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The Internet of Everything: Smart things and their impact on business models

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A B S T R A C T

The internet of everything (IoE), connecting people, organizations and smart things, promises to fundamentally change how we live, work and interact, and it may redefine a wide range of industry sectors. This conceptual paper aims to develop a vision of how the IoE may alter business models and the ways in which individuals and organizations create value. We review literature on networked business models and service ecosystems, and show that a clearer understanding is needed of how the IoE will impact on the ways that organizations go about their business at the micro, meso and macro levels. Combining this with an inductive, vignette-based approach, we present a new taxonomy of smart things based on their capabilities and their connectivity. We derive their implications for business models and conclude the paper with propositions that form a research agenda for business researchers.

1. Introduction

The rise of the Internet of Things (IoT), has the potential to change the world as we know it and will fundamentally change many companies' business models as well as the way consumers interact with these companies and other stakeholders (Fredette, Marom, Steinert, & Witters, 2012). Over the past five years, common day-to-day objects have evolved to embed new capabilities, often through connectivity linking sensors and control systems. From door bells, cars, fridges, and TVs, to things where the benefits of connectivity are less immediately obvious such as ice cubes and clothing, the IoT is slowly creeping into the daily lives of citizens and businesses (Ng, Scharf, Pogrebna, & Maull, 2015). The term IoT is being used to describe the connectivity of things as "*a system of uniquely identifiable and connected constituents (termed as Internet-connected constituents) capable of virtual representation and virtual accessibility leading to an Internet-like structure for remote locating, sensing, and/or operating the constituents with real-time data/information flows between them*" (Ng & Wakenshaw, 2017, p. 6). For the purposes of this paper, we use the term "smart things" to describe these connected constituents.

The explosion of connectivity is subtle and often not noticeable to many people. Hyperconnectivity as a "*myriad means of communication and interaction*" that is always on, readily accessible, information-rich and interactive enables connections between virtually everything, resulting in the broadening of the IoT concept to the Internet of Everything (Fredette et al., 2012). The Internet of Everything expands the IoT concept by adding links to data, people and (business) processes. It therefore comprises other connection-based paradigms such as IoT, Internet of People (IoP), and Industrial Internet (II) (Yang, Di Martino, & Zhang, 2017). In this context we understand the *Internet of Everything (IoE) as a network of connections between smart things, people, processes, and data with real-time data/information flows between them.*

Despite the huge interest in these new concepts that have the potential to radically alter where we live, how we work and how we interact with each other and with organizations (Fredette et al., 2012), there is a lack of understanding of how the emergence of the IoE will impact businesses. Businesses that succeed in adapting their extant business models to the new technological possibilities have considerable opportunities to innovate and are potentially highly competitive. Yet, the IoE also poses considerable challenges to firms, including the development of interoperability between systems, coping with entrenched industry partners that do not collaborate with the new developments, path-dependent legacy processes and transactions, contractual and liability issues, security challenges, loss of control, as well

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as privacy concerns related to the explosion of data collected and used by businesses and their smart things. For businesses, it is therefore important to understand the extent to which smart things will transform existing business models, and as a part of this, how value creation in such service ecosystems will be affected by the rise of the IoE. This would critically depend on the configuration of the smart things and their capabilities.

In this paper, we first use current theoretical expositions on networked business models and service-based value-creating ecosystems to describe the potential impact of IoE on current business models and the processes of value creation by firms and their customers. We then propose a conceptual taxonomy of different levels of smartness that things can be endowed with. Finally, using this taxonomy, we explore the impact of different levels of smartness on business models and evolve a research agenda. Our study proposes that the connectivity impact of the IoE goes beyond the boundaries of a single company and its business model, thus requiring a multi-layered understanding. We discuss potential implications of the IoE by framing it through micro, meso, and macro levels of a service ecosystem (Ng & Vargo, 2018; Ng & Wakenshaw, 2018). As part of the research agenda, we develop theory-based propositions for future research that are important from both a scientific and a management perspective.

In the next sections we discuss extant literature on networked business models and the service-dominant logic in relation to how smart things may impact business models, and we explore the impact of these changes on the process of value creation. Following that, and acknowledging that the impact of smart things on business models may critically depend on their configuration, we develop a taxonomy where we describe conceptually different levels of smartness that things can be endowed with. In the discussion, we draw on this analysis and insights from the two literature streams, and we derive propositions showing avenues for future business research.

