Service Innovation Analytics:
Leveraging Existing Unstructured Data to Assess Service Innovation Capability

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ABSTRACT

The importance of innovation for firms for gaining competitive advantage has been widely acknowledged. Innovation in services exhibits some particular challenges. In order to support formal service innovation management, several frameworks of capabilities for service innovation have been published in recent years. However, these frameworks often do not support the use of existing information to apply them to a firm's context and to guide managerial decisions. In this paper the authors aim to show that a firm's service innovation capability can be operationally diagnosed with the help of such a framework in a more concrete way, using existing unstructured data. Building on established methods in text mining, the authors are working towards an approach to realise this. The paper outlines the approach and presents the encouraging results from our exploratory study, as well as avenues for further development of the approach and its implementation in a management information system.

Keywords: *Innovativeness of Firms, Machine Learning, Service Innovation, Service Innovation Capability, Service Innovation Framework, Text Documents, Text Mining, Unstructured Data*

INTRODUCTION

Many service ecosystems are undergoing significant changes. The banking industry was surprised by Starbucks, introducing a mobile payment programme in 2011, the same year that the BMW group, amongst other car manufacturers, introduced their car sharing service DriveNow and have begun to change the landscape of urban transportation. Starbucks, in January

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2011, integrated their previously used loyalty card programme into a mobile application. Arguably thanks to seamless payment integration – the customers' card codes got stored in the application to allow a convenient and fast checkout process – Starbucks was already processing 26 million mobile payment transactions by December 2011, a number that has been growing ever since (Mobile Commerce Daily, 2012; Starbucks Coffee Company, 2011). BMW introduced their DriveNow programme in cooperation with car rental firm Sixt in March 2011 and by the end of 2012, they had over 70,000 users in Germany, servicing Berlin, Munich, Dusseldorf, and Cologne (BMW Group, 2011, Tagesspiegel, 2013). As the first city outside of Germany, the programme had also been launched in San Francisco. Like Starbucks, they are expecting solid growth in this emerging field in the coming years.

These examples demonstrate some of the key characteristics of innovation in services (Vermeulen & van der Aa, 2003): Innovations are often introduced as a new combination of existing concepts and resources, called architectural innovation (Gadrey et al., 1995), they are typically created without the use of a research and development (R&D) department (Sundbo, 1992; Sundbo, 1997), and therefore barriers to entry for services are comparably low (Bryson et al., 1993). Taking the Starbucks mobile payment service innovation as an example, inspired by the use of barcodes to issue mobile boarding passes in the airline industry, any internal or external party, without specific expert knowledge, could have come up with the idea of integrating an existing payment card into a mobile application environment and the realisation of the innovation could be executed using readily available (IT) infrastructure.

As laid out above, the lack of an R&D department in some service firms implies an allocation problem between daily business and organised innovation that is carried out on many levels of the organisation, as opposed to the top of the organisation in the case of organised R&D (O'Reilly & Tushman, 2004; Sundbo, 1992; Sundbo, 1997). A different aspect to this is that the co-creation of value in services (Grönroos, 2006) puts these firms in an ideal position to utilise their on-going relationships and acquired customer intimacy (Chesbrough, 2003; Habryn et al., 2012) to create new offerings. Arguably though, this potential is underutilised due to a lack of methods and tools specific to the characteristics of service innovation (Ganz et al., 2012). In fact, even for more mature industries, scholars have pointed out that while firms are recognising innovation as one of the main drivers of competitive advantage, they are ill equipped to assess their own capability for realising innovation (Adams et al., 2006).

As a consequence of these characteristics of service innovation, incumbent firms are not infrequently taken by surprise by new market introductions and are increasingly trying to take a more systematic and proactive approach to innovation in services, an approach that has been termed service innovation management (Maglio & Spohrer, 2008; Tidd & Hull, 2006).

For service firms, innovation management poses particular challenges and offers particular advantages, due to their organisational set-up, and interaction with customers in delivering services. This is independent of the exact organisational form of the service firm, from 'pure' service firms, to service departments or organisations within large industrial corporations (Salter & Tether, 2006). Consequently, no specific distinction is made in this study with regards to the concrete organisational form, and for reasons of simplicity, we will use the term 'service firm' throughout the paper.

In order to further our understanding of innovation in services and to support service innovation management, a number of frameworks describing service innovation capability have been published in recent years. As shown below, however, these frameworks are predominantly of conceptual nature, and are usually not directly applicable for the purposes of practitioners.

In order to support firms' ambitions of fostering service innovation management, the purpose of this paper is to extend this existing body of knowledge on service innovation capability, and to present avenues towards an assessment of innovation capability in service firms, by using unstructured data. An implementation of this assessment will allow firms to monitor their capability configurations for innovation and their developments over time, as well as to benchmark their organisation internally and against external parties, and to focus on developing the most critical aspects of their innovation capability. In working towards this goal, the authors are leveraging existing data, which accrues in service interactions, reporting, and general communication, inside of firms, across firm boundaries, and on the Internet in general (Fromm et al., 2012). Furthermore, our focus lies on using unstructured data (text documents), since this has been reported to account for up to 90 per cent of all information stored in firms' information systems and networks (Van den Hoven, 2001), with similar numbers being reported for the Internet. This leads to the two following research questions this paper strives to answer:

RQ1: How can service innovation capability be represented so as to afford its assessment on the basis of the concrete resources of and explicit information available about a firm?

RQ2: How can explicit information about a firm, presented in the form of text documents, be mined for the sake of conducting such assessments?

This paper extends on the work published in Feldmann et al. (2013) and presents promising results of our analyses, while showing avenues for the further development of this analytical approach. The paper is structured as follows. In the subsequent chapter on related work we will introduce the theoretical background of service innovation capability assessment and relevant frameworks. After selecting one of the presented frameworks as a test case for the purposes of this study, we provide a brief overview of relevant techniques for data preparation and text mining and introduce the approach adopted in this study. The study approach and its corresponding methodology are presented in chapter three. This comprises the creation of a vocabulary for carrying out the text mining approach, the acquisition of relevant documents, and the selection of an external evaluation. We present the results of our exploratory study, using one of the frameworks for service innovation introduced in chapter four, followed by a discussion and a qualitative analysis of some of the text mining results in chapter five. The paper is concluded by a summary, limitations, and a detailed outlook on further adaptations and extensions of the analytical approach adopted in our study.

RELATED WORK

The question of how service firms can outperform their competitors and forestall potential entrants is in its core a special aspect of one of the oldest and most discussed issues in the field of strategic management, the question of how firms can build and maintain competitive advantage. Around the mid 1980s, a stream of thought emerged, challenging earlier static and equilibrium-based approaches, which focused on companies' strengths and weaknesses based on their resource-base (Barney, 1991; Grant, 1991; Kraaijenbrink et al., 2010). This lead to the establishment of the stream of research called the resource-based view (RBV).

