gaglio & Katz, 2001; Kirzner, 1979; Shane & Venkataraman, 2000). Alertness is defined as recognition of opportunities without actively searching for them (Kirzner, 1979). People recognize opportunities rather by immediate discover than by search (Shane, 2000). Thus, the discovery of an opportunity happens while being otherwise engaged. In this regard, a deliberate search is thus impossible, as noted by Fiet (2007).

Prior knowledge is probably the most frequently mentioned variable. Prior knowledge is argued to not only influence the search/recognition process, but also to enable entrepreneurship as we know it today. Different people possess different knowledge at various points in time as it is easier to accumulate more information around known information. This 'information stickiness' creates a so-called knowledge asymmetry (Von Hippel, 1994). Knowledge asymmetry—which also leads to belief asymmetry—is a precondition for the existence of entrepreneurial opportunities (Fiet, 1996, 2007). Without this asymmetry all people would recognize the same opportunities, thus the opportunities would not exist anymore. Shane (2000) found that opportunities are recognized depended on individual's prior knowledge on 1) a market, 2) how to serve a market and 3) customer problems within that market. Individuals recognize opportunities that lie within their expertise (Shane, 2000). Based on Dublin's Theory Building approach, Ardichvili et al. (2003) distinguish three steps in the opportunity recognition process: 1) sensing market needs of unemployed resources, 2) recognizing a 'fit' between needs and available resources, and 3) creating a new 'fit' in form of a business. Differences in the 'sensing' capabilities are believed to be due to different "heterogeneity in individuals' sensitivity" caused by "genetic makeup, background and experiences […] and information" (Ardichvili et al., 2003, p. 110). This is similar to the concept of entrepreneurial alertness, mentioned above. Though some people might be more alert (or sensitive) than others, this does not mean that they are also better in creating ideas for a new step (Ardichvili et al., 2003). Furthermore, the authors suggest that the opportunity recognition process may differ between four types of opportunities. These types of opportunities are: 1) *dreams* in which both the value creation capability as well as the aspired value (e.g. a customer problem to solve) are unknown; 2) *problem solving* opportunities where only the problem to solve is identified but not the mean how to solve it; 3) *technology transfer* opportunities, i.e. the means are known but not the purpose (aspired value); and 4) *business formation* opportunities where both the capabilities as well as the purpose is known (Ardichvili et al., 2003).

Baron and Ensley (2006) propose that opportunity recognition depends on mental models or 'prototypes' and entails an analogous matching process, i.e. existing mental prototypes of a business venture are compared with new prototypes of a venture (e.g. idea or opportunity) and then selected based on how well the prototypes match. That means, one has not only to recognize an opportunity, but the opportunity must also be considered to be valuable (match with the prototype) in order to be pursued. Baron and Ensley (2006) show that more experienced entrepreneurs have a higher agreement between these two mental prototypes compared to novice entrepreneurs, and that their prototypes were more defined and included more dimensions. According to experienced entrepreneurs, to be good, business ventures should solve a problem, generate cash, have a manageable risk, generate revenue in a considerable amount of time, and be able to realize with capabilities in their network. In contrast, novice entrepreneurs see an opportunity as good when it is novel, based on a new technology, is

superior in term of product or service, can change the industry potentially, and when it feels right (Baron & Ensley, 2006). More experience might help people to overcome the fallacy of relying on one's intuition (Huang & Pearce, 2015), which I mentioned already earlier. However, as the mental prototypes become more clearly defined with experience, experienced entrepreneurs might, in turn, rely more on deductive/inductive logic and scan the opportunities for fit with their mental prototype rather than viability. Experienced entrepreneurs thus have to develop strategies to overcome availability biases and to renew their mental models. Gaglio and Katz (2001, p. 99) note that "Counterfactual thinking and mental simulations facilitate the reassessment process and may (but not always) indicate that it is necessary to radically alter the contents or the relational dynamics of schema and the existing means-ends framework". Abductive reasoning (see above) might also help during this process as it, similar to counterfactual thinking, creates new means-end-chains and utilizes mental models to test plausibility of outcomes. However, for this process to happen, one need to experience a surprise as stressed by Peirce (1932). How an individual evaluates a surprise might lead to either incremental (reallocation or more efficient use of resources) or radical innovation that realize a new formed vision (see Gaglio, 2004, p. 535). Cognition thus plays a vital role for opportunity recognition and it depends on an individual's capability to sense and seize such opportunities; the inability of others to do so enables entrepreneurship. In the area of location choice for example, Zaheer and Nachum (2011) argue that a superior 'sense of place' is required to recognize an opportunity a specific location offers to create location capital.

An example of a strategic decision against the trend

In the first example (see *3.3.2 Upper echelon theory*) I have shown that location choice—though argued often differently—is dependent on the decision maker. In addition, scholars come the conclusion that location choice does not create a competitive advantage. Only a few recent studies argue otherwise (see also Shaker A Zahra et al., 2000). In the following I show that location choice can in fact lead to a superior positioning.

Besides other factors, agglomeration (geographical concentration of businesses) is said to be one of the drivers of location choice (e.g. Head, Ries, & Swenson, 1995) due to the benefits of 'knowledge spill-overs' (whether within or across industries), increased accessibility of resources, and reduced purchase costs (Nielsen, Asmussen, & Weatherall, 2017). However, some multinational enterprises (MNEs) do not follow this trend. In contrast, they make use of the self-reinforcing effect of agglomeration and create infrastructures to attract other businesses. IKEA and Tesla are two examples to name here. IKEA strategically selects locations that do not have an existing infrastructure—but potential for such infrastructure—and purchases the land, to then later lease the land to other companies that want to profit from the then existing infrastructure and agglomeration effects. Tesla had a different strategy when choosing their location outside of the city. As Tesla expected growth within the next five to twenty years (also

for new businesses), they purchased land outside the city which left them with the possibility to build further buildings close to the headquarter.

Arguably, *location* then becomes an ownership characteristic (O). These characteristics have shown to, besides others, influence performance (Baghdasaryan & la Cour, 2013). Such strategic decisions might be more applicable for MNEs with many intangible assets, such as their brand name and prior experience with foreign direct investment (FDI), as this may allow them to compensate for location deficits and uncertainty (see also Buckley et al., 2007; Davidson, 1980; Nielsen et al., 2017, pp. 67-68). However, studies have shown different effects of cost factors and intangible assets on location choice (see Nielsen et al., 2017 for more detailed review). Alcantara and Mitsuhashi (2012) for example found that for small firms GDP per capita negatively affects location choice. The decisions of IKEA and Tesla do not follow the trend of the industry, are counter intuitive and entail risk. For example, Tesla's location might have been to unattractive for people as work location. Instead, the decisions rely on abductive reasoning. Using this type of reasoning, the companies were able to create a competitive advantage (e.g. by creating a new revenue stream). Abductive reasoning is thus not only vital for the evaluation and selection of concepts or the development of strategies, but also for the recognition of opportunities that then lead to the development of growth creating strategies.

4. Hypotheses

In the prior sections, I have shown that abductive reasoning is vital for the design process, such as synthesis, evaluation and selection (see *3.2.2 Application of abduction*). When using abductive reasoning, people form mental models, start to think more towards the future and create plausible hypotheses. Individuals that use more abductive reasoning perform better in decision making, i.e. successful projects were chosen and unsuccessful rejected, and choose more projects compared to individuals that rely on deductive/inductive logic. Abductive reasoning helps to identify success (and failure) of future concepts before they are introduced in the market. In line with these findings, Dong et al. (2016b) introduce the concept of generative sensing and argue that abductive reasoning, as its microfoundation, leads to superior sensing of growth options. One explanation for this might be that this reasoning process reduces risk aversion and biases which often lead to Type-1 errors. As a consequence, companies that apply a higher ratio of abductive reasoning during design evaluation should have a higher likelihood of creating better design concepts. Therefore, when this reasoning is applied during concept selection, companies should introduce more successful products to the market.

However, not only the design of a product is important for its success on the market but also the strategy and business model of a company. Dew (2007) and Dong et al. (2016b) argue that abductive reasoning helps to develop these strategies. Research examining the process of strategy development indeed found that abductive reasoning is used during this process (Calabrese & Costa, 2015). In the context of strategy development, abductive reasoning could help to 1) identify strategic growth options and to 2) formulate new strategies (see *3.2.2.5*

Abductive reasoning in the process of strategizing, *3.2.2.6 Abductive reasoning for sensing strategic options*). Hence, companies engaging in more abductive reasoning, compared to companies using less abductive reasoning, should be better in recognizing options for growth before they are proven by the market. This creates a bigger pool of options from which a company can choose. As more and better options are recognized, companies can then employ abductive reasoning to develop the most (potentially) profitable option further.

Building on the findings on abductive reasoning mentioned above, it thus stands to reason that companies engaging in abductive reasoning during strategy development perform better than companies relying more on deductive/inductive logic. Therefore, I hypothesize that

H1) The higher the ratio of abductive reasoning in a company's strategy, the higher its performance.

In line with this argumentation, if companies recognize more options also the competitive repertoire of a company should become more complex (compare Ferrier, 2001). This means that companies are more flexible and adapt their products and strategies accordingly. Pivoting may allow a company to survive among competitors, thus affecting profitability positively.

H1.1) A higher ratio of abductive reasoning in a company's strategy affects profitability performance of a company positively.

Besides the effects on profitability, flexibility may allow the company to grow faster. Therefore, strategies that entail a higher ratio of abductive reasoning should show a greater impact on the growth performance than on profitability of a company.