1.1. Methodology

This research is conceptual in nature and takes a multidisciplinary approach in investigating the phenomenon of endowing things with smartness, and its consequences. Owing to the diverse, recency and transcendental nature of the topic, a critical literature review on the IoE is a challenge, compounded by the scarcity of relevant papers published in scientific management journals. Therefore, we chose two theoretical lenses most relevant to the breadth of the challenge and use them to frame the phenomenon of smart things and how they impact on business models: technology-enabled networked business models and value-creating service ecosystems. Additionally, we consider the technologies that are forming the IoE and what their implications are for enabling smartness. By combining these perspectives, we are able to provide a new comprehensive and multi-faceted exposition of how smart things impact on business models.

We combine a deductive with an inductive approach. On the one hand, we build our understanding of the implications of increasing levels of smartness for business models based on the two theoretical lenses mentioned above. On the other, our research follows an inductive approach through a vignette description of real examples, to both interrogate and expand on the theoretical foundations, as well as develop our understanding of smart things in the IoE. We apply this latter approach particularly when current theoretical insights appear inadequate to explain the phenomenon at hand. Subsequently, we develop a new taxonomy to make explicit what levels of smartness of things in the IoE are, and what their implications are for business models. Finally, we derive propositions for future research, not only for theory testing, but also for the development of novel theoretical concepts.

2. Theoretical lenses for the Internet of Everything

While many disciplines have touched on the subject of smart technologies and their influence on the way that businesses operate from their specific point of view, there appears to be a lack of comprehensive approaches that explain the phenomenon and its consequences for business models. Therefore, we base our theoretical discussion on two complementary streams of literature, since combining lenses brings major benefits in terms of new insights and novel hypotheses (Okhuysen & Bonardi, 2011). We look to the ongoing discussion in the management and information systems journals regarding *technology-enabled business models*, including digital business models, which go beyond the boundaries of a single organization. We also consider the growing literature on *value creation in service ecosystems through a service-dominant logic approach,* which reflects the growing appreciation of the role of the end users of products and services as co-creators of value. These perspectives enable us to emerge the importance of an extra-organizational ecosystem level in the developing theory on technologies' influence on business.

2.1. Technology-enabled networked business models

Despite serious concerns about the business model concept's construct validity and explanatory power (Doganova & Eyquem-Renault, 2009; Foss & Saebi, 2017; Massa, Tucci, & Afuah, 2017), it has been developed and applied in multiple ways both scientifically and in practice. In the field of Technology and Innovation Management, a key direction has been the new opportunities for creating value offered by digital technologies, such as those incorporated in the IoE (Gambardella & McGahan, 2010; Keen & Williams, 2013; Wirtz, Schilke, & Ullrich, 2010). Indeed, digital technology is not simply "yet another technology" in this respect; it offers opportunities throughout the entire process of value creation and appropriation whereby it influences not only the functional level of business operations but also the strategic level of business purpose and ability to generate new value propositions (Barrett, Davidson, Prabhu, & Vargo, 2015; Massa et al., 2017). Following Massa et al. (2017), we define business models as *attributes of firms in terms of the activities they perform, and the outcomes they generate, that determine their performance in markets*.

In their review of relevant literature, Foss and Saebi (2017) identify the need for more predictive and theory-advancing research into digital technologies as an antecedent to business model innovation. A key motivation is the role of network externalities that are inherent in the increasing number of internet-based products and services; these play an important role in defining the value of a firm's offerings, as potential customers' perceptions are strongly influenced by expectations of the "winner takes all" market scenarios (Cennamo & Santalo, 2013; Loebbecke & Picot, 2015).

One group of studies highlight the benefit to firms that are able to employ the dynamic capabilities necessary to take advantage of smart things (Teece, 2012). Within organizations, smart things may complement the capabilities of employees thereby enhancing the overall ability of the firm to efficiently and effectively operate, particularly if the smart technology helps people to free up time for the tasks they are best able to carry out (Marinova, de Ruyter, Huang, Meuter, & Challagalla, 2017). Other studies highlight how smart things may endow firms with new abilities for flexible adaptation, explaining how organizations rapidly adapt to changing circumstances in order to profit from new opportunities or avoid damaging threats (Drnevich & Croson, 2013; Teece, Pisano, & Shuen, 1997). These scholars posit that the type of digital data available in the IoE offers rich new opportunities for enhancing this flexibility, whereby a "superadditive" effect can boost the data's value when it is used by organizations with a high level of flexibility (Drnevich & Croson, 2013); having more data makes having a given amount of flexibility more valuable, and vice versa.