The RBV essentially argues that organisational resources and capabilities are the source of competitive advantage of the firm, as long as they are valuable, rare, inimitable and non-substitutable (VRIN criterion), i.e. at least to some extent unique to the firm (Barney, 1991). Due to its simplistic view, however, the RBV has been prone to criticism, summarised by Kraaijenbrink et al. (2010) in a review of existing works on the topic. The main points of criticism are a lack of generalisability and concrete managerial implications for the use and improvement of the resource base. Priem and Butler (2001) call this a lack of 'operational validity' of the RBV. In addition, the dependence of the RBV's logic on relatively predictable environments is criticised, as the value of given resource sets can hardly be predicted in changing environments.

To meet this criticism, Barney (1991) argues that the RBV also considers dynamic capabilities, which apply a static set of resources to new environmental set-ups and, thus, constitute a source of sustainable competitive advantage. This notion has led to the emergence of a new stream of literature around dynamic capabilities in the mid 1990s.

The dynamic capabilities view (DCV), as an extension of the RBV, shares some of its criticisms and limitations, mainly a lack of operationalisation and conceptual consensus. One of the few agreed-upon basic notions is Teece et al.'s (1997) definition of a dynamic capability as "the firm's ability to integrate, build and reconfigure internal and external competencies to address rapidly changing environments" (p. 516). However, going beyond this, researchers have proposed a variety of approaches with regards to the DCV, from describing a reaction to external environments (Teece, 2007; Eisenhardt & Martin, 2000; Helfat & Peteraf, 2003), over dynamic capabilities as a 'higher-order' counterpart to substantial capabilities (Winter, 2003; Zahra et al., 2006), to dynamic capabilities as a capability builder (Makadok, 2001; Wang & Ahmed, 2007), and as a problem solver (Barreto, 2010).

While supporting this research's goal of assessing innovation capability in service firms in general, the concept of the DCV in a generic sense lacks operationalisation of the constructs introduced, and therefore exhibits some limitations. In recent years, a number of frameworks describing service innovation capability have been published, building on ideas of the DCV and trying to make the generic constructs introduced by the DCV more concrete in an innovation-specific context. Innovation capability in this sense is understood as a construct that improves the productivity of other resources of the service firm, specifically in facilitating the creation of innovative outputs (Essmann & du Preez, 2009; Makadok, 2001). Prominent examples of these frameworks are the Capability Maturity Model Integration for Services (CMMI-SVC) (CMMI Product Team, 2010), the Innovation Capability Maturity Model (ICMM) of Essmann and du Prez (2009), Müller-Prothmann and Stein's (2011) Integrated Innovation Maturity Model (I^2MM), Hogan et al.'s (2011) measurement scale for innovation capabilities of professional service firms, Ordanini and Parasuraman's (2011) measurement framework of service innovation capability, and the dynamic service innovation capabilities framework of den Hertog et al. (2010). The frameworks are briefly presented in the following and their limitations are discussed, before the basis for the analytical approach of this study is described.

The basic idea of the CMMI-SVC as an extension of the popular CMMI in the area of software engineering is to collect best practices for a set of process areas and to assess a service firms' maturity for the individual processes by means of questionnaires. As a service-focused extension of a framework from a different domain, the service specificity of the CMMI-SVC framework is arguably somewhat limited. Furthermore, the framework was not specifically developed to capture innovation capability, but contains some aspects of new service and service systems development. In summary, this means that while the framework in general promises a good basis for operationalisation and assessment of the constructs introduced, its relevance for service innovation management is limited.

Essmann and du Preez's Innovation Capability Maturity Model (ICMM) builds on the underlying idea of the CMMI framework family introduced above. It also employs the concept of maturity levels and has been established using empirical data from the domains of engineering and manufacturing. While the framework has been evaluated in an exploratory manner using single case studies in service firms, it cannot be deemed service specific, due to its non-service foundations. In addition, the framework unfortunately offers fewer possibilities for assessment and monitoring than the CMMI-SVC framework, the process area best practices of which have been enriched with years of collected industry experience.

Müller-Prothmann and Stein's Integrated Innovation Maturity Model (I^2MM) adopts an approach similar to the ICMM framework and introduces five capability maturity levels. By allowing a firm to identify its current maturity level for given capabilities, as well as the gap to the aspired capability level with the help of a questionnaire instrument, the framework aims to enable an operational assessment. 'Innovation Management' here constitutes one of the so-called process areas encompassed by the framework. Criticisms similar to those for the ICMM framework apply. The I^2MM does not offer any service specificity and consequently has limited applicability to service innovation management. Furthermore, it allows empirical assessment by means of a questionnaire instrument, but is limited by the costs of (regularly) carrying out surveys in a firm and the subjectivity of the respondents' views.

Hogan et al. have introduced a multi-dimensional measurement scale for innovation capabilities of professional service firms. Building on the concept of Wang and Ahmed (2004) and exploratory interviews, they have developed a framework consisting of three capability dimensions. These are the client-focused innovation capability, marketing-focused innovation capability and technology-focused innovation capability. These three dimensions in turn are broken down into 26 single capabilities by the authors. The framework has been evaluated using a large empirical survey among professional service firms, with a sample size of 463 firms. Due to the profound study design and the large evaluation basis, the results promise a high reliability. However, the work is lacking measurement scales for the innovative output of service firms, also considered a limitation of the framework by the authors. In consequence, the capabilities are only assessed using the perception of the survey participants, which is likely to produce subjective and biased responses, similar to the frameworks discussed above.

Another approach is offered by Ordanini and Parasuraman. They report three sources of service innovation, collaborative competence, dynamic capability of customer orientation, and knowledge interfaces, and analyse their effects on firm performance. However, the authors report collaborative competence as the main capability, reducing the other two to antecedents in the form of competencies and mechanisms, supporting innovation capability The authors employ a quasi-longitudinal design, which measures the impact of the instantiations of the sources of service innovation in one period on innovation outcomes, measured by volume and radicalness, and ultimately firm performance, in later periods. The framework, thus, provides a first measurement of service innovation capability, since it puts innovation outcomes in relation to the firm's innovation capability, and subsequently maps the innovation outcomes to the performance level of the firm. Due to the framework's focus on customer orientation (see above) and a resulting number of nine single capabilities proposed, the framework is in principle able to assess different capabilities regarding their contribution to the output performance. However, the focus of the framework is rather narrow for an extensive assessment of a service firm's innovation capability. In addition, the framework so far has only been validated by a single case study on a luxury hotel.