H1.2) The higher the ratio of abductive reasoning in a company's strategy the higher the growth performance.

5. Methods

In order to test the formulated hypotheses, I used a combined qualitative and quantitative approach to investigate the underlying reasoning in business hypotheses. The aim of this study was to test whether a higher ratio of abductive reasoning used in business hypotheses leads to higher company performance, and to investigate when abductive reasoning is used. I collected and codified data on 30 companies in the Software & Computer Service Industry and analyzed companies' reasoning utilizing secondary, historical data, such as growth and market development. Preliminary assessment showed that the prospectus summary and business section of S1-files are most suited for such analysis. In contrast, S1-files need to be submitted when applying of listing at the stock market (NASDAQ) and are therefore available for all companies (see also 4.2 *Data acquisition*). Performance was assessed three years after the Initial Public Offering (IPO).

5.1. Sample

To conduct the study, I collected data on thirty-one companies in the Software & Computer Service Industry that applied for listing on NASDAQ in the US between 2013 and 2014. The final sample includes thirty companies as one had to be dropped because the company did not exist anymore after two years and no information about an acquisition by another company, change of name or any accounting data could be found for the third. Three companies were sold in the third year. As data on the transaction was available, the companies kept their CEO and most of the board, and continued to act mainly independently; these companies are included in the sample. The final sample includes thus all Software & Computer Service companies (SIC codes 7370 to 7374) that filed an application to the US stock market (NASDAQ) in 2013-2014 and were listed for at least three years.

The Software & Computer Service Industry is very dynamic. As market trends and changes in the business environment have shown to quickly impact the industry, companies need to adapt at a fast speed. This, in turn, allows me to make a suitable assessment of the performance within a, arguably, short time-span of 3 years. Therefore, this industry sector is well suited for this research.

5.2. Data acquisition

The S1-files were acquired from the public database of the US Securities and Exchange commission (https://searchwww.sec.gov). S1-files follow specific guidelines and include a variety of aspects on the company, such as 1) observed trends, 2) product/service offering, 3) hypothesized reasons why the company will be successful, 4) business model, as well as 5) (growth) strategy. The prospectus summary provides an overview of all these aspects and was thus used for this analysis. A second data source was the *business* section of the same document as a few companies did not provide the same information as others in the prospectus summary directly but referred to the business section.

Data on company performance (see *6.2 Assessment of performance*) was derived from the *Compustat* database. One company was not included in the database and another three companies had missing data for the last year of analysis. Those missing data were acquired manually from the annual reports publicly available online.

6. Measures

In the following I describe how abductive reasoning and performance are assessed in this study. In section *6.1 Assessment of abductive reasoning*, I first present a framework which has been developed to measure quality and quantity of reasoning output. I then give examples of reasoning instances in strategy development, and finally present two measures for performance—growth and profitability—in section *6.2 Assessment of performance*.

6.1. Assessment of abductive reasoning

Following Dong et al. (2016a, 2016b), abduction was coded as verbalizations that introduce hypotheses which explain strategic steps, product developments, or relevant components for the success of a business. The prospectus summaries were coded according to instances of abductive reasoning. This means, first, each prospectus summary was divided into instances of reasoning (or ideas), i.e. an idea how a technology can be applied and a forward-looking strategic move (e.g. expansion to a new market) are treated as two separate instances. The sample of 30 companies amounted to a total of 576 instances with an average length of 65 words per instance.

For the analysis of abductive reasoning, a coding scheme was developed. The scheme builds on theories on abductive reasoning and coding schemes used in prior research on abductive reasoning during product extension generation and evaluation (Dong et al., 2016a, 2016b; Guenther et al., 2017). Based on the existing schemes and screening of the instances (see also *7.2 Qualitative analysis)*, four scales were developed ranging from 0 (no abductive reasoning) to 3 (strong abductive reasoning). I coded all prospectus summaries over multiple passes and revised the coding scheme in consultation with two researchers in the field until each instance could be identified without discrepancy. Table 1 illustrates the final Coding scheme.

Table 1 Coding scheme

Code	Description	Example
No abductive reasoning (0)	Trends that are spotted by others and of which the direction is not changed; commonly known user or market needs, …	"The display, mobile and video digital advertising market is projected to grow to $90 billion by 2017, and the need for automation in this market is growing commensurately, with real time bidding alone projected to grow at a compounded annual growth rate of 57% from $1.4 billion in 2011 to $20.8 billion in 2017." *Company #2*
Low abductive reasoning (1)	Explanatory abduction with only one element, e.g. explanations for motives of competitor's actions* or market, customer or supply-chain behavior*; product function believed to lead to a competitive advantage; observed but unproven market opportunity, hypothesized user need	"Our Fabric inspects and intelligently filters data packets from concurrent traffic streams in accordance with a set of user-defined criteria, which provides IT organizations with pervasive visibility and intelligent control over how traffic flows from the network to management, analysis, compliance and security tools." *Company #13*

Medium abductive reasoning (2)	Combining a) two trends that have not been connected yet; b) function and use, c) need and technology, d) market opportunity that is against a trend or unproven, i.e. new product/service offering* (in an unproven market) OR Analogies that work in another field and are brought into a new market; Analogy of technology which could solve (aspired) user need or applied to market opportunity (e.g. to discern technology developments*) OR Mission, belief, or new value proposition which has not been validated in the market, (2-sided)-Business model*, Paradox	"We believe that the human mind is better able to process information, discern trends and identify patterns when presented with information in a visual format. By fundamentally integrating data analysis and visualization, our software allows people to create powerful visualizations and dashboards that can lead to new discoveries." *Company #10* "Our technology recognizes the possibility to operate the Internet as a spoken medium by cataloging each section of a website into an audio "filing cabinet." *Company #11*
High abductive reasoning (3)	Combining three elements that interact interdependently. That is I.e. when this and this, then that is possible. OR analogy from another field combined with another element such as different BM.	"Users do not like creating usernames… which underlies the recent popularity of the "Sign in with Facebook" button. However, because the majority of cannabis consumers do not feel comfortable syncing their Facebook profile with cannabis-related websites and apps, we believe there is a need for a "Login with COMPANY" button on cannabis-related digital properties. This will not only allow users to sync data between applications and save time, but also give developers access to data and services they otherwise would not have." *Company #3* "Our platform is unique in its simplicity: Tweets are limited to 140 characters of text. This constraint makes it easy for anyone to quickly create, distribute and discover content that is consistent across our platform and optimized for mobile devices. As a result, Tweets drive a high velocity of information exchange that makes Twitter uniquely 'live.'" *Company #6*

* as suggested by Dong et al. (2016b)

6.1.1. **Examples of abductive reasoning in strategy development**

As mentioned above, an abductive hypothesis is as an explanation of 1) a surprising observation or 2) how to achieve a desired outcome when not all factors important for formalizing the explanation are known at the given moment in time (e.g. Dorst, 2011). The former abductive hypothesis is explanatory as it tries to find the most plausible explanation for an event or observation, whereas the latter invents a solution principle of how to achieve a desired outcome (Dong, Garbuio & Lovallo, 2016). Remember, such hypothesized explanations cannot be derived from deductive or inductive reasoning and hence cannot be proven true or false. Examples follow to illustrate the differences between explanatory and innovative hypotheses.

Company #5 that created a semi-anonymous social network for the cannabis community in the US, states the follow: "*Given the history of cannabis in the United States, many people would prefer to keep their cannabis experiences separate from Facebook, Instagram and Twitter where a user's family, co-workers and employers may be connected with them."* Here, the 'history of cannabis' is hypothesized to be the reason why people don't like to share cannabis related content on other social media. Another plausible reason would be existing restrictions on these platforms that prohibit the sharing of this type of content. Earlier formed explanatory hypothesis can also later be used to hypothesize the desired outcome (product offer) and how to achieve it: *"Our goal was to provide a platform where users were not required to provide personally identifiable information, as to create a semi-anonymous environment where users feel comfortable posting about cannabis."*

The company uses their hypothesized explanation about user behavior to propose 1) a desired outcome (platform for cannabis) and 2) the mode of operation, that is, if a platform is semi-anonymous people will share their experiences. They further hypothesize that *"By creating a network of end cannabis consumers, THE COMPANY is creating a valuable marketing and distribution channel for cannabis and its ancillary products"* thus justifying their engagement in the market.

Another example of abductive reasoning can be found in the following quote by Twitter: *"Our platform is unique in its simplicity: Tweets are limited to 140 characters of text. This constraint makes it easy for anyone to quickly create, distribute and discover content that is consistent across our platform and optimized for mobile devices. As a result, Tweets drive a high velocity of information exchange that makes THE COMPANY uniquely 'live.'"*

As seen in the examples provided above, for the creation of new businesses, innovative abduction is primarily used (forward thinking) while explanatory abduction provides explanation of observations (backwards thinking) which then can be used to hypothesize desired outcomes.

6.2. Assessment of performance

Performance of companies is assessed in various ways using either self-reported, perceptive measures (subjective) or secondary, financial data (objective). As company performance is very hard to measure exhaustively, scholars recommend the use of multiple variables in doing so (Sandberg, 1986). The meta-analysis of Combs, Russell Crook, and Shook (2005) confirms the variety of measures used ranging from single to 30 items utilized for the assessment (56 different ones in total) and three to eight dimensions of performance identified. Two related yet different kind of performance measures can be distinguished; these are 1) growth measures, e.g. sales growth and 2) profitability measures e.g. ROA or ROE (Combs et al., 2005; Rauch, Wiklund, Lumpkin, & Frese, 2009). Prior studies suggest to use both profitability and growth measures as tradeoffs might exist between these measures (see Shaker A Zahra, Neubaum, & El- Hagrassey, 2002). I use two depended variables separately as recommended.