However, to what extent these potential advantages can be realized is dependent on just how smart the technology functions; this means that *different levels of smartness* may exist. If the technology is not very smart yet, employees have to expend significant time in data preparation and training of the smart thing, such that people are tethered to the supposed smart thing as a form of human assistant (Huang & Rust, 2018). Only when the things achieve a higher level of smartness, such that they can deal with messy, heterogeneous data, will the people be free to fruitfully handle their specific tasks, such as interpretation and ideation. Indeed, smart things pose many new challenges to the firm, not least the difficulties of adapting existing, and often historically successful, business models to new digital possibilities. When firms fail to develop their business models in this way, they may quickly find themselves at a disadvantage compared to their digitally savvy competitors (Benner & Tripsas, 2012; Massa et al., 2017).

In the context of the IoE, an important and highly relevant development in business model thinking is the notion of an abstraction level that is higher than one single firm. Network-level business models are becoming increasingly more relevant than the firm-centric level alone (Adner, 2017; Bankvall, Dubois, & Lind, 2017; Oskam, Bossink, & de Man, 2018), and network-focused studies are increasingly acknowledging how a firm's activities are interdependent with its partners whereby the process of value creation is boundary-spanning (Zott & Amit, 2010; Zott, Amit, & Massa, 2011). Through the IoE, networks of firms, people and things will overlap in more tightly coupled systems, such that the connections between these entities will challenge the existing structures of industry and markets, and in turn firms' business models (Turber, Vom Brocke, Gassmann, & Fleisch, 2014; Westerlund, Leminen, & Rajahonka, 2014). When information can flow from a door to a phone, markets that were never connected become 'wet-wired', much like a short circuit, resulting in the value proposition of a firm within one industry being realized in conjunction with another firm from a different industry. This leads to the potential fracturing of business models in individual industries (Ng, 2014).

Thus, digital technology inherently lends itself to cross-sectoral innovations, challenging firms from previously unconnected industries to work together. It removes traditional entry barriers to existing markets, and intensifies competition. Together, these challenges are forcing firms to redesign their value propositions and their long-term business strategies for shareholder value, profit and growth (Barrett et al., 2015; Majchrzak, Markus, & Wareham, 2016).

If we attempt to assess the extent to which this literature can be applied to smart products and things, then we may conclude that theory development for network-embedded business models is needed (Bankvall et al., 2017). There is a paucity of theoretical argumentation, especially with respect to an explanation of the consequences of smart things for business models. We may criticize extant literature for failing to address the effects of pervasive connectivity on firms' business strategies. The levels of connectivity being brought about by the IoE does not simply offer connection to social networks and applications, but enables wholly new forms of 'smartness' embedded in network constituents due to the interconnection between data streams from both social and physical systems and sources. A major challenge associated with such a shift is how firms develop their existing business model towards a new networked business model that fits best in the IoE context. This implies that the development of a new business model has to deal with path dependency effects as the organization attempts to extend its current strategy and value propositions step-by-step in the direction of the new IoE context (Wirtz et al., 2010). Any new theorizing must be able to guide the creation of new business models starting from the context of smart things at a low smartness level right up to fully autonomous, adaptive and self-determining things.

2.2. Service ecosystems

Theorizing business models in the age of the IoE requires a mindset that is less linear, less cause-and-effect inclined, less dyadic (customer and firm) in nature and less sequential in its process. In other words, when objects and people are interconnected, resource flows may not always be deterministic, or follow the original design. Business models of one industry overlap with others, resulting in unintended or unforeseen consequences.

A potentially informative way of understanding business models in a hyperconnected world is to adopt a service ecosystems mindset (Ng & Wakenshaw, 2018). This ecosystem view, developed from service-dominant logic (S-D logic), can provide a framework for studying wider systems, or the interaction and value co-creation among multiple service systems (Vargo & Lusch, 2017). S-D logic as a perspective for service has been extensively discussed (Vargo & Lusch, 2004; 2016; 2017; Vargo & Akaka, 2012), although less has been written on the business models that might emerge once connectivity and interrelations increase dramatically. Its fundamental premises have been explained at length (Vargo & Lusch, 2004, 2017; Vargo & Akaka, 2012), and the S-D logic's basic tenet is that service – the application of competences for the benefits of another – is the basis of all exchange which means that all economies can therefore be understood to be service economies. Service-for-service exchange is recognised as a theoretical foundation for the development of service science and the study of service systems (Maglio & Spohrer, 2008; Vargo & Akaka, 2012). Under this logic, value is co-created by multiple actors, each of which integrates their own competences and resources with those of the other actors; a concept that can also be extended to objects as actors in a hyperconnected world.