Lastly, den Hertog et al. have introduced a framework encompassing six so-called dynamic service innovation capabilities. The framework is built on an extensive review of the (service) innovation literature and selected case studies in service firms. The authors propose six service innovation capabilities: *Sensing User Needs and Technological Options, Conceptualising, (Un-) Bundling, (Co-) Producing and Orchestrating, Scaling and Stretching,* and *Learning and Adapting.* Similar to the other frameworks discussed above, they suggest that firms that are innovative in services will score high on the individual capabilities. The framework of den Hertog et al. constitutes one of the more recent publications in the service innovation capability literature and is being advanced by members of the service science community (Janssen et al., 2012). Furthermore, the framework is one of the few that has been specifically designed for service innovation management (Kohler et al., 2013), and describes the individual capabilities in detail in qualitative form.

Our discussion of relevant frameworks of service innovation capability has revealed some common criticisms of these works, indicative of the current state of service innovation management support. The underlying problem is constituted by the operationalisation of the (service) innovation capability construct in the frameworks. Some of the authors do not attempt to operationalise the constructs described in their works. This of course constitutes a some limitation with regards to the actual assessment of innovation capability in service firms. For the frameworks that do operationalise their constructs, usually survey-based instruments are used. A sole reliance on these methods, however, also exhibits some limitations for service innovation management practice. In order to assess and monitor a firm's innovation capability over time, continual surveying is needed, which is costly and invasive for the practitioners affected. While of course we do not want to discourage this empirical assessment of a firm's innovation capability, we would like to argue that an approach integrating analytical methods making use of existing data could provide advantages for service innovation management practice with regards to scalability and information sources considered.

We employ the framework of den Hertog et al. as a test case in this study. Due to its exploratory nature, we focus on one of the six capabilities of the framework here: *(Co-) Producing and Orchestrating*. The authors present this capability as a firm's ability to conduct service innovation across organisational boundaries and to engage in relevant networks. Den Hertog et al. call this "key dynamic capability" the "capability to organize and act in open service innovation systems" (p.502). These systems are stated to consist of the innovating firm, its clients, and trusted partners, as well as other stakeholders. The importance of this aspect of innovation management has been prominently discussed and demonstrated in the past decade (Chesbrough, 2003; IBM, 2006; Laursen & Salter, 2006).

The selected framework of den Hertog et al. is well suited for the purpose of this study, since it provides an extensive view of service innovation capability, it describes the contained capabilities in great detail, making it easier to obtain information on resources associated with the individual capabilities, and while it is based on an extensive literature review and case studies, the framework admittedly is of a "conceptual" nature and requires empirical validation (den Hertog et al., 2010, p. 505).

As described above and in Kohler et al. (2013), a direct operationalisation and assessment of this framework, as well as other frameworks describing service innovation capability is not possible, due to the lack of a layer describing concrete resources of the firm, supporting the innovation capability. We suggest that specific resources of a firm contain evidence that it has implemented certain aspects of the innovation capability. By assessing these constituent resources, the firm is given the means to ultimately assess its innovation capability. In the context of this study, the selected capability of den Hertog et al.'s framework is operationalised through expert interviews with experienced service professionals, as described in the following.

RESEARCH APPROACH AND METHODOLOGY OF THE STUDY

A review of the literature underlines the newness of analytical approaches to assess service innovation capability. We have not found prior work that deals with text mining in the context of a (service) innovation capability framework. However, speaking more generally, there is some literature employing text mining techniques in the area of innovation management. The approach closest to our research is a study by Kabanoff and Keegan (2007) – for relevant earlier work, see references therein. The authors aim to measure firms' top teams' attention to seven strategic dimensions, which include innovation, and therefore process annual reports from 2002 to 2004 of Australian Stock Exchange listed firms using computer aided text analysis. The text corpus is limited to the respective letters of the CEOs / managing directors to shareholders and comprises 177 firms in 2002, 775 in 2003, and 151 in 2004. External validation of the results is performed through comparison to the firms' score on the Innovation Index Score (IIS), developed by the Intellectual Property Research Institute of Australia (IPERA). While the approach adopted in the study exhibits some similarities to our research set-up, a direct application to our study is not possible. Our model for the assessment of innovation capability can be succinctly visualised as shown in Figure 1. We elaborate on the design of the individual elements of our analytical approach and its application to the scenario of this study in the following. In doing so, we follow ideas of situational method engineering, adapting and integrating method components to the purposes of our study, as opposed to developing a completely new approach (Kornyshova et al., 2011).

DESIGN OF AN ANALYTICAL ASSESSMENT APPROACH USING TEXT DOCUMENTS

As discussed above, the underlying logic of the employed den Hertog et al. framework is that we should be able to classify a service firm scoring relatively 'high' (i.e. scoring high in comparison to others) on the capabilities described in the framework as 'innovative' (i.e. more innovative than others). The same logic applies for firms scoring relatively 'low' on the capabilities, allowing us to classify them as 'less innovative'. We call this a direct classification (See Figure 2).

Building on our discussion above, we argue that a service firm's capability can be operationalised by the use of more concrete resources. Consequently, a set of resources (called the 'vocabulary' in accordance with text mining nomenclature) can be used to describe this capability and to classify firms based on the framework. Thus, the vocabulary describing the service innovation capability serves to classify the firms as innovative or less innovative, based on a match with text documents associated with