Following Kotha, Rajgopal, and Rindova (2001) and Gilbert, McDougall, and Audretsch (2008) we assess performance as growth measured as change in sales over two years after IPO. Performance growth is thus measured as:

$$\left\lfloor \frac{Sales_{t+2} - Sales_t}{TotalAssets_t} \right\rfloor$$

The period of two-year time has been chosen for two main reasons. First many software companies firms are acquired soon after IPO (Gilbert et al., 2008), which can be either a strategic opportunity or due to high competition. The performance assessment after the acquisition by another company might thus be biases. Second, for a strategy to show affects, a certain time is required. Studies on abductive reasoning use reasoning frames which stimulate decision makers to think 2-3 years ahead (Dong et al., 2015; Guenther et al., 2017; Mounarath et al., 2011). I use the same timespan for to measure growth performance.

The profitability performance was operationalized as Market value (MV) after two years after IPO in relation to the total assets. This measure is similar to Kotha et al. (2001) who used Market value of firm equity (MVE) at time t. However, MVE is used less frequently in literature. Therefore, profitability is assessed as:

$$\left\lfloor \frac{MV_{t+2}}{TotalAssets_{t+2}} \right\rfloor$$

Book value, earnings information, firm age and size are often used in the accounting literature as control variable (Gilbert et al., 2008; Kotha et al., 2001). However, due to limited sample size I perform a descriptive analysis. As all companies are within the same industry, listed at the same stock market, and all service orientated (as compared to manufacturing), these variables should affect the sample only marginal.

7. Results

The result section is structured as followed: first, results of the *Statistical analysis* are presented (see *7.1*). Statistical results include findings pertaining to the influence of abductive reasoning on company growth performance and on profitability. Then, results of the *Qualitative analysis* are presented in section *7.2*. The quantitative section comprises findings which illustrate 1) for which purpose abductive reasoning is used, and 2) the kind of observations that are source for new strategic options. Finally, I introduce the concept of *observation sets* and present three different categories of observation sets—analogy, anomaly and paradox—that encourage abductive reasoning (see *7.2.3 Categories of observation sets that encourage abductive reasoning*).

7.1. Statistical analysis

7.1.1. Abductive reasoning and growth performance

Analysis of the frequency distribution showed one outlier for growth performance. This company was thus excluded from the analysis, resulting in a sample of 29 companies. To investigate the effect of abductive reasoning on companies' growth performance (i.e. pertaining to H1 and H1.2) I first calculated Pearson's correlation for all companies. The correlation links the ratio of abductive reasoning found in the analysis of the prospectus summaries (AR) and the growth in sales over a period of two years after IPO (GROWTH). The results show a significant, positive correlation between AR and GROWTH (see Table 2). A linear regression was conducted to verify whether abductive reasoning in the strategy predicts the growth of a company. I found that AR explains a significant amount of variance in the GROWTH ($F(1,27) = 18.03$, $p < .001$, $R2 = .40$, $R2Adjusted = .38$). AR is hence a valid predictor for GROWTH ($\beta = .05$, $t(27) = 4.25$, $p < .001$), which is a strong support for H1.2. In other words, the higher the ratio of abductive reasoning in a company's strategy, the higher the growth performance.

Table 2 Pearson's correlations

	AR	GROWTH	PROFIT
AR	1	.63**	.24
GROWTH	.63**	1	.37[a]
PROFIT	.24	.37[a]	1
**Correlation is significant at the 0.01 level (2-tailed). [a] Correlation is significant at a 0.05 level (1-tailed).			

As the sample of 29 companies is relatively small for a regression analysis, I conducted an additional between-group analysis comparing the quartiles of the companies' abductive reasoning ratio (AR_QUART) in relation to their growth performance. Table 3 shows the

descriptive of the quartiles' growth performance. The 1st quartile represents the 25% of companies with the lowest ratio of abductive reasoning, while the 4th quartile represents the top 25%.

Table 3 Descriptives for growth performance (GROWTH)

AR_QUART	Mean	N	Std. Deviation	Median	Minimum	Maximum
1st QUARTILE	.08938	7	.25	.14	-.19	.50
2nd QUARTILE	.38668	8	.37	.39	-.16	.93
3rd QUARTILE	.38507	8	.27	.34	.08	.94
4th QUARTILE	.99932	6	.53	.96	.46	1.91
Total	.44123	29	.46	.40	-.19	1.91

The results of the between group analysis show that the bottom quartile differs significantly from the top quartile, however not from the others. The 2nd and 3rd quartiles show nearly no difference between each other and differ only from the 4th quartile. Consequently, the 4th quartile differs significantly from all other quartiles. While all quartiles showed positive growth, the 4th quartile showed an over 110% higher growth compared to the average growth of .47. The other quartiles showed a mean growth below the average growth of the whole sample. These results again support H1.2.

Table 4 Between-Group analysis for growth performance

	AR_QUART	Mean Difference	Sig.
1st QUARTILE	2nd QUARTILE	-.30	.12
	3rd QUARTILE	-.30	.13
	4th QUARTILE	-.91*	.00
2nd QUARTILE	1st QUARTILE	.30	.12
	3rd QUARTILE	.00	.99
	4th QUARTILE	-.61*	.00
3rd QUARTILE	1st QUARTILE	.30	.13
	2nd QUARTILE	-.00	.99
	4th QUARTILE	-.61*	.00
4th QUARTILE	1st QUARTILE	.91*	.00
	2nd QUARTILE	.61*	.00
	3rd QUARTILE	.61*	.00
*Mean difference is significant at the 0.05 level.			

7.1.1. Abductive reasoning and profitability

Penetrating H1.1, I conducted similar analyses. The Pearson's correlation (see Table 2) shows no significant correlation between AR and PROFIT. The between group analysis also does not show significant differences between the quartiles. The descriptives of PROFIT for each quartile are presented in Table 5.

Table 5 Descriptives for profit (PROFIT)

AR_QUART	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1st QUARTILE	2.21	1.26	-.40	4.82
2nd QUARTILE	3.58	1.06	1.37	5.78
3rd QUARTILE	3.62	1.06	1.41	5.82
4th QUARTILE	3.70	1.15	1.32	6.08

For further statistical analysis, I divided the sample into a high abductive (AR+) and a low abductive group (AR-). Due to the small sample size, I used a simple bootstrapping method of 1000 samples with a confidence interval of 95% and conducted Pearson's correlations for the two groups separately (see Table 6). For AR- the correlation based on 1000 bootstrapping samples showed nearly significant results (p = .07). For AR+ no significant results were found (p = .92). However, the low abductive group (AR-) showed a nearly significant correlation between profitability and the ratio of abductive reasoning found in a company's strategy. These results are only a marginal support for H1.1. The null-hypothesis can, thus, not be rejected.

Table 6 Pearson's correlation for AR+ and AR- and profitability

	AR+, r(13)	AR–, r(12)	PROFIT
AR +	1	--	-.03
AR -	--	1	.53[a]
PROFIT	-.03	.53 [a]	1
[a] Correlation is significant at a 0.05 level (1-tailed).			

An independent sample t-test showed no differences between the high abductive (AR+) and the low abductive (AR-) group regarding PROFIT $t(23) = -.59$, $p = .56$, while AR- showed a numerally lower PROFIT mean with 3.00 compared to 3.66 of AR+. The results of the t-test as well as the group statistics are presented in Table 7 and Table 8 respectively.

Table 7 Bootstrap for Independent Samples Test for PROFIT

		Mean Difference	Bootstrap[a]				
			Bias	Std. Error	Sig. (2-tailed)	95% Confidence	
						Lower	Upper
PROFIT	Equal variances assumed	-.65	.10	1.11	.56	-2.73	1.66
	Equal variances not assumed	-.65	.10	1.11	.55	-2.73	1.66

[a]. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

Table 8 Group statistics t-test

				Bootstrap a			
				Bias	Std. Error	95% Confidence Interval	
						Lower	Upper
PROFIT	AR-	N	12				
		Mean	3.01	.07	.89	1.50	5.01
		Std. Deviation	3.03	-.16	.59	1.54	3.82
		Std. Error Mean	.88				
	AR+	N	13				
		Mean	3.66	-.03	.66	2.29	4.9
		Std. Deviation	2.41	-.11	.32	1.63	2.88
		Std. Error Mean	.67				

[a]. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

Before discussing the findings in section 9, I will present qualitative analysis including observation sets and abductive reasoning instances.

7.2. Qualitative analysis

While Dong et al. (2016b) and Dew (2007) suggest *for what* abductive reasoning can be used (see *3.2.2.6 Abductive reasoning for sensing strategic options*) and Calabrese and Costa (2015) show that abductive reasoning *is used* in the process of strategizing (see *3.2.2.5 Abductive reasoning in the process of strategizing*), none of these studies investigates *when* or under which *conditions* abductive reasoning is used. Though all scholars acknowledge the role of a surprise the characteristics of such surprise have not been investigated thus far. Therefore, the aim of the qualitative analysis was to better understand *when* abductive reasoning is used to formulate new strategic options.