Service ecosystems in IoE is a useful framework as it sets out why and when a system is a *service* ecosystem, which is when the flow between actors is that which results in mutual value creation, through actors' service-for-service exchanges (Ng & Wakenshaw, 2018). An essential aspect of service ecosystems is the coordination mechanisms through which actors are able to co-create value and enact resource-integrating practices. Such practices occur within institutions, i.e. through norms that are both explicit and implicit (Furubotn & Richter, 2005; North, 1990), with certain enforcement guarantees that could be formal or informal. Hence, institutions create expectations regarding the behavior of actors within a value-creating and resource-integrating service ecosystem and can be enabling or disabling. According to the S-D logic, a particular institutional *arrangement* is a set of rules and values that drive a set of behaviors (Vargo & Lusch, 2016). More importantly, institutional arrangements enable coordination between actors of a system and have regulative, normative and cognitive functions in creating value (Kleinaltenkamp, 2018).

When people, things and businesses become connected in IoE, they are confronted with institutional arrangements that may be mutually incompatible. Conflicting institutional arrangements bring about complexity (Greenwood, Raynard, Kodeih, Micelotta, & Lounsbury, 2011), resulting intensions within and across organizations. Thus IoE has the potential to disrupt how entrenched actors conform to specific institutional arrangements and when such disruptions occur, a system may exhibit uncertainty and conflicts.

2.3. A combined perspective

When we combine the perspectives of service ecosystems and the technology-enabled business models to the IoE, the advancement of the technology seems key to the understanding of its consequences. "Flows" of resources from one actor to the other can also comprise flows of information between different smart things, or other entities connected through the IoE. The extent to which smart things are connected will largely determine the flows of information and therewith the reach and richness of the service ecosystem.

Technology-enabled networks of people and things are value co-creating actors actively involved in value generation and appropriation via the application of their competencies. Combining the use of technology-enabled business models with a service ecosystems perspective in the S-D logic is a useful frame for IoE business models. It presents an opportunity to 'zoom out' and broaden the perspective (Vargo & Lusch, 2016). More importantly, these combined views can provide a multi-layered understanding of IoE, from micro to meso to macro levels, so that the impact of a business model at a micro level can be better understood in terms of its influence by events at the meso level; the wider economic or market level. Such a frame also provides an understanding of interactions between different business models at the meso level, such as when smart things, which may be sold by a focal firm, connect with other smart things, sold by other firms with different business models. When many such interacting business models are considered together, they provide an understanding at the macro level, such as that of a regional economy, or an industry sector.

Although these two theoretical lenses differ in focus; the first centered on technology-enabled business models and the second on service ecosystems, we consider their conceptual distance as low and the compatibility of their conceptual assumptions as high (Okhuysen & Bonardi, 2011). Both lenses emerged within management disciplines (Information Systems and Marketing respectively) and focus on value creation through an analysis of the entire process. While most literature in business models traditionally focuses on the firm's business model as a unit of analysis without a framework for understanding how other firms' business models within related industries might normatively impact the firm, more recent literature goes beyond the boundaries of a single organization. For example, embedding a sensor into a door allows for a connection between the business model of a door manufacturer with that of actors in the security industry. A service ecosystem worldview, as suggested by these two theoretical lenses that describe value creation occurring across networked systems, through the understanding of resource integration at micro, meso and macro levels can provide insights into this new phenomenon and, as such, bring insights into how the IoE could change business models.

Summing up, the IoE has the potential to radically alter current business models and the configuration of existing business networks, where the combined perspectives of the technology-enabled business models and the service ecosystems view is a useful and appropriate theoretical lens to conceptualize these changes. The extent to which networked business models will evolve to cross domains and industries depends on how advanced IoE technologies become, most notably the level of smartness that objects possess. However, there is a lack of theory on this important characteristic of future business models embedded in the IoE. In the following section, we therefore develop a taxonomy for different levels of the smartness of things.

3. Enabling technologies for the Internet of Everything

Technology is clearly a major driver for the increasing smartness of things in the IoE. We highlight four areas of technical development and specify how they relate to the notion of smartness: interconnectivity, big data (Xu, He, & Li, 2014), artificial intelligence (Russell & Norvig, 2009), and semantic interoperability (Miorandi, Sicari, De Pellegrini, & Chlamtac, 2012).