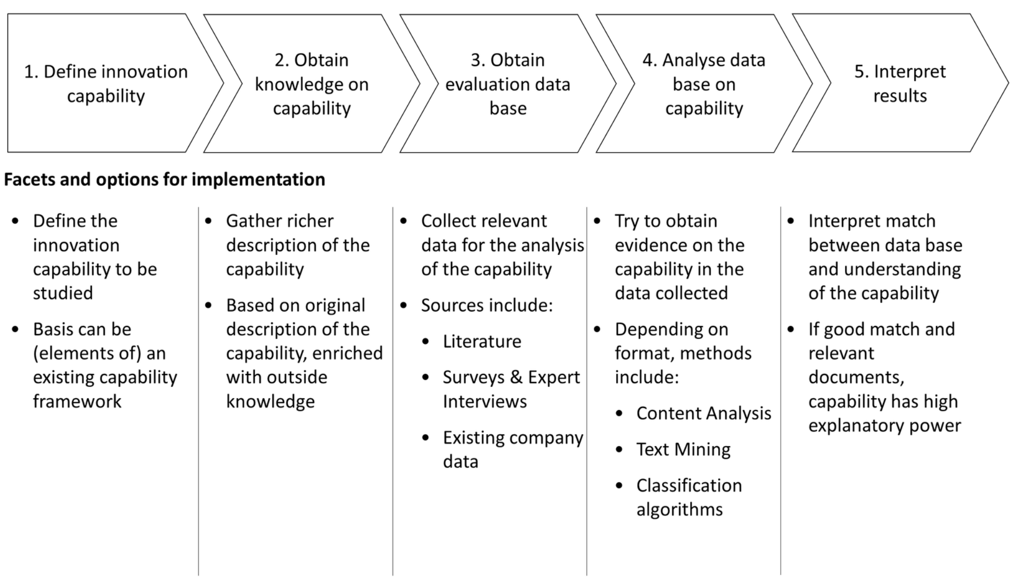
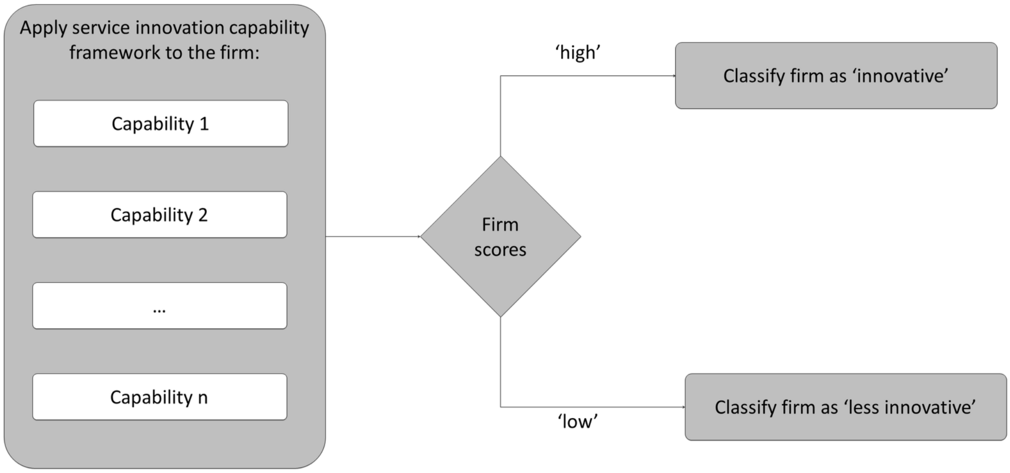


Figure 1. Model for the assessment of innovation capability

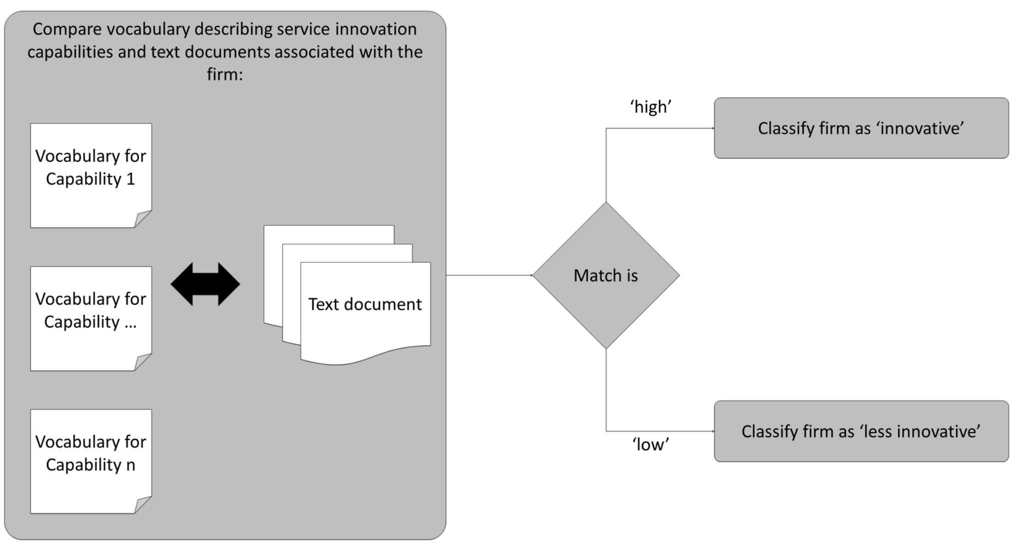
Figure 2. Direct classification of a firm using a capability framework



the firms in question. We call this an indirect classification (See Figure 3).

For the purposes of this study, we are limiting ourselves to the consideration of the capability *(Co-) Producing and Orchestrating* of the den Hertog et al. framework, since it has often been reported to be a strong driver of innovation capability of a service firm (see discussion above). Based on this, we classify a firm as innovative, if the vocabulary used to describe the capability and the text documents associated with the firm exhibit a high matching score. The same logic is used to classify a firm with a low matching score as less innovative. Having classified a firm as innovative or less innovative, the approach is now only missing

Figure 3. Indirect classification of a firm using a capability framework, vocabulary and text documents



an external comparison in order to interpret the results. This step results in a so-called confusion matrix, capturing the firms classified correctly and incorrectly, based on the comparison with the external classification. An overview of the whole approach and its components is given in Figure 4.

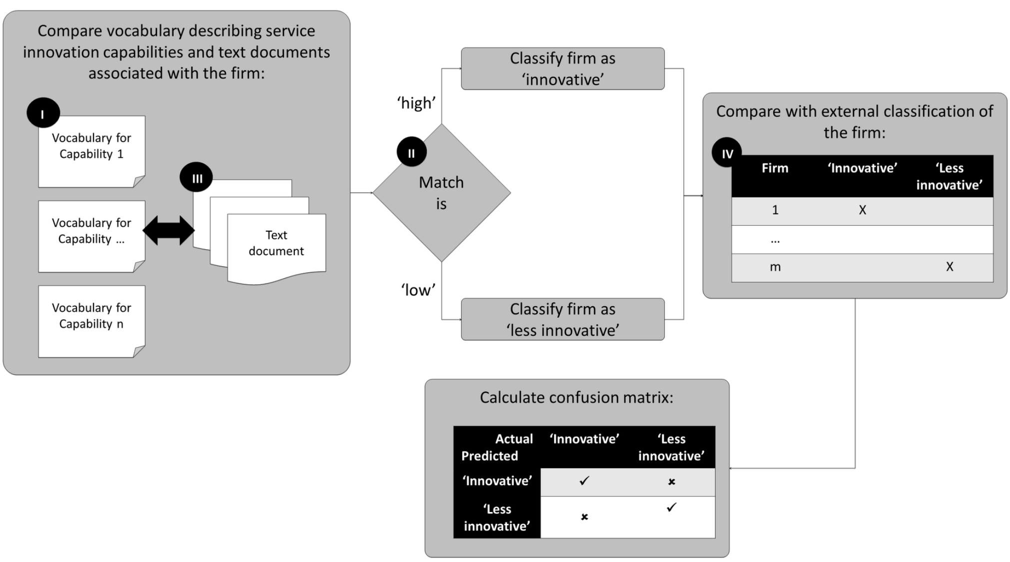
The first necessary component is a vocabulary describing the selected service innovation capability ("I" in Figure 4), sometimes also called a concept vector (Manning et al., 2008). Second, an appropriate text mining approach for the matching has to be identified ("II"). Third, text documents associated with a set of firms to be analysed is required ("III"). Fourth, an external classification ("IV") for comparison and interpretation of the approach's results is needed, which provides information for all the firms considered. All of these components are described in detail in the following.