For the qualitative analysis, ten companies were randomly selected of which five showed superior performance in regards to abductive reasoning. I first categorized all reasoning instances, including those that were coded with "0" (see *6.1 Assessment of abductive reasoning*). Two different classifications sets were thus derived. The first set of categories groups the instances into eight types of content, i.e. reasoning instances on how a technological solution could be used or on a demographic development that lead to a new opportunity; the second set classifies the observations made by a company that 'encouraged' abductive reasoning.

7.2.1. **Abductive reasoning content**

The first set of codes categorizes the content of abductive reasoning, that is for which particular purpose abductive reasoning is used. These codes build on the suggestions presented by Dong et al. (2016b) and were also used to develop the coding scheme (see *6.1 Assessment of abductive reasoning*).

Abductive reasoning was found to have been utilized by the companies 1) formulate new value propositions (i.e. *what*), 2) sense future market opportunities or define growth strategies (*how, with and for whom*), 3) introduce a new business or revenue model (*what's in it, with whom*), 4) identify a target group (*for whom*), 5) define a product or service offering (*what*), 6) invent technical solutions (*how it is realized/implemented*—often the *mode of operation*), 7) form beliefs/visions about future outcomes and or missions how these can be achieved (*why*), and to 8) explain observed problems or (abnormal) market behavior or trends (*why is what happening what*). All these components (see also Table 9) are important for a business model of company and answer four leading questions of business model innovation: What, who, how and what's in it (see text brackets).

The codes were then applied to the whole sample. Though the sample is too small to conduct statistical analyses with multiple variables, it seems that companies that apply abductive reasoning across categories perform better. Therefore, I propose:

P1) The more divers the categories (codes 1-8) in which abductive reasoning is used, the higher a company's performance.

Table 9 Content categories of abductive reasoning

Code	Description
Value proposition	A company identified a new user/customer need and forms a new value proposition which covers this need
Opportunity	Future opportunities that may be realized by expanding the current portfolio, through new partners or new markets
Business or revenue model	Introducing a new pricing strategy, revenue model or parts of the business model (e.g. stakeholders) that are hypothesized to be beneficial in the future and fit market needs.
Target group	A specific target or customer that is identified as 'ideal customer' or potential future target group.
Product/service offer	A product or service offer which matches the value proposition and the intended customer need to cover.
Technical solution	Technological solutions or functions that allow the product or service offer to be realized, that lead to a competitive advantage, or that allow expansion into new markets.
Belief or mission	Formulated beliefs that are fundamental for a company's actions. This might be for instance the formulation as a mission statement or a hypothesis that is fundamental for the explanation for company's actions.
Explain problem or trends	Explanation of why a (user) problem exists, why trends are changing or behaving differently.

7.2.2. **Observations enabling business creation**

The second set of categories divides the observations made by a company that led to the discovery of a business opportunity. Four different types of observations can be distinguished: 1) technological, 2) demographical or organizational, 3) economical or operational and 4) fundamental beliefs. Not all these types of observations need to be made by a company in order to discover an opportunity. However, qualitative analysis of the sample shows that companies with multiple observations from different areas are more likely to discover a successful business opportunity. I refer here to multiple observations which lead to an opportunity as diverse *observation set*. Successful companies made observations which illustrated a problem for people. The identified business opportunity aimed to solve this problem.

P2) Business opportunities that are derived from observed problems, whether of customers or organizations (organizations are run by people) are more successful.

Other companies identified technical developments which could be applied in another context, i.e. a new target group within a market or a new market. There are two different ways how a technological observation is used: 1) as an enabler, 2) as a solution (or opportunity) in itself.

While technology is used to enable a problem to be solved in the former, i.e. use machine learning to match data of car buyers with car sellers and to propose car prices, the latter makes only use of the technology itself. This means, if the developed solution does not solve a customer problem but only has monetary benefits, companies only show short-term but no long-term performance. Therefore, I propose that

> P3) Companies that use technical change as enabler of a solution perform better compared to companies that use the technology as opportunity in itself.

Again, it seems that companies with a more diverse observation set, e.g. technological developments, demographical change and fundamental beliefs, are more likely to recognize business opportunities, and as consequence show higher performance.

> P4) Companies that make observations in various areas, are better in recognizing successful business opportunities.
>
> P4.1) Companies that build their business hypothesis on observations in various areas show a higher performance.

Table 10 illustrates four observation sets that function as a fundament for the business opportunities recognized by companies. Note that the problem (Observation 1) can either be a demographical/organizational (a person) or economical (see also P3). However, as noted above, when a solution only solves an economical problem (i.e. efficiency or effectiveness) without solving a problem for a user or customer, the opportunity will be less successful in the long-term (see P2 and first observation set).

Table 10 Observation sets leading to business opportunities

Company	Observation 1 Problem domain	Observation 2 Need domain	Observation 3 To be changed	Observation 4 Enabler
Company #2	Operational	Demographical	Organizational	Technological
Company #8	Demographic	Demographical	Operational	Technological
Company #10	Operational	Organizational & Demographical	Fundamental Belief	Technological
Company #13	Fundamental belief	Organizational	Technological	Technological

The nature or function of observations differ. Observations can function as the basis for an explanation, i.e. demographic change might explain market behavior, as a plausible solution for an observed or hypothesized problem, i.e. how a problem can be solved by using sensor technology, or as a surprise which 'encourages' abductive reasoning and belief revision. The latter will be discussed in the following part.

7.2.3. Categories of observation sets that encourage abductive reasoning

The importance of each observation in an observation set might differ and not every observation includes abductive reasoning. However, it seems that every observation is essential for the observation set to be 'solved'. That is, each observation contributes to the formulation of abductive hypotheses and belief revision. Note that a surprise is essential for the abductive reasoning process. When no surprising observation is made, deductive or inductive logic is used.

Through grounded, qualitative coding, I identified three different types of observation sets that stimulates abductive reasoning in addition to different types of observations (see section *7.2.2 Observations enabling business creation* above). Abductive reasoning (either explanatory, inductive or both) is encouraged since deductive/inductive logic cannot provide a plausible explanation for the observation set, i.e. how single observations in an observation can co-exist. Assuming that opportunities derived from abductive show superior performance, then the identification of observation sets which stimulate abductive reasoning should be of high value for companies. Therefore, I propose that

> P5) Companies that identify a stimulating observation set, perform better in recognizing potential business opportunities.

In the following I present the three types of observation sets (or categories of abductive reasoning instances, respectively). They represent 1) an analogy, 2) an anomaly, or 3) a paradox.

7.2.3.1. Analogy (or missing analogy)

An observation set is classified as analogy when the observation set includes an analogous observation from another field (e.g. market) or area (e.g. technology) which does not exist yet and thus could be applied to aid field or area, or when an observation in the set represents a solution to a problem which is similar to the one observed. The final solution is then developed through an abductive reasoning process using analogies of similar problem-solutions-sets.

> One company for example observed that in multiple industries and in day to day life any information is accessible across devices at any given point in time. This is possible as many software solutions are cloud-based and synchronize data with the cloud. The company thus formed the belief that data has become available at any given point in time on any device. Another observation the company made is that, due to demographic change,

people have become more mobile and often work at home or while commuting. As people work more online and are more connected, the demand for easy exchange has increased, enabling the raise of many platforms. However, the company then made the observation that—although they believed that data was seamlessly accessible—many companies still struggle to deliver solutions that work across devices and allow employees to be mobile and location independent when working. Through innovative abductive reasoning they formed a hypothesis of how the (missing) analogous solution could be realized. In logic notation where p is a premise (or observation) and q is a conclusion, the reasoning process can be illustrated as followed:

1: Induction forms belief (b)

p_1 Photos are accessible across devices (e.g. Flickr, Instagram)

p_2 Documents are accessible across devices (e.g. google docs, adobe cloud)

p_3 Calendar and other applications are accessible across devices

p_4 Music is available across devices (e.g. Soundcloud, iTunes, Spotify)

$\sum p \Longrightarrow q$ Data are available across devices

This conclusion forms the belief $(q \Longrightarrow b)$

2: Surprising observation is made

$p_5 \nRightarrow q$ Work related data is often not available across devices

However, the belief holds that $b \leftrightarrow \sum p$

3: Innovative abduction

Solution s_1, s_2, s_3, s_4 are $\in \sum p$

Solution *s'* is interfered from $\sum p$, s' is hence analogous to $\sum s$ and is the plausible hypothesis of how p_5 can be realized.

IF s' THEN $p_5 \leftrightarrow b$

Thus, belief b is correct when *s'* is applied to p_5.

This means, an *analogy* is belief driven and does not require change of one's revision. Instead, an analogy leads to the realization that an exception to the rule (belief) exists. In order to keep the belief intact, an abductive hypothesis of how to achieve the desired outcome, i.e. no exception to the rule, is then formulated. Another example of analogy that leads to a business

opportunity is a product existing in market B that is solution *s*' to a problem *p*' which is similar to an unsolved problem *p* in market A.

7.2.3.2. Anomaly

The second category is an *anomaly*. Anomalies are surprising observations which are different to what is known, to what has been observed in the past, or to one's (fundamental) beliefs. As an example, when social media became popular, the amount of shared content continuously increased as the number of users and connections increased too. However, this trend did not only stop increasing, it even decreased, leading to a smaller number of content being shared. A deductive/inductive way of explaining the decrease of content being shared would be to say that people are not interested anymore in sharing content or that the market for social media is saturated. However, when explanatory abduction is used, one might come to the conclusion, that the way *how* the content is shared and made accessible is not appropriate. The cause of the observed fact is then no longer an external factor, which is hard to influence. Instead, the cause is hypothesized to be the solution itself, more concrete, its mode of operation. While the length of content was not limited at the time, twitter introduced the format of a tweet that limits a message to 140 characters. Twitter hypothesized that due to the limited size of content, people would share more content. To support this hypothesis, twitter was introduced as an open network. Other networks like Facebook or LinkedIn are closed and thereby limit the content reach to their users.