First, the emergence of IoT as a global interconnected network of things has opened up new opportunities for increasing the level of smartness of things. One of the key aspects for smart things is their ability to sense the environment to understand the state of the system in order to act accordingly. Interconnectivity allows for an increase in the specialization of smart components, as each component can then focus on one particular aspect (such as sensing) while other interconnected components can exploit that functionality to use and improve its own performance. This specialization in the constituents of the IoE is useful when each constituent is *reactive* to the environment and to other constituents to which it is connected. In relation to the IoE there are now new challenges for the supporting capabilities collectively termed function-as-a-service, often provided via cloud computing services, that are enabling technologies for the computational IoE infrastructure, including computational resource-on-demand services, micro-services and so-called server-less and edge computing (Azodolmolky, Wieder, & Yahyapour, 2013).

Second, Big Data is a key enabling technological development driving the growth of smart things. The technological advancement has proceeded in two directions: enhancing the quality of sensing resulting in higher data quantities, and improving algorithms to interpret the massive amounts of sensing data. The amount of continuously gathered data has allowed researchers to use statistical methods that were previously considered to be of lesser importance as, due to the lack of data, they often resulted in overfitted models, as was the case with multi-layered neural networks (Hippert, Pedreira, & Souza, 2001). This success of Big Data is possible due to advancements in distributed systems, as we now know how to build scalable fault-tolerant applications, making storing (e.g., databases) and processing of large amounts of data possible. When it is not feasible to transmit all this data over networks to be analyzed in centralized data centers, the physical things that generate data can carry out computations at the source, which is made possible by advances in Edge Computing (Shi, Cao, Zhang, Li, & Xu, 2016). Additionally, multilayered neural networks, deep learning, and reinforcement learning use the copious amounts of available data to train smart systems. This allows smart things to exhibit *adaptive* abilities as they learn from the massive amounts of historical data. For example, Big Data analysis is used to refine an objective function based on real-world optimization, such as improving user comfort, energy efficiency, or other human defined aims.

Third, the foundations of smartness has been long been studied in the context of theoretical Artificial Intelligence (AI), where smart things are understood as objects that are sensing, reasoning, and performing actions based on the input data to reach a certain predefined goal. Smartness in this particular case implies *autonomous* behavior, and often involves various AI algorithms. The concept of a rational, autonomous agent is not new, and has been studied since the early days of AI, resulting in a number of specialized research areas focusing on different aspects. For example, research into AI planning (Ghallab, Nau, & Traverso, 2004) examines how to achieve a given goal by constructing a sequence of actions from the initial state, and forms a representation of reasoning (Cohen & Feigenbaum, 2014; Kaldeli, Lazovik, & Aiello, 2016). Research on machine learning employs advanced statistical methods both to improve quality of the interpretation of the sensing data and to enable smart agents to learn how various actions contribute to the achievement of the desired objectives, as exemplified by, for example, reinforcement learning (Leonetti, Iocchi, & Stone, 2016). Research on knowledge representation uses different logic models to describe the world so that agents can interpret facts about the world and make reasoned decisions (Bench-Capon, 1990). Such fields study both the behavior of individual agents but also multi-agent systems, where different agents interact to achieve a common goal (Pinyol & Sabater-Mir, 2013).

Finally, the importance of semantic interoperability – the ability of heterogeneous devices to understand each other – was clearly understood from the early beginnings of the Web, and was further developed after the success of online services, resulting in a Semantic Web with a number of standards, largely based on the theoretical work in logic and knowledge representation to enable the reuse of reasoning algorithms (Poggi et al., 2008). However, the lack of widely adopted IoT standards does not allow for global interoperability at the current time, at least not at the same level of seamless interconnectivity that the traditional Internet has. At this point, vendor-specific IoT platforms are used to bypass this issue. The global interoperability over the Web was first widely possible after the introduction of service-oriented computing relevant web service protocol stack. More recently, distributed ledger technologies, such as the blockchain, allow for decentralized cooperation between things whereby the interoperability is arranged within subsystems that interact via smart contracts (Anjum, Sporny, & Sill, 2017). Successful interoperability results in so-called smart environments, where multiple *collaborative* devices are seamlessly integrated and work together towards a common goal (Kaldeli et al., 2016). While the semantic web has been successful, we still cannot say that the problem of a general semantic interoperability was solved, as different systems still require a lot of expert knowledge to realize some form of semantic interoperability, such as the well-known IBM jeopardy-solving computer (Tesauro, Gondek, Lenchner, Fan, & Prager, 2013).

Taken together, the technological developments described here enable physical objects to be endowed with wholly new levels of smartness.