VOCABULARY CREATION

Kimbrough et al. (2013) point out two methods for the creation of a vocabulary, called the ex-post and the ex-ante approach. Applied to our context, the ex-post approach would mean learning from a collection of text documents which words are most effective at predicting a firm's implementation of a service innovation capability. However, Kimbrough et al. state that the application of this approach is problematic for a number of reasons, particularly due to a lack of external validity of the predictive words.

The ex-ante approach addresses this issue by generating a vocabulary based on external knowledge, such as existing literature and expert knowledge. This approach appears intuitively suitable for our study, since we would like to use knowledge from outside of the company documents for their analysis. To satisfy the requirement of grounding the representation of the service innovation capability in question in practice as much as possible, we used a series of interviews with five managers and executives from German knowledge-intensive professional service firms to create the initial vocabulary. We conducted the interviews in the context of a related study in May and June 2012 (Kohler et al., 2013). Each of the interviews was approximately 60 minutes long and was carried out over the phone or in person. After

Figure 4. Overview of the study approach



presenting the experts with the den Hertog et al. framework's capabilities and short textual descriptions, they were asked to "name assets that support or represent the individual service innovation capabilities in [their] organisation". In addition to their experiences in their own firm, they could also report examples they had seen at client firms. A wide spectrum of collected items was ensured by providing the interviewees with a list of governance-oriented asset types, provided by Weill and Ross (2004).

The interview transcripts were broken up into a redundancy-free and cleansed list of words and sentence fragments. The resulting initial vocabulary for the capability *(Co-) Producing and Orchestrating* was extended with additional words and fragments from relevant literature targeted at practitioners, in order to ensure similar language styles (Bjelland & Wood, 2008; Hemp & Stewart, 2004). In a subsequent step, the vocabulary was enriched with synonyms, allowing for the use of different terminology to describe the facets of open innovation in different company reports. The resulting vocabulary was translated into the standard format using regular expressions as employed by our matching software, mostly by breaking up phrases into the characteristic component words (See Figure 5). The regular expressions allow small variations, such as singulars and plurals of words, as well as a small number of intervening words in a given phrase.

MATCHING ALGORITHM: TEXT MINING APPROACH EMCUT

The matching of entities to classifications using text documents associated with them has been termed EMCUT, for 'entity matching [to] classification [schemes] using text' (Kimbrough et al., 2013). In their work, Kimbrough et al. indicate three ways to address EMCUT problems: Content analysis, a novel technique called the 'external approach', and machine learning. Content analysis as a rather classical approach is carried out by reading the text documents and manually assigning (parts of) them to the relevant capability of the framework. While this approach is established and a variety of techniques exist to avoid subjective bias, such as voting among multiple readers (Krippendorff, 2004; Morris, 1994; Neuendorf, 2002; Weber, 1990), it does not scale well and even skilled readers can miss vital information (Pennebaker, 2011). This approach is consequently not ideally suited for treating large collections of text documents.

The so-called external approach does not apply to the set-up of our study, since it assumes that a vocabulary is created for the classifiers, 'innovative' and 'less innovative' in our case, without further empirical knowledge, and is then used to classify the text documents. For our study, however, we have created an empiri-

Figure 5. Excerpt of the study's vocabulary in the standard format used by the matching software

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1    \bcollaboration\b\W{1,}?\bplatform\b                     collaboration_platform
1    \bopen\b\W{1,}?\binnovation\b                            open_innovation
1    \bcustomer\b\W{1,}?\bintegration\b                       customer_integration
1    \bclient\b\W{1,}?\bintegration\b                         client_integration
1    \bcustomer\b\W{1,}?\binvolvement\b                       customer_involvement
1    \bclient\b\W{1,}?\binvolvement\b                         client_involvement
1    \bexternal\b\W{1,}?\bexperts{0,1}\b                      external_expert(s)
1    \bpartner\b\W{1,}?\bnetworks{0,1}\b                      partner_network(s)
1    \bsharing\b\W{1,}(\w{1,}\W{1,}){0,}\bideas{0,1}\b        sharing_idea(s)
1    \bcrowdsourc\w{1,}\b                                     crowdsourc*
1    \brelationships{0,1}\b\W{1,}\bwith\b                     relationship(s)_with
1    \blisten\w{0,}\b\W{1,}\bto\b                             listen*_to
1    \binvolv\w{1,}\b                                         involv*
1    \bcollaboration\w{0,}\b\W{1,}\bwith\b                    collaboration*_with
1    \bco-{0,1}operation\w{0,}\b\W{1,}?\bwith\b               cooperation*_with
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cally based vocabulary from expert interviews, as described above.

Finally, Kimbrough et al. point out machine learning as an effective approach for solving EMCUT problems using large collections of documents, making it well-suited for our purposes. More specifically, we apply a supervised machine learning approach to carry out our study. The so-called "document classification using supervised learning" approach is an established method to match documents associated with firms to a classification, as is the case in our study (Bird et al., 2009; Manning et al., 2008). Specifically, we apply a 'classification tree' to learn about the classifiers, i.e. the items of our vocabulary, that help discriminate 'innovative' from 'less innovative' service firms. The machine learning algorithm starts with the vocabulary described above and scores all text documents initially. Subsequently, it identifies which words and phrases of the vocabulary need to occur how often and in which patterns in the firms' documents to be able to classify them as innovative or less innovative. For this exploratory study, MATLAB's classification tree implementation was employed, using 10-fold cross validation to find a robust, pruned classification tree, based on the match scores of the firms' documents with the vocabulary.

The results of the machine learning approach were subsequently enriched with a keyword in context (KWIC) analysis. A KWIC analysis is a manual, albeit computer-assisted means of analysing the occurrences of particular terms or 'keywords' in more detail than possible through automated approaches (Krippendorff, 2004). This allows evaluating the results of the classification in depth and getting a better sense of the elements of the vocabulary and the contexts in which they occur.

DOCUMENT ACQUISITION AND EXTERNALLY AVAILABLE CLASSIFICATION

The remaining two components of our approach, the acquisition of a collection of text documents associated with service firms ("III" in Figure 4), and an externally available classification for the same set of firms ("IV" in Figure 4), are interdependent, and are consequently described jointly below. Document acquisition and the selection of an external classification were done in cooperation with Kimbrough et al. (2013), as both studies require the same kind of input data.