When an anomaly is discovered, both explanatory as well as innovative abduction are used to find 'solving' hypotheses. The process starts by making an abnormal observation, followed by the use of abductive reasoning to interfere a hypothesis that explains the observed effect. This hypothesis is then used to formulate two more hypotheses: the desired outcome, which either forms a new or reinforces an existing belief, and how the desired out can be achieved (mode of operation).

$p \notin \sum p$Surprising observation that does not match existing beliefs.
$ARe: p \Longrightarrow q$Hypothesis that explains the observation
$ARi: p \Longrightarrow b$ Hypothesis of desired outcome (or belief revision)
$ARi: s' \Longrightarrow p$ Hypothesis of how to achieve desired outcome
conclusion: IF *s'* THEN$p \Leftrightarrow b$

7.2.3.3. Paradox

A paradox contains simultaneously existing, interrelated yet contradicting elements that—though each element seems plausible—lead to a logically unacceptable conclusion. In the context of innovation and business strategy, a paradox is observed when e.g. solution *s* is introduced to the market to solve customer problem *p*. However, while solving *p*, *s* creates a new problem p_2. The new problem can either affect the same or another customer, user or entity.

Differently said, a paradox reveals that a 'solution' in fact does not solve, but shifts the problem. Paradoxes can also represent solutions that solve a problem only partially. This, then, often leads to trade-off-decisions between the solutions presented in order to choose the smaller remaining problem. Paradoxes can be difficult to identify as effect (new problem) and cause (the proposed solution) might be only loosely related and appear in different contexts (e.g. industry or for another target group). Abductive reasoning is used to explain the cause of the paradox and to then abduct a hypothesis of how to solve the problem, i.e. introduce a product in the market that solves the problem without creating a new one.

In the following example p is an observation (or premise), q the conclusion, and s a solution.

p_1*:* "The impact of virtualization and cloud computing, mobility, big data and SDN are combining to increase network complexity and introduce new network vulnerabilities while creating new challenges for enterprises and service providers that are struggling to maintain or improve service delivery and limit network downtime."

$p_1 \Longrightarrow q_1$: "As a result, organizations are seeking to improve visibility and control of their networks through the intelligent collection, modification and analysis of traffic without adversely impacting network performance or reliability."

p_2: "IT organizations have historically had access to a limited range of approaches to address these requirements, including deploying additional management, analysis, compliance and security tools, repurposing Ethernet switches, duplicating traffic via mirroring ports or dividing traffic flows via network TAPs."

$p_2 \Longrightarrow q_2$*:* "Enterprises and service providers utilizing these approaches struggle to scale and ensure the performance, reliability and integrity of their network infrastructure."

$s \Longrightarrow q_2$: "Given the performance limitations, cost and complexity of traditional approaches."

$q_2\ acts\ as\ p_3$ "Enterprises and service providers utilizing these approaches struggle to scale and ensure the performance, reliability and integrity of their network infrastructure."

$p_3 \Longrightarrow q_3$ "IT organizations are struggling to provide increased bandwidth and expanded service offerings in the face of increasing pricing pressure."

$s \Longrightarrow q_3$: "Without the ability to scale with network growth and to analyze packet contents, prioritize latency-sensitive data and intelligently direct individual packets to the

relevant tools, these approaches fail to deliver a comprehensive solution that offers visibility into and control over network traffic."

$\sum p \Longrightarrow q$: "Organizations increasingly require enhanced visibility and control of their networks through the efficient collection and analysis of network traffic flows without degrading network performance or reliability."

Thus, though 'solutions' for the problem exists (e.g. Ethernet switches, network TAPs), these 'solutions' have downsides (e.g. low scalability, complexity). Alternative approaches exist too (e.g. highly scalable networks), however, these have downsides too (e.g. less secure). The aim of the company therefore is to create a solution which solves these issues.

Company #13 that made the observations cited above, then developed a solution for the control, modification and visualization of traffic across networks. Distributes network appliances enable IT organizations to forward traffic from their network and severs to other tools, such as analysis, management and security tools, and to manage the data on a centralized console. The developed tool combines the benefits of the alternatives available (e.g. reliability, performance, security) while not causing the downsides of former 'solutions' (e.g. high costs, complexity). Note, that paradoxes can also create new paradoxes.

8. Limitations

Due to the limited sample size of thirty companies, I did not include control variables in the statistical analysis. Controlling for the variables such as company size, i.e. number of employees, age or board diversity could affect the results. As the study includes only companies from one industry and is limited to the US, market influences should have only marginal implications. Since the analysis relies on secondary data, I was not able to allocate the reasoning to specific individuals. Qualitative screening of the sample via data acquired from the EXECUCOMP database, however, showed that all CEOs stayed with the companies over the investigated period. Influences caused by a change of upper leadership are therefore unlikely.

Limitations may further come from the specific industry selected. Since the Software & Development Industry is considered to be more dynamic, as compared to e.g. the oil and gas industry, this may result in a higher amount of abductive reasoning found in the hypothesis to start a business might. However, as I compared the quartiles based on their reasoning, this should not affect the overall results.

The way performance was assessed might also influence the results. As many of the companies in the Software & Development Industry have a relatively small amount of assets, measures such as ROA could not be used. Return on equity (ROE)—another frequently used measure for profitability—was not used as the payment and equity distribution of relatively young companies as in my sample may have biased the results. For instance, one company may

pay relatively low salaries to CEO and other leading positions in order to keep more money within the company, whereas another company may pay full salaries. Due to this, I adopted the measure used by Kotha et al. (2001). In their study of internet based companies, they faced the same problem. Therefore, the assessment of profitability using Market Value seems to be the best option. Since three companies were acquired by competitors, these were not included in the analysis testing the effect of abductive reasoning on profitability. This however, again reduced the sample size pertaining the hypotheses on profitability. To measure the profitability of companies after a relatively short period of time may have affected the results too.

9. Discussion & conclusion

The presented study aimed to investigate the influence of abductive reasoning on company performance. Statistical analysis of data from companies in the Software & Development Industry showed strong support for hypothesis H1.2. This means, companies with a comparatively higher ratio of abductive reasoning in their strategy showed higher growth performance relative to companies with a lower ratio.

Pertaining to the effect on profitability, I found only numeral indicators for the support of H1.1. The ratio of abductive reasoning in the strategy of a company did not significantly correlate with the profitability of a company. Interestingly, a positive trend was observed for the companies that exhibit a ratio of abductive reasoning below the mean. For these companies a higher ratio of abductive reasoning positively influences profitability. One explanation for this finding might be that abductive reasoning creates a greater number of strategic options from which a company can choose (compare Friedel & Liedtka, 2007), allowing companies to revise their strategy, to respond and foresee threats and new opportunities. Creating more strategic options—which may increase a company's flexibility—may allow companies that only exhibit a relatively low ratio of abductive reasoning to survive among competitors. While flexibility may increase the survival, changing the strategy may require additional investment of time and funds, thus reducing the positive effect of abductive reasoning on profitability. Acquisition of additional resources would then contribute to the growth but not to the profitability of a company.

Qualitative analysis confirmed six of seven suggested applications of abductive reasoning for the development of strategies, as defined by Dew (2007) and Dong et al. (2016b). Abduction was found to 1) introduce new business or revenue models 2) identify market segments 3) define a product or service offering, 4) invent technical solutions 5) revise and form beliefs/missions 6) explain observations such as (market) behavior. The seventh, which suggests that abductive reasoning is used to identify motives of competitor's actions/reactions, could not be supported due to the type of data used for the analysis. Analysis of my obtained data suggests two more uses: to introduce a new value proposition and to sense future market opportunities. The latter is similar to the concept of generative sensing (Dong et al., 2016b)

while the former extends the suggested introduction of product/service offers. Value propositions propose (intangible) values or benefits to customers or relieve 'customer pains'.

Through further analysis, different types of observations that lead to the identification of business opportunities could be identified. Insights obtained suggests that companies which solve problems of customers, rather than exploit monetary opportunities, perform better in the long-term. Observations about technological developments were found to support the realization of an opportunity, i.e. development of a product/service. Thus, technical knowledge and observations seem to mediate company's ability to innovate, while observations of demographic and market change are more important to identify the opportunity as such. In a recent study, I found that prior knowledge with a use case was more important than familiarity with a technology to generate ideas for product extensions (Guenther et al., 2017). In addition, the diversity of observations made appears to influence opportunity recognition.

Observations that, as a total, lead to an opportunity—referred to as observation set—stimulate abductive reasoning. Three different categories of observation sets were identified: an *analogy*, *anomaly*, and a *paradox.* While analogies are often used in design to define problems (Visser, 1996) and in companies to get stakeholders on board after a strategic change (Cornelissen & Clarke, 2010), our data suggests that analogies are vital for the recognition and development of opportunities (see also Garbuio et al., 2017).

When an analogy, anomaly or a paradox is identified, abductive reasoning is encouraged and used to 'explain' the observation, then innovative abduction is used to hypothesize a plausible way for achieving a desired outcome. Both steps are crucial for the development of a business opportunity. The concepts of the observation sets (analogy, anomaly, paradox) is somewhat similar to the mental models and metaphors suggested by Hill and Levenhagen (1995). They suggest that beliefs are revised when a new metaphor emerges *and* is seen as beneficial. Applied to my findings, this would mean that only when an analogy (anomaly or paradox, respectively) is evaluated as useful, the second step is initiated, i.e. how the analogy could be applied and how it creates value in another field. In the presented study, only developed strategies were evaluated. Future research may also include analysis of strategic options that were not followed because they seemed to be less attractive.