4. A taxonomy of smart things in the IoE

4.1. Taxonomy development

New IoE products and services are starting to appear regularly in a wide range of markets. With this rapidly expanding range of IoE applications, it becomes difficult to identify where new applications belong in the expanding IoE-enabled business ecosystem. Researchers, and IoE developers and business strategists need to be able to determine where a new IoE innovation fits alongside existing applications in order to ascertain if it enables something entirely new and unique, a significant variation of an existing application, or just a rehash of what we already have. A concise, comprehensive, and extendible taxonomy of IoE applications would provide a basis for making this determination.

In general, a taxonomy is understood as classification of a set of objects in a domain of interest (Nickerson, 2013). According to Baily (1994), taxonomies can be distinguished from typologies in that the former is derived empirically and inductively and the latter conceptually and deductively. However, Nickerson (2013) pleads for common recognition over precision and uses the term taxonomy for inductively, deductively and intuitively derived classifications. In the management literature the importance of taxonomies is recognized and various taxonomies exist, including software development methods (Blum, 1994), organizational structures (Mintzberg, 1985) and mobile applications (Nickerson, Varshney, Munterman, & Isaac, 2007). Taxonomies help researchers to understand and analyze complex and emerging domains (Nickerson et al., 2007), they provide a structure and an organization to knowledge of a field, and they enable researchers to study the relationship among concepts (Glass & Vessey, 1995).

Therefore, in this paper we propose a taxonomy of various levels of smartness of things in the IoE, with which we can describe the business model implications. Such a taxonomy makes it easier to compare different IoE applications and benchmark the level of maturity of an IoE ecosystem built around interconnected smart things. It may also provide guidance to strategists and IoE innovation developers to realize the potential benefits of IoE.

Rijsdijk and Hultink (2009) define *product smartness* as a sum of capabilities over several dimensions, such as *autonomy, adaptability, reactivity, multi-functionality, ability to cooperate to achieve a common goal, human-like interaction*, and *personality*. *Human-like interaction* and *personality* mainly refer to the perception of the end user, and as such, in this paper we focus on the first five capabilities. We also introduce an additional orthogonal dimension based on *connectivity* that represents the potential for smartness of the system where the smart things reside (together with people, organizations, businesses, etc.). As we concluded in the consideration of the theoretical lens of service value ecosystems, the extent to which smart things are connected determines the reach and richness of the service ecosystem, including flows of resources and information, and it thus determines the nature of the networked business model. Consequently, we consider *connectivity* as a main characteristic of smartness at a system level. It directly influences the complexity of possible interactions within the environment, thus defining also the complexity and the type of business landscape.

For the first dimension of capabilities, we define *reactive* smart things as having the ability to immediately adjust to a changing environment. *Adaptive* smart things have the longer-term ability to adjust their behavior to changes, such as by learning from historical data or usage patterns. *Autonomous* smart things have the ability to act independently, without direct intervention from human agents. *Cooperative* smart things have the ability to interact with other constituents of the IoE in order to jointly work towards a unified objective. The final smartness capability from Rijsdijk and Hultink (2009) is *multi-functionality* which refers to the ability to support and combine several functions in a single device. However, due to the other dimension for our taxonomy, connectivity, we no longer see the relevance of focusing on multi-functional things when a set of connected, uni-functional, things can amount to the same. As such, we drop multi-functionality from our taxonomy. Therefore, we utilize four smartness capabilities that denote how smart things can be reactive, adaptive, autonomous and collaborative. It may be clear that each of these capabilities is a technological achievement in its own right, a fact highlighted in our earlier discussion of enabling technologies, but it is in their combination that the highest levels of smartness may be achieved.

For the second dimension, connectivity, we define three levels that are relevant for the IoE. A *closed system* refers to connectivity between a limited and predefined set of things whereby physical or technical measures are taken to prevent influence from external factors. This is then a self-contained network and it may be considered not to be a part of the IoE at all. An *open system with a restricted communication protocol* refers to connectivity between a larger set of things that are not predefined but that may only connect together if they adhere to a specific set of rules and standards. Such rules and standards may be designed to intentionally restrict connectivity access to a subset of IoE-connected things, but it may also be a temporary state before globally agreed upon protocols and standards are developed. Finally, an *open system with full interoperability* refers to the situation when connected things have unrestricted access to each other and to all constituents of the IoE, whereby each thing clearly understands the communication of all other things.

By combining these two dimensions of capabilities and connectivity, we may define increasing levels of smartness for things in the IoE, as they become more able and more connected. In order to develop our taxonomy and to explore the implications of smartness for business models we now describe a hypothetical example, in the form of a vignette on business models related to waste collection and recycling, to illustrate the consequences of smart things for businesses in practice.