A review of suitable available external classifications yielded a ranking published by BusinessWeek (2010) as one of the most complete and multi-faceted rankings of firms, based on their innovation capability. The ranking was produced by the Boston Consulting Group, contracted by BusinessWeek, through a survey conducted between November 2009 and January 2010 (The Boston Consulting Group, 2010). The survey was sent to a panel of senior managers of the BusinessWeek Market Advisory Board, of which 1,590 executives across all major markets and industries, replied. These responses were complemented by the weighted average of three readily available key financial indicators: Three-year shareholder returns, three-year revenue growth, and three-year margin growth. The panel's responses accounted for 80 per cent of the ranking score, while the first financial indicator was given a weighting of 10 per cent, and the other two of 5 per cent each.

From the resulting final ranking of the 50 most innovative firms, we selected the 22 US-based companies, in order to ensure homogenous reporting guidelines for the firms' documents collected as described below. These 22 firms make up our set of 'innovative' firms. In order to obtain a complimentary set of 'less innovative' firms, for each of the specific industries determined by BCG, we randomly selected five other firms from the same industry that were not listed as one of the innovative firms in the available ranking. This led to a set of 110 'less innovative' firms.

The subsequent task of obtaining documents for the resulting 132 firms was conducted by collecting the firms' annual reports for the four years from 2007 to 2010, in order to ensure a reasonable representation of recent behaviour, and to compensate for the typical 'noisiness' of unstructured data, following the procedures of the externally available innovation ranking. Our collection of text documents was limited to annual reports in order to ensure both an extensive and uniform representation of the firms in the sample. The annual reports were primarily obtained from the firms' websites, or, for firms that use Form 10-K as requested by the U.S. Securities and Exchange Commission (SEC), we retrieved those Form 10-K filings directly from the SEC (http://www.sec.gov/edgar/searchedgar/webusers.htm). Naturally, there was some attrition in document acquisition, for example due to too small industry sets or documents that could not be converted into a machine processible format, which led to a document collection of 455 annual reports for the four years, 78 from innovative firms, and 377 from less innovative ones.

RESULTS

The application of the analytical approach laid out above to the collection of documents in combination with the studied service innovation capability *(Co-) Producing and Orchestrating* has yielded very encouraging results. The machine learning results are reported in two forms: A list of classification rules, visualised in tree form in Figure 6, and confusion matrices that indicate the number of correctly classified firms, as well as that of the incorrectly classified ones (type 1 and type 2 errors). These result from a comparison of the results of the classification rules with the external classification.

The full classification tree based on the vocabulary derived by the process described above is pruned to yield the discovered classification tree depicted in Figure 6 by multiple runs of 10-fold cross validation trials. This resulting pruned tree has 13 leaf nodes. The full tree found by the regression tree algorithm produced a much larger tree with 28 leaf nodes, which is extremely accurate in classifying the training data. As is standard practice, we must assume that the full tree over fits the data and will perform poorly on predicting out of sample cases. This concern was addressed by applying 10-fold cross validation as a way of finding a smaller tree that performs well on samples randomly drawn from the data. The depicted tree, thus, constitutes a considerable trimming of the full tree found by the classification tree program, which is very reassuring in the face of worries about over fitting the data. The numerical scores given in the tree represent the breakpoints discovered by the classification tree algorithm in fitting the model to the data. The scores were obtained through the software used by counting the number of occurrences of a term from the vocabulary (e.g. "people") in a firm's documents. The matching score for a given document and a given term is the number of occurrences times 100,000, divided by the document's length in characters. The multiplication step is done simply to scale the scores to numerically convenient ranges, while the division step ensures comparability of text documents of different lengths.

Taking the root node "people" as an example, these numbers are computed from the scores for all 455 documents in the collection, for which the matching scores ranged from 0 (no occurrence of the term in a document) to a maximum of 53.62, with mean and median scores of 3.43 and 0.84, respectively (for better readability, all scores are rounded to two decimals in this report). In Figure 6, the branches beneath the root node "people" are labelled "< 2.60" and ">= 2.60".

This means that the classification tree algorithm found that splitting the 455 documents at a score of 2.60 for the term "people" is highly effective at classifying the documents as belonging to 'innovative' or 'less innovative' firms – the confusion matrix for this top node is shown in Table 1. The scores for the other nodes shown in Figure 6 have a corresponding interpretation. The confusion matrix for the pruned best tree found by cross validation (See Figure 6) is shown in Table 2.

The quality indicators associated with these results are very encouraging for our approach.

Figure 6. Classification tree for den Hertog et al.'s capability "(Co-) producing and orchestrating" (all numbers rounded)

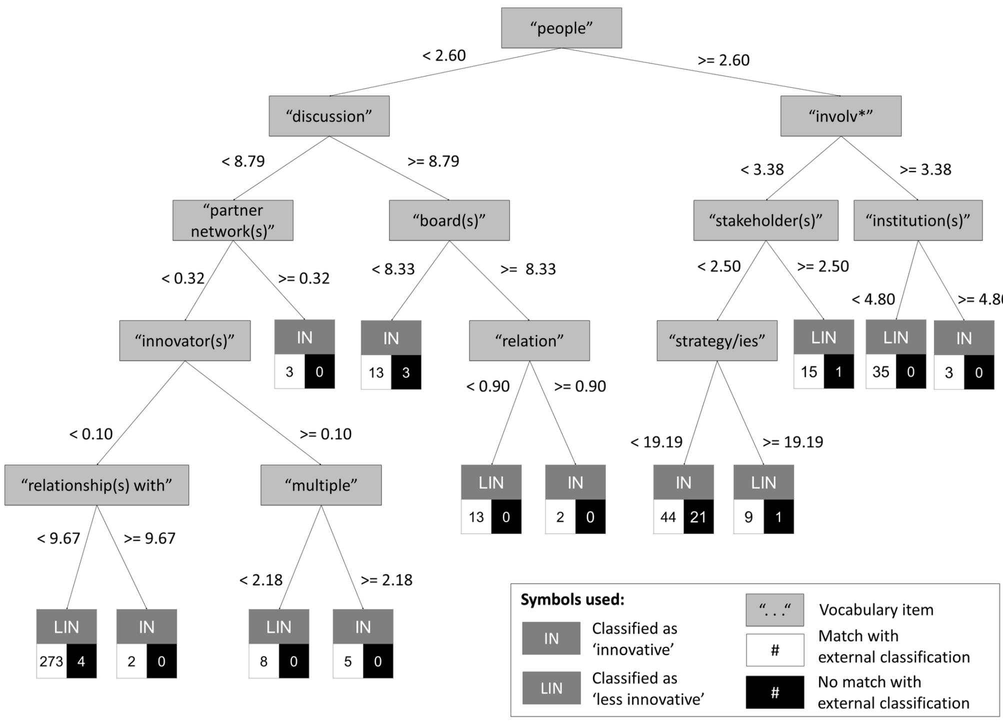


Table 1. Confusion matrix for node "people"