Whether an analogy is considered beneficial might depend on factors such as prior knowledge (compare Fiet, 2007; Shane & Venkataraman, 2000; Shepherd & DeTienne, 2005), perceived feasibility, desirability, and risk (see also Krueger & Brazeal, 1994). In a recent study, I found that the ability to reason abductively differs between people depending on their cognitive abilities, particularly creative capabilities. Highly creative people showed a greater ability to reason abductively and to produce ideas for product extensions, thus to be more innovative (Guenther et al., 2017). Results of a yet unpublished work indicate that the influence of prior knowledge depends on cognitive capabilities of individuals and suggests that people are differently affected by prior knowledge to generate innovative ideas.

In line with these findings, it stands to reason that how individuals assess whether an analogy is beneficial differs depending on individual's cognitive capabilities. I believe that, as less creative people tend to use easily assessable knowledge, less creative individuals will more likely accept analogies that are within their domain of expertise, while this effect should be smaller for highly creative people. This means, highly creative people should more easily revise their beliefs and 'make use' of an identified observation set to derive a strategic opportunity. They thus should be able to produce/identify more strategic options.

As generating strategic options is important for existing as well as new ventures, the ability to do so is not only essential for executives but also for entrepreneurs. Prior research shows that successful entrepreneurs rely more on their own thinking rather than on routines to find solutions, and that successful entrepreneurs create more creative ideas compared to less successful entrepreneurs (Ames & Runco, 2005). As strategies that entailed a higher ratio of abductive reasoning positively influence companies' growth and highly creative people show a greater ability to reason abductively, creative capabilities should influence companies' growth. This not only has implications for new venture creation but also for innovation management and investors, for instance cognitive capabilities of entrepreneurs could be used to decide whom to support in early-stage development.

9.1. Managerial implications

The findings of the presented research show substantial implications for management, business venturing, and strategy development. Comparing top and bottom quartile within the industry, I found that companies that use a higher ratio of abductive reasoning for the development of a strategy show an over ten times higher growth performance—measured in sales—compared to companies relying on deductive/inductive logic. While most of scholars come to the conclusion that strategic decisions are made in a rational way and advise the use of tools to assess and create strategic options which rely on deductive and inductive logic, the presented research suggests that companies should instead make an effort to complement their strategy development with abductive reasoning approaches.

The findings of the presented study lead to the following managerial recommendations:

- **Think forward:** Executives should try to apprehend future potential of opportunities and become more forward thinking and rely less on quantifiable metrics or tools that encourage deductive/inductive logic to forecast future events.
- **Do not dream:** Executives are encouraged to apply more abductive reasoning. However, it is important that abductive reasoning complements other forms of logic. While companies that exhibit a higher ratio of abductive reasoning show higher growth, company profitability is only positively affected when abductive reasoning is complemented with deductive/inductive reasoning. Therefore, executives should not only formulate hypotheses but also evaluate these for their plausibility. Abductive

reasoning without the co-occurrence of deductive/inductive logic might be less valuable.

- **Observe abnormal behavior:** Independent from cognitive capabilities, the obtained insights suggest that entrepreneurs and companies should pay attention to abnormal or paradoxical (market) behavior or developments as well as analogies from other fields. Abnormal, paradoxical or analogical observations may stimulate individuals to reason more abductively and thus enable them to develop growth creating strategies.
- **Look outside your domain:** While many problems are found within a specific domain, many solutions (e.g. analogical problem-solution pairs) can be found outside of the domain. Therefore, executives should not only be aware of developments within, but also outside of their market.
- **Solve a problem:** While technological developments often enable innovation, demographical and organizational changes are origin of value creation. I therefore suggest that executives should focus on demographical and organizational changes and potential problems that these changes may produce.

9.2. Contribution to literature

In this work, I presented a new framework for the assessment of the ratio of abductive reasoning in the context of strategy development. While Dong et al. (2015) and Mounarath et al. (2011) assess instances of abductive versus deductive/inductive reasoning, the framework presented in this work provides the opportunity to assess the quality of abductive reasoning instances. So far, scholars tend to use tools for semantic analysis which look at the occurrence of specific words or they divide the data into topics (e.g. Rhee, 2015). As abductive reasoning is context dependent, it cannot be identified by searching for a specific word or cluster of words. Also, the assessment per topic is less detailed. Assessing the quality of abductive reasoning per instance (ratio of abductive reasoning) allows for more sophisticated analyses and might shed light on unanswered research questions. A similar framework has been used in a prior study (Guenther et al., 2017), yet this works extends the field of application.

In a preliminary study, I identified documents which are most suitable for the assessment of abductive reasoning in a company's strategy. Sources like conference/earning calls or annual reports, which are often used in other studies for the analysis of cognition, have shown to be highly dependent on third party questions and more backward instead of forward looking. Hence, these data sources are less suitable for the assessment of abductive reasoning. Instead, I advise scholars to use the prospectus summary of S1-files or data sources of similar nature.

This work focused on the development of a framework for the assessment of abductive reasoning and used existing theories such as the Austrian Economics Theory and Peirce theory of abductive reasoning to develop hypotheses. In the future, scholars may use the presented framework to develop new theories.

9.3. Future research

For this study, I deliberately chose a dynamic industry (Software and Development industry) which changes frequently and might rely on more abductive reasoning than companies in less dynamic industries. Future research could thus investigate differences in the effect and application of abductive reasoning and generative sensing strategies in relation to varying industry dynamism. Another question is whether the ratio of abductive reasoning in a company's strategy influences the competitiveness.

Due to the limited sample size, I did not control for variables such as company age, board diversity or tenure. I therefore suggest to conduct follow-up research with a larger sample that includes these variables. Also, whether and to which extent different categories (analogy, anomaly, and paradox) influence venture growth and the success of developed strategies is worth investigating. Finally, future research could investigate whether executives' and entrepreneurs' cognitive capabilities impact opportunity recognition and business performance.

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12. Appendix: Example of Prospectus Summary

12.1. Prospectus summary of company #13

PROSPECTUS SUMMARY

the terms "COMPANY #13," "our company," "we," "us," and "our" refer, prior to the conversion discussed below, to THE COMPANY, and, after the conversion, to THE COMPANY Inc., in each case together with its consolidated subsidiaries as a combined entity.

Overview

We have developed an innovative solution that delivers pervasive and dynamic intelligent visibility of traffic across networks. Our solution, which we refer to as our Traffic Visibility Fabric, consists of distributed network appliances that enable an advanced level of visibility, modification and control of network traffic. Our Fabric enables IT organizations to forward traffic from network and server infrastructure to management, analysis, compliance and security tools in a manner that is optimized for specific uses or functions. Our patented Flow Mapping™ technology identifies and directs incoming traffic to single or multiple tools based on user-defined rules that can be managed from a centralized management console. Our Fabric is designed to help organizations optimize the reliability, performance and security of their physical and virtual network infrastructure, minimize capital investment in management, analysis, compliance and security tools, reduce operating expenses and realize greater value from the existing tools that are deployed throughout their networks.

Virtualization and cloud computing, mobility, big data and software-defined networking are reshaping the way enterprises and service providers operate and the way people communicate over IP networks in an increasingly connected world. Organizations increasingly require enhanced visibility and control of their networks through the efficient collection and analysis of network traffic flows without degrading network performance or reliability. Our Fabric provides the pervasive and intelligent visibility and control over network traffic, including voice, video and data, that organizations need to successfully manage, analyze and secure their network environments.

We sell our products directly through our own sales force and indirectly through our channel partners. As of June 29, 2013, our end-user customers included 62 of the Fortune 100. Additionally, as of June 29, 2013, we had sold products to over 1,100 end-user customers across many vertical markets, including seven of the top ten U.S. retailers, seven of the top ten U.S. banks and diversified financial services companies, five of the top ten U.S. integrated and wireless telecommunication service providers, seven of the top ten U.S. managed healthcare providers, six of the top ten U.S. cable and satellite providers and four of the top ten global securities and commodities exchanges, based on market capitalization as set forth in independent industry data from S&P Capital IQ.

We have experienced significant growth since our inception in 2004. Our total revenue increased from $46.5 million in 2010 to $96.7 million in 2012, representing a compound annual growth rate, or CAGR, of 44%, and from $39.2 million during the six months ended June 30, 2012 to $58.2 million during the six months ended June 29, 2013, representing 49% growth. Our net income was $6.6 million, $16.9 million, $7.5 million and $1.8 million for the years ended December 31, 2010, 2011 and 2012 and the six months ended June 30, 2012, respectively, and our net loss was $9.1 million for the six months ended June 29, 2013. We have generated positive cash flows in each of the last seven years.

Industry Overview

Powerful forces are transforming the traditional ways that enterprises and service providers design, operate and manage their networks. These forces include:

Virtualization and Cloud Computing. Enterprises and service providers are seeking to enhance visibility and control over their network traffic as they manage the transition from static physical architectures to dynamic virtual environments.

Mobility. Enterprises are looking for ways to improve the productivity of their increasingly mobile workforce by providing enhanced access to their network. Service providers are seeking to monetize new service offerings and improve the satisfaction and retention rates of their subscribers.