4.2. Vignette on waste collection and recycling

0. *Traditional non-smart solution.* There is a waste collection bin to collect waste plastic at a municipal site. The physical things in the waste collection and recycling process are not smart. An organization that wants to buy recycled plastic makes contact with the municipality and agrees on the amount, quality, price and other terms. The business models are traditional, trade-based models focused on individual transactions.

1. *Things are reactive, but not connected to the wider IoE.* The waste collection bin is equipped with sensors and a closed-system communication system. This makes the bin somewhat smart as it is able to measure characteristics of the waste as it is deposited, such as the weight and quality. On a daily basis, an operator drives to the municipal waste collection site and records the data about the deposited plastic from the built-in sensors, using a hand-held recording device made specifically for this purpose. Back at the office, this device connects to a database and when an organization wants to buy recycled plastic, they can see a representation of the data via a website, and note that this was automatically generated. Due to the data accuracy and frequency, the municipality can develop a new business model, such as allowing firms to bid for plastics of different qualities as they become

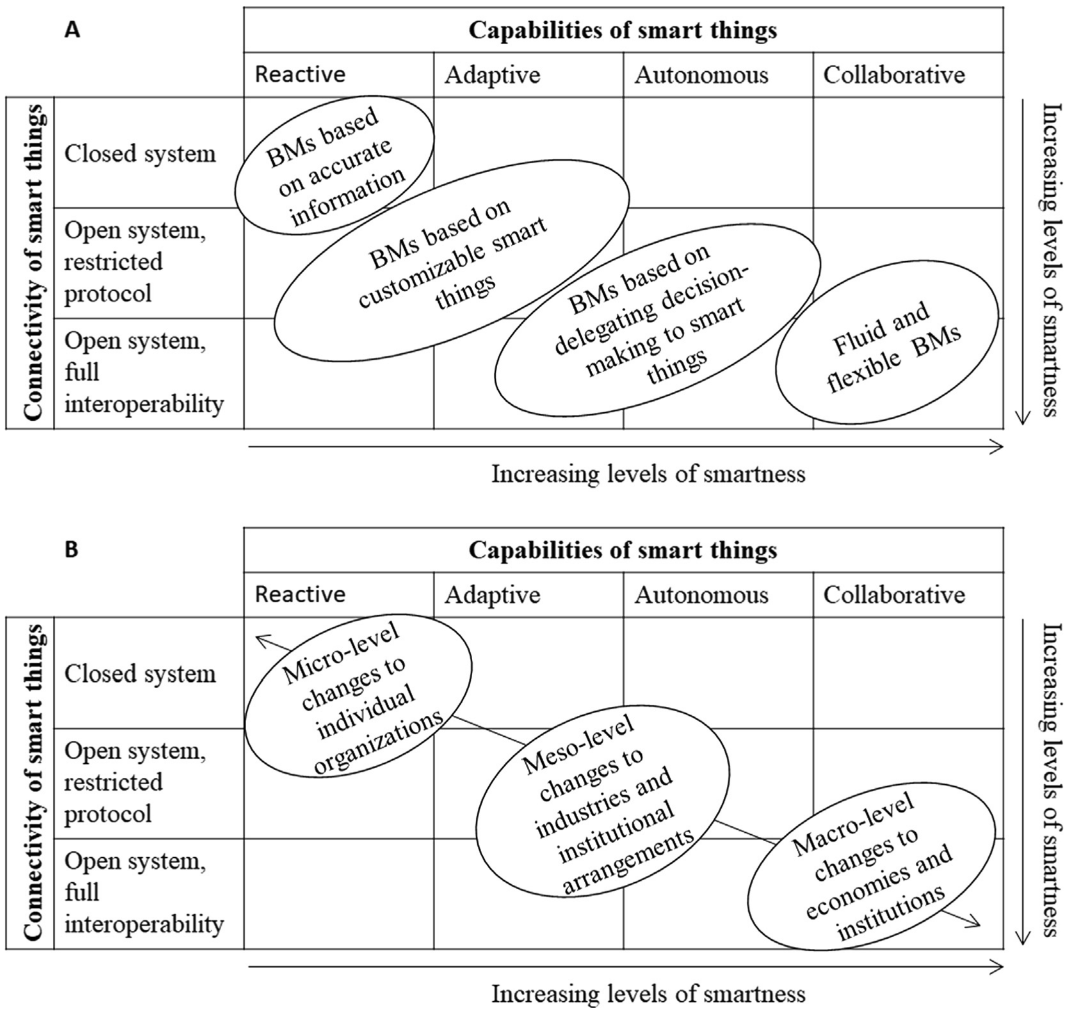

Fig. 1. Taxonomy of the increasing levels of smartness for things in the Internet of Everything, (**A**) their implications for business models (BMs), and (**B**) the abstraction level of their effects in the economy.

available. The effects of this change are mostly felt at the level of individual organizations and the overall waste collection and recycling system is unaffected.