ActualPredicted	Innovative	Less Innovative
Innovative	49	80
Less innovative	29	297

Table 2. Confusion matrix for best pruned tree (as depicted in Figure 6)

ActualPredicted	Innovative	Less Innovative
Innovative	72	24
Less innovative	6	353

Of the 455 documents, 93.4% (calculated as (72 + 353) / 455) are classified correctly by comparison with the external classification. Precision, i.e. the share of correctly predicted classifications, was at least 75% (72 / (72 + 24)). Recall, i.e. the share of documents, the actual classification of which was discovered by our approach, was at least 92% (72 / (72 + 6)), which are both impressive compared to common Information Retrieval results (Blair & Maron, 1985; Manning et al., 2008).

Some of the discovered classification rules warrant particular attention. The basic argument presented above was that firms with documents scoring high on the terms of the vocabulary for the service innovation capability *(Co-) Producing and Orchestrating* can be expected to be classified more often as ‘innovative’, since the terms of the vocabulary are related to this important innovation capability. Quite remarkably, considering the bottom left leaf “relationship(s) with” and its parent nodes in Figure 6, there are 277 documents, in which “people” scores < 2.60 AND “discussion(s)” scores < 8.79 AND “partner network(s)” scores < 0.32 AND “innovator(s)” scores < 0.10 AND “relationship(s) with” scores < 9.67. Of these 277 documents, all classified as associated with ‘less innovative’ firms by the classification tree, 273 are in fact associated with ‘less innovative’ firms in the external classification, while only 4 are from the ‘innovative’ category. Since all of the branches considered in this rule are on the ‘low’ scoring side of their respective nodes, this intuitively fits very well with our basic argument presented above.

With regards to the richest leaf for ‘innovative’ firms, “people” scores >= 2.60 AND “involve*” scores < 3.38 AND “stakeholder(s)” scores < 2.50 AND “strategy/ies” scores < 19.19. From our sample, 65 firms are classified as innovative by this combination of rules, of which 44 are correctly and 21 are incorrectly classified, based on the external classification. Interestingly, this shows that while still good at classifying innovative firms, the tree classifier is far more accurate at classifying less innovative firms (see above).

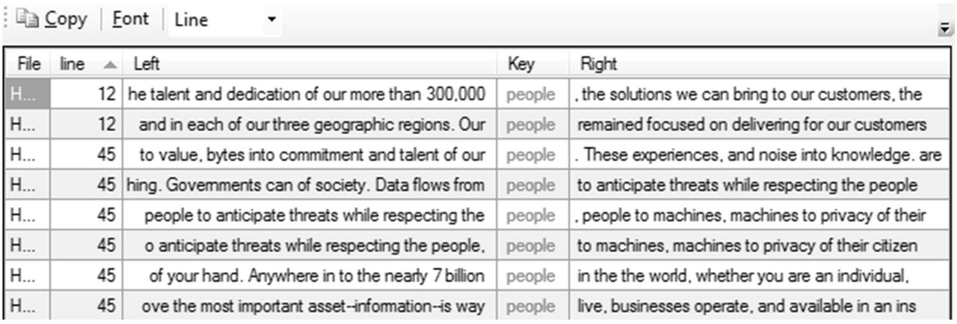
Another noteworthy result is that with two exceptions (“boards” < 8.33 and “strategy/ies” < 19.19), all leaves classifying documents as ‘innovative’ branch to the right, that is come from the “>=” or ‘high’ scoring branch of the parent node. This means that the occurrence of these two classifiers, unlike all the other terms of the pruned tree, has a negative impact on the prediction of innovation capability of a firm in the sample. Possible reasons for this, as well as further observations and implications are discussed based on the results of a KWIC analysis in the following.

DISCUSSION OF THE RESULTS

Our KWIC analysis was supported – as is typically the case – by corresponding software. We applied the software tool ‘KWIC Concordance’, which allows the user to see all of the occurrences of a given term in a document in a clearly presented visualisation, together with the antecedent and successive words of the phrase it is used in (see Figure 7).

In order to learn more about the classifiers in our rule set, we considered all of the nodes and leaves in the final pruned classification tree, and selected approximately 20 documents per term for analysis. The documents were selected so as to ensure a cross section across the range of matching scores from very low to very high, with a relatively even split between ‘innovative’ and ‘less innovative’ firms (based on the external classification). For each term, the contexts of its occurrence were separated into intuitive and distinct categories. These categorisations were adapted as needed in the course of the analysis, finally yielding two categories for most of the terms. Interestingly, the contexts of occurrence, and consequently the categories used, turned out to be very stable across the individual documents, which usually allowed us to associate the document in question with one of the two categories. Relevant insights from the KWIC analysis for the documents considered are presented here by term:

Figure 7. Screenshot of analysis in KWIC concordance software



Copy | Font | Line

File	line	Left	Key	Right
H...	12	he talent and dedication of our more than 300,000	people	, the solutions we can bring to our customers, the
H...	12	and in each of our three geographic regions. Our	people	remained focused on delivering for our customers
H...	45	to value, bytes into commitment and talent of our	people	. These experiences, and noise into knowledge. are
H...	45	hing. Governments can of society. Data flows from	people	to anticipate threats while respecting the people
H...	45	people to anticipate threats while respecting the	people	, people to machines, machines to privacy of their
H...	45	o anticipate threats while respecting the people,	people	to machines, machines to privacy of their citizen
H...	45	of your hand. Anywhere in to the nearly 7 billion	people	in the the world, whether you are an individual,
H...	45	ove the most important asset--information--is way	people	live, businesses operate, and available in an ins

- **"Involv*":** The use of this term could be classified into problem-related and potential-related. Interestingly, the problem-related use of the term is more frequent among innovative firms. Arguably, this could mean that by explicitly stating problems, firms can gather feedback and ideas for new solutions and approaches;
- **"Institution(s)":** This term is used primarily with one of two meanings in the annual reports. Reports that show a high score on 'academic institutions' could not be clearly discriminated. Documents associated with 'financial institutions' more often were classified as 'less innovative';
- **"Innovator(s)":** Firms typically use this term to talk about either their own innovation capability, or about that of others. For the documents considered in the analysis, all of those categorised as using the term in the sense of others, they belonged to firms classified as innovative. Accordingly, the use of the term in the sense of one's own innovation capability is predominantly associated with less innovative firms;
- **"People":** Two distinct categories emerging form the analysis are internal (employees or staff) and external (customers). While the category "customers" occurs in every document assessed, fewer times this is the case for "employees". For 'innovative' firms, whenever they used the term "people" in the sense of employees, it went hand in hand with an explicit mention of the word "innovation" or one of its variations;
- **"Strategy/ies":** The term is used either to talk about past actions of the firm or plans for the future. However, for the documents considered, the two categories do not directly correlate with a classification of innovative or less innovative;
- **"Relationship(s) with":** This key word is predominantly used in two contexts – industrial partners and customers. This was the only key word in the analysis for which there was significant variety for the contexts of its occurrence, for both categories. This variety should be taken into account in further analyses.