Big Data. As the volume of network traffic generated, transmitted and consumed grows rapidly, organizations are increasingly challenged to maintain, analyze, improve and secure the performance and reliability of networks as they scale to meet demand.

Software-Defined Networking. IT organizations are struggling to provide increased bandwidth and expanded service offerings in the face of increasing pricing pressure. IT organizations may migrate to software-defined networking, or SDN, to create network infrastructure that is more agile and responsive and better aligned with the needs of the applications deployed in the network.

The foregoing forces are enabling significant benefits to be realized from IT innovation, but are also presenting significant challenges in how organizations manage, analyze and secure their networks to address growing network traffic volumes, security and compliance, the proliferation of mobile devices, the consumerization of IT and adoption of cloud-based IT.

Limitations of Traditional Approaches

The impact of virtualization and cloud computing, mobility, big data and SDN are combining to increase network complexity and introduce new network vulnerabilities while creating new challenges for enterprises and service providers that are struggling to maintain or improve service delivery and limit network downtime. As a result, organizations are seeking to improve visibility and control of their networks through the intelligent collection, modification and analysis of traffic without adversely impacting network performance or reliability. IT organizations have historically had access to a limited range of approaches to address these requirements, including deploying additional management, analysis, compliance and security tools, repurposing Ethernet switches, duplicating traffic via mirroring ports or dividing traffic flows via network TAPs.

Given the performance limitations, cost and complexity of traditional approaches, enterprises and service providers utilizing these approaches struggle to scale and ensure the performance, reliability and integrity of their network infrastructure. Without the ability to scale with network growth and to analyze packet contents, prioritize latency-sensitive data and intelligently direct individual packets to the relevant tools, these approaches fail to deliver a comprehensive solution that offers visibility into and control over network traffic.

Need for a Comprehensive Visibility Solution

We were founded on the belief that organizations need a fundamentally new approach to network traffic visibility to address growing demand for increased infrastructure efficiency and performance, and to improve the quality and breadth of service offerings. We believe a solution that can optimize the efficiency and performance of these tools by delivering pervasive visibility to users and subscribers and control over network traffic creates a significant market

opportunity. Our belief is supported by the results of an independent survey conducted in 2012 by the Enterprise Strategy Group, or ESG, in which 78% of respondents indicated that a traffic visibility fabric would be a useful enhancement to their network environment.

Our Solution

The key benefits of our Traffic Visibility Fabric include:

Providing Pervasive Visibility and Control. Our Fabric inspects and intelligently filters data packets from concurrent traffic streams in accordance with a set of user-defined criteria, which provides IT organizations with pervasive visibility and intelligent control over how traffic flows from the network to management, analysis, compliance and security tools.

Enabling Rapid Response to Dynamic Change. Our Fabric significantly improves network flexibility by enabling static tools to connect to virtualized applications, dynamic infrastructure and mobile machines, which allows our end-user customers to efficiently and securely address their business needs.

Delivering Scalable, High-Throughput Capacity. Our Fabric provides increased visibility and intelligent traffic filtering without impeding the delivery of traffic to management, analysis, compliance and security tools and can scale as the network grows and performance requirements increase.

Improving Network Efficiency and Economy. Our Fabric improves the return on investment of existing tools, reduces capital and operating costs associated with deploying new or more advanced tools, limits the infrastructure footprints in space-constrained data centers and curtails the staff required to monitor and maintain the network.

Enhancing Network Reliability. By reducing the need to process non-relevant traffic, our Fabric increases the reliability of tools and the associated management of critical business processes running on production networks. Because our Fabric is deployed "out of band," or in parallel to, the production network, modifications to the Traffic Visibility Fabric do not require network downtime.

Ease of Deployment and Use. We have designed our Fabric to be easy to install, configure and maintain. Our Fabric can be controlled locally or remotely, enabling our end-user customers to reduce management and maintenance of unmanned, or dark, data centers.

Growth Strategy

Key elements of our growth strategy include:

Continuous Innovation. We intend to enhance the functionality and scalability of our Fabric to address new use cases, tool capabilities, deployment environments and performance levels and the drive for greater software definition of network infrastructure.

Increase Awareness of Our Value Proposition. We plan to invest in our brand and develop awareness of the benefits of our Fabric in order to help us grow our business and market opportunity.

Expand Our Relationships with Existing End-User Customers. We intend to deepen our relationships with our end-user customers by offering new products that help them increase the value of their new and existing management, analysis, compliance and security tools, adopt virtualization and cloud technologies and efficiently scale their network environments.

Invest in our Global Distribution Network. We plan to continue to invest in strengthening our existing relationships with channel partners and expand our network by adding new channel partners to target new end-user customers and broaden our reach.

12.2. Prospectus summary of company #31

PROSPECTUS SUMMARY

This summary highlights information contained elsewhere in this prospectus and does not contain all of the information that you should consider in making your investment decision. Before investing in our common stock, you should carefully read this entire prospectus, including our consolidated financial statements and related notes included elsewhere in this prospectus and the information set forth under the headings "Risk Factors," "Selected Consolidated Financial Data" and "Management's Discussion and Analysis of Financial Condition and Results of Operations." Unless the context requires otherwise, the words "COMPANY Corporation," "THE COMPANY," "we," "our company," "us" and "our" refer to COMPANY Corporation, a Delaware corporation, and its subsidiaries. Unless otherwise indicated, all numbers of shares, per share amounts and share prices related to our common stock in this prospectus reflect the 2 for 1 stock split in the form of a stock dividend declared on March 28, 2013.

Overview

We are a leading provider of on-demand business collaboration software to the commercial construction industry. Our solutions are focused on facilitating collaboration between owners/developers, general contractors and subcontractors. Our solutions increase efficiency, enable better risk management, and provide improved visibility and control of construction activities for our clients.

Our collaboration solutions offer robust functionality, data sharing and exchange capabilities, and workflow tools that support several mission-critical business processes at various stages of the construction project lifecycle:

Construction Payment Management ("CPM") enables the generation, collection, review and routing of invoices and the necessary supporting documentation and legal documents, and initiation of payment of invoices.

Submittal Exchange enables the collection, review and routing of project documents.

GradeBeam supports the process of obtaining construction bids, including identifying potential bidders, issuing invitations-to-bid and tracking bidding intent.

Pre-Qualification Management ("PQM") supports contractor risk assessment and qualification.

Greengrade facilitates the management of environmental certification processes.

In addition, we offer PlanSwift, a take-off and estimating solution used in preparing construction bids, and Contractor Default Claims Management, which supports the process of documenting a subcontractor default insurance claim.

Each of our collaboration solutions was designed from inception as a software-as-a-service ("SaaS") solution with an on-demand architecture. Our collaboration solutions each use a single code base and we do not customize our solutions for any of our clients. Our technology platform is designed to be highly configurable, scalable, reliable and secure.

We believe we are a leading example of a new generation of on-demand software solutions focused on enablement of business-to-business collaborative processes. Such solutions are by design on-demand, as they require neutral third parties to act as the platform for collaboration by multiple parties and to facilitate the exchange of data and documents.

We believe the construction industry represents a large and growing market for technology solutions of all types. The industry, we believe, is especially attractive for our solutions and our growth because it is underpenetrated by technology solutions that enable construction industry participants to more easily collaborate and operate more effectively. We have established a strong market position

serving this industry. As of June 30, 2013, since the date of launch or acquisition of our solutions, our clients have used one or more of our on-demand collaboration solutions to help manage over 15,000 commercial construction projects representing more than $140 billion in construction value as reported by our clients. Our collaboration solutions have been used by more than 3,000 general contractors, owners/developers, and architects. This includes 62 of the 100 largest general contractors in North America, ranked as of May 2013 by Engineering News-Record based on annual construction revenues. In addition, based on management estimates, approximately 300,000 subcontractors were active on our solutions during fiscal 2012. Our solutions are used on construction projects of all sizes, from small remodels or renovations to multi-billion dollar developments.

We have achieved significant growth since introducing our solutions to the market. In the fiscal years ended September 30, 2010, 2011 and 2012, we generated revenue of $6.0 million, $10.5 million and $21.7 million, respectively, which represented growth over the prior period of 90.0%, 74.7% and 106.2%, respectively. During the nine months ended June 30, 2012 and 2013, we generated revenue of $15.4 million and $24.7 million, respectively, representing an increase of 60.7% year over year. We had net losses of $15.9 million, $18.9 million, $18.8 million, $14.3 million and $31.3 million, respectively, in the fiscal years ended September 30, 2012, 2011 and 2010 and in the nine months ended June 30, 2012 and 2013. As of June 30, 2013, we had an accumulated deficit of $169.9 million.

On June 12, 2013, we completed an initial public offering of 5,750,000 shares of common stock, including 750,000 shares sold pursuant to the underwriters' option to purchase additional shares, at an offering price of $15.00 per share. We received proceeds from the initial public offering of $80.2 million net of underwriting discounts and commissions but before other offering costs of $2.5 million.

Our Industry

Construction is a major global industry and consists of building new structures, making additions and modifications to existing structures, as well as conducting maintenance, repair and improvements on existing structures. Worldwide construction spending was $8.6 trillion in 2012, according to "Global Construction 2025," a study produced by Global Construction Perspectives, an industry research provider. A total of $153.9 trillion will be spent on construction worldwide during the period from 2012 to 2025, and in 2025 construction is expected to reach more than $15 trillion in annual spending and account for 13.5% of world GDP, according to the same study.

We believe the outlook for the construction industry is strong. The industry currently continues to be impacted in certain markets across the globe by slow economic recovery from the global financial crisis, oversupply of occupiable space, and limited availability of credit. However, long-term trends of population growth, deteriorating infrastructure and changing needs for buildings—driven by both socioeconomic and technological changes—all imply a continuing and growing need for construction activity. In certain markets, including our core markets in North America, the industry's growth rate also is benefitting as a result of the recovery from the factors described above. Overall, global construction spending is expected to grow at a compounded annual growth rate of 4.3% from 2012 to 2025, according to Global Construction Perspectives.

Each construction project requires a complex collaborative effort between the many different participants that play a part throughout or at different stages of the project's lifecycle. The practices used by the industry to manage this complexity have been largely manual, paper-based and inefficient, or have relied on technology solutions not designed for collaboration. As a result, we believe participants face numerous challenges collaborating on construction projects, including significant administrative overhead burdens; disparate standards, procedures and systems; lack of workflow discipline and control; inefficient process coordination; errors, inconsistencies and omissions; limited risk management tools; and siloed applications and data repositories. Furthermore, the industry is changing in response to the many issues it faces, including those resulting from the global financial crisis, new approaches to project delivery and an increased focus on risk management, transparency and efficiency.

In order to meet these challenges and as companies seek to support growth while limiting costs, we believe industry participants are increasingly adopting software solutions that can also increase

visibility into and control over critical stages of the construction lifecycle. We believe software solutions delivered on an on-demand basis and by a neutral third party are necessary to meet this demand. Such solutions can facilitate the exchange of data and information in a cost-effective, flexible, scalable and secure manner.

We believe therefore there is a significant opportunity to offer comprehensive on-demand collaboration software solutions that are designed to address the evolving needs of the construction industry as it responds to the many challenges it faces and seeks to achieve greater operational and financial efficiencies, better manage risk and grow significantly over the next decade and beyond.

Our Solution

Our on-demand business collaboration software solutions address the several challenges associated with the traditional paper-based and personnel-intensive manual approaches or with technology solutions not designed for collaborative processes, and support many of the trends currently occurring within the commercial construction industry. We believe our solutions benefit our clients because they are:

Designed specifically for collaborative processes. Our collaboration solutions facilitate the sharing and exchange of data between and within organizations and provide robust workflow tools to ensure that necessary steps are carried out in the right sequence by appropriately authorized users.

Developed to meet the needs of the construction industry. Our solutions are built to meet the unique requirements of the construction industry and our delivery capabilities have been organized around the specialized needs of our clients.

Delivered through a trusted and neutral third party. We host, provide access to and facilitate the exchange of information, enabling project participants to achieve a common and transparent view of project status.

Valuable to all participants. Our solutions are designed to reduce costs, manage risk and improve visibility and decision-making for each participant independent of their specific role or responsibility.

Interfaced with existing enterprise systems. Our solutions leverage and protect our clients' existing investments, facilitate their business processes and reduce or eliminate duplicate data entry.

Easy to implement, use and adopt. Our solutions can be configured by our clients to meet their specific needs without needing customization, and can be rapidly implemented by our clients across their organizations.

Accompanied by high levels of training and support to all users. Our client services team provides extensive on-site training for enterprise clients and unlimited remote live support for all end-users.

Our Key Business Attributes

Key attributes of our business include the following:

Large, attractive market. The construction industry affords us a large market in which to sell our solutions and we believe it is currently underutilizing on-demand business collaboration software solutions.

Next-generation approach to solving the challenges facing our clients. We believe ours is a disruptive approach to solving business-to-business collaboration challenges and also can be applied to many processes and industries.

High recurrence of fees, favorable timing of cash flow and predictable reported revenue. Our revenue is derived primarily from fees driven by construction project activity and from

monthly fees. We increase revenue both as we add clients and our clients increase the number of their projects on our solutions. We historically have experienced high recurrence of fees, favorable timing of cash flow and predictable reported revenue.

Highly defensible market position. We believe our industry expertise, leading market share, large installed base and strong intellectual property portfolio represent significant barriers to successful competitive entry.

Ability to differentiate through our business and technology approach. We believe we are uniquely positioned to integrate our solutions with other enterprise software and support our solutions with a strong client service capability, and that we have the resources to support significant investment.

Focus on quality of service. Our solutions support mission-critical processes and time-sensitive interactions and communications, which require timely and accurate client support. Client service and support is a cornerstone of our value proposition, and we believe it is a significant element of our long-term success.

Our Strategy

We intend to leverage our existing solutions and industry presence to become the industry standard for collaboration solutions in the construction industry, both domestically and in targeted international markets. The key elements of our strategy to accomplish these objectives are as follows:

Increase our market penetration of the construction industry. We intend to actively pursue new client relationships with owners/developers, general contractors and subcontractors that do not currently use our solutions. We intend to focus our existing sales and marketing capabilities on large, strategic owners/developers and general contractors, as they can generate significant, multi-year growth. At the same time, we plan to launch solution and channel initiatives that target smaller industry participants in a cost-effective fashion.

Expand our suite of solutions. We plan to continue to use our domain expertise in construction and to work closely with our clients to identify and develop new applications, features and functionality that address business processes we currently do not support.

Pursue acquisitions of complementary businesses. We believe that acquisitions of complementary businesses can help us expand our suite of solutions more rapidly, enter into new markets, expand our client base and increase the knowledge and skill sets within our organization. We believe we can enhance the value of these solutions through our financial, technical and other resources, industry presence and their integration into our existing suite of solutions.

Increase our client penetration. We believe we have a significant opportunity to cross-sell to our existing clients both our current and our future solutions, and increase the utilization or adoption of our solutions to include a greater number of their projects. We also plan to integrate both our current and our future solutions into a single platform solution, which we believe will significantly increase the value of our solutions and drive increased adoption of multiple solutions by our clients.

Expand globally. We believe a substantial opportunity exists to grow sales of our solutions globally. To date, substantially all of our revenue has been generated from clients located in the United States and Canada. However, in certain markets, due to local business practices and regulations, we believe our value proposition could be even stronger than in our established markets in North America. Certain of our large current and potential construction clients also have or are seeking to establish international operations, and have indicated their interest that we support their current or planned international operations, especially as they seek new growth opportunities outside their traditional North American markets. We believe we have

accumulated significant experience with the process necessary to enter new markets successfully.

Increase the number of industries we serve. Our solutions are designed for complex collaborative environments with significant subcontracting activity. We believe that these characteristics exist in several industries in addition to the construction industry. While we currently do not operate in these other industries, we believe based on our research that there could be demand for our solutions in these other industries.

Our Sales Approach

We generally market and sell our solutions directly to our clients. Our solutions generally provide significantly greater benefits if deployed to manage all of a client's related construction activities, which requires buy-in and commitment at the highest levels of our clients' organizations. In our experience, this requires an in-person, relationship-driven, consultative approach with a high degree of solution and domain expertise on the part of our employees. Certain of our solutions or clients, however, are effectively sold and supported remotely, primarily over the phone and using email, webinars and other appropriate methods. We intend to grow our remote sales and support capability significantly in order to address the market opportunity we believe is available to us, as well as to support new solutions and segment initiatives.

12.3. Relevance to the domain of Industrial Engineering and Strategic Product Design

The project built on prior research conducted by the graduation student in the SPD research Project in collaboration with the supervisor, Boris Eisenbart (see Guenther et al., 2017). The project is relevant for all three pillars of the Industrial Design Engineering at Delft University of Technology as explained below, and aims to foster the understanding of the interaction of business, human interaction, and technology, and their impact on innovation.

Business: Innovation is not only driving companies, but companies also drive innovation by fostering their internal innovation capability (see above). Many companies (i.e Nike, Coca-Cola, and IBM) have proven that a focus on design thinking can lead to successful business venturing. Furthermore, many of these companies have already implemented in-house structures that foster intrapreneurship. However, little research has been done to identify the mechanism of creativity/designerly ways of thinking that create competitive advantages, enable companies to improve their innovative performance, foster entrepreneurial/intrapreneurial behavior, and lead to the development of superior strategies. Findings of the conducted research shown that abductive reasoning—which is associated with creative thinking—leads to business growth and the generation of innovative strategies.

Human Interaction: Decision making in businesses is often result of a combined effort of analysis and human sense making. Many decision models exist (i.e. actuarial decision models) that have shown to outperform humans. However, all too often, these models are not used when coping with dynamic markets (Zacharakis & Meyer, 2000) since executives have little confidence in such formal analyses (BCG, 2010). Therefore, it is relevant to understand decision making on a cognitive level. Cognitive differences have shown to significantly influence decision-making accuracy in selecting innovation concepts (see above, Dong et al. 2015, Guenther et al. 2017). Findings of the presented study suggest that cognitive strategies—particularly forms of logical reasoning—also affect other stages of the innovation process such as strategizing and the generation of new venture ideas. Understanding the underlying cognitive strategies of successful decision-making and venture creation improves innovation capabilities and creates sustainable competitive advantages.

Technology: The innovation process is affected by people, the context, as well as technology. Different technological discoveries lead to different innovations and business creations. Shane (2000) showed that one same technology can lead to different innovations depending on individuals recognizing an entrepreneurial opportunity. This suggests that people show different abilities in searching and recognizing opportunities. While the project focused mainly on the *business* pillar of IDE, results show that observations of technological developments enable innovation, i.e. without a specific technological development, the innovation could not be realized. Therefore, knowledge about technological developments and an understanding of what is possible is important for innovation and particularly strategizing.