2. *Things are reactive and adaptive, connected to the IoE via a protocol with pre-defined rules.* The waste collection bin continually measures the weight, types and quality of plastic that is deposited in real time, and via a network connection, sends that data to the database. Using image recognition software, the bins are able to learn to separate different types of used plastic. The operator has now lost this job of reading out the weight, and other technicians have acquired new jobs to develop and build the more advanced waste bins that include sensors, cameras, network connections, etc. For organizations that want to buy recycled plastic, the municipality can now offer access to the database by providing a remote access protocol. Their business model can change to take advantage of the adaptability of the waste bins and they can customize their offering to different customers, to meet each party's specific requirements. The effects of these changes are felt by individual firms but also through the plastic recycling industry, as different parties are more able to specialize and fine-tune their service offerings.

3. *Things are autonomous and more broadly connected to other constituents of the IoE.* The waste collection bin is in contact, via a trading platform, with transport trucks of known organizations in a business network that want to buy recycled plastic. When a buying organization wants plastic, their trucks connect to the waste collection bin (via a standardized application programming interface) and a transaction takes place autonomously, according to predefined contractual arrangements. The firms involved and the municipality have delegated the day-to-day negotiation and transaction completion to the smart waste bins and trucks via logistics systems, and trust is ensured by only providing access to this open system to predefined parties and their smart things. The effects of these changes may be felt at the micro level of the individual organizations, as they streamline their business models, and at the meso level of the plastic recycling industry, as the autonomous things in the IoE make efficient choices and learn from the increasing amounts of historical data. Additionally, there may be effects felt more widely at the macro level across industries, as manufacturers change their designs for all manner of objects to make use of the improved accessibility to cheap, high quality recycled plastic.

4. *Things are autonomous and collaborative, working together to achieve mutual objectives with full interoperability through the IoE.* There is a transactional system within which the waste collection bin is one agent. There is a globally standardized way of exchanging data, based on semantic interoperability, allowing for automated transactions for data or recycled plastic. The use of the data or plastic may not have originally been foreseen and could be used in a totally different context; for example, the municipality may design a smart solution, using data on the amount and type of plastic being recycled to understand the local population in order to designate where to locate a new children's playground. Smart contracts between agents may be negotiated in real time within restrictive boundaries set by organizations or regulators, according to utility functions, in order to achieve specific objectives. The smart things and the contracts they work with are designed to achieve

given goals of increasing plastic recycling, plastic re-use, etc., and they collaborate to achieve these aims. The business models of organizations that make use of the benefits offered by these collaborative, openly connected smart things are fluid and flexible, regularly changing to adapt to new circumstances. In this way, the strategic flexibility of organizations becomes highly important. The effects of these changes are widely felt throughout the economy as this recycling system and many other similarly smart, interconnected systems interact. Industry boundaries become less relevant as data and materials flow freely across domains. Institutional arrangements, including regulations, also adapt to keep pace with the emerging needs of the society.

4.3. A taxonomy of smart things and their consequences for business models

The vignette above helps to explain the implications of increasingly smart things for business models. We now present our taxonomy in Fig. 1, which shows several levels of smartness for things on the two dimensions of capabilities and connectivity that are missing in traditional, non-smart things. On top of these two dimensions, we add two types of consequences of smartness, following the insights from the vignette. First, the implications for business models are plotted. Second, the abstraction level - micro, meso or macro - where the consequences are felt are plotted.

The taxonomy illustrates the impact of the IoE on business models from a service ecosystem perspective. When objects are neither smart nor connected, business models of individual organizations are not impacted, given that the flow of operant resources and information remains unaffected. However, when objects become more capable and more connected, the flow of operant resources and information will change, therewith affecting interactions between the business models at the micro level. This can create complementarities or conflicts at the meso level where smart things become actors in service ecosystems that span different domains or industries.

So, following Fig. 1A, when objects connected in the IoE have a low level of smartness then the most valuable added resource is accurate data, conveying