These insights enrich the quantitative perspective of the classification rules presented above and offer guidance for further applications of our study's approach. Considering our second research question, *RQ2*, we can state that the application of an analytical approach using unstructured data and EMCUT techniques has yielded very encouraging results in terms of the assessment of innovation capability of service firms. These results can be further enhanced and complemented by the use of manual analyses, such as our KWIC analysis presented above.

With regards to our first research question, *RQ1*, a comparison of the classification rules obtained by the machine learning algorithm with the externally available classification suggests that the innovation capability of service firms can indeed be operationalised by more concrete resources, allowing an indirect assessment of the innovation capability through assessing information on the individual resources. The relation of the resources with the innovation capability studied, that of *(Co-) Producing and Orchestrating* from the den Hertog et al. framework, is based on expert knowledge, and enables the use of readily available information to carry out this assessment.

Regarding our research objective of showing that service innovation capability can be assessed analytically by constructing measures for underlying resources and deriving indicators for these resources, it appears that most of the resources reported by the practitioners are quite suited to this approach. Many of them are already quite tangible, materialising in procedures, methods, tools, organisational designs and processes. Thus, they provide a solid basis for the development of robust quantitative measures, ranging from mere counting (e.g. in the case of partnerships a firm has entered) to scale-based rankings (e.g. for an assessment of more multi-faceted terms, such as people). By using these measures for individual innovation capability related resources, performance indicators can be derived according to the above logic. This approach has been successfully employed in seminal works in the strategic management and operations management literature, such as the Balanced Scorecard concept (Kaplan & Norton, 1992).

CONCLUSION AND OUTLOOK

In our exploratory study we have found an indication that text mining algorithms can be applied to firms' documents in natural language so that elements of innovation capability can be assessed. As a test case, we selected a service innovation capability called *(Co-) Producing and Orchestrating* from the recently published framework of den Hertog et al. (2010). By involving experts on the practice of service innovation, complemented by an analysis of relevant literature, we were able to create a vocabulary representing this innovation capability. Employing machine learning approaches, the vocabulary was subsequently matched with firms' documents, in order to classify the firms with regards to their innovation capability. This assessment was compared with an external classification, in order to interpret the results.

Although the initial results are promising, they can only be considered an indication, rather than hard evidence. First, the framework of den Hertog et al. suggests that service innovation capability is multi-faceted, and we only selected one aspect for consideration in our study. Whether the contribution of capabilities to the outcomes of service innovation efforts is additive or more complex can be questioned. Another limitation refers to the documents used in our exploratory study. So far, we have shown that our text mining algorithms and an expert-based vocabulary applied to annual reports can classify companies according to their innovation capability. This does not necessarily mean that the same method applied to different documents, in particular documents not written by the firms themselves, e.g. newspaper articles or blog posts, will be able to reproduce these results. This is a important aspect, since at this stage, the analysis could be heavily influenced by PR departments modifying their firms' documents based on the vocabulary known to classify firms as 'innovative'. However, the impact of this is somewhat mitigated by studies gleaning new information from annual reports on a regular basis, although companies have had quite a lot of time to strategically word these documents, since serious studies of text in annual reports can at least be dated back to Bowman (1973). Still, we consider the use of independent sources of text documents as input for the text mining analysis a vital extension of the current approach.

What is more, the external knowledge used in the form of the vocabulary derived from expert interviews plays a pivotal role in the assessment of the framework and the described innovation capabilities. For future studies, we recommend systematically looking at vocabulary and query extension and using multiple sources to ensure robust results. In doing so, conciseness and focus on the relevant topic still has to be ensured, building on the assumptions of the ex-ante approach.

Despite these current limitations, the results promise interesting applications and avenues for development, both in terms of scientific research, and in the context of service innovation management. For scholars, the presented approach represents a way towards a generalised way of capability framework validation, allowing use and modification in a variety of contexts. Frameworks are used in almost every discipline and are important tools for structuring our thoughts. However, they are often not validated – as in the case of den Hertog et al. (2010) – so our contribution could ultimately help strengthen their use in research and application. For practitioners, while the current state of our approach is not directly implementable in organisational contexts, it holds many relevant implications for practice, as it could build the basis for management information systems and benchmarks in service innovation management. The importance of such analytical IT-systems, allowing the aggregation of information across the firm, creating transparency and synergies, and supporting management in making complex decisions, has been suggested by many authors, including Davenport (2007), Johannesson et al. (2010), and Joshi et al. (2010). To conclude this paper, we briefly present an outlook on the extension and implementation of such an approach in a service firm.

First, through its own efforts or building on further studies on the assessment of service innovation capability, the firm is able to determine the resources supporting the facets of its innovation capabilities. Subsequently, the firm would be able to use analytical approaches, such as the one employed in this study, to assess the presence of these resources, both independently and in comparison with industry benchmarks. In the firm's case, they could use much richer information than was feasible in our study, since internal documents, project reports, and intranet systems could be tapped. By aggregating the scores for the resources associated with the individual aspects of the firm's innovation capability, the practitioners would then be able to determine a profile of strengths and weaknesses on the service innovation capability level. For the poorly implemented areas of the firm's innovation capability, the executives could perform a drill-down analysis and investigate the associated resources in detail. Furthermore, by integrating such an approach into an IT management information system, analyses could be run on a regular basis and could be integrated into available systems. Results could be presented using dashboard-type visualisations, and time series profiles for detail analysis of innovation capability developments, enhancing transparency across the firm. In addition to using the approach inside the organisation, we could imagine setting up a stand-alone benchmarking platform, to which firms can submit their unstructured data, i.e. various text documents, and obtain feedback both on the distribution of their innovation capabilities and on their standing in comparison to peers. We encourage fellow scholars and practitioners to develop and evaluate the approach further, in the ways suggested, as well as otherwise. All in all, we expect this to help provide a broader basis for informed service innovation management decisions.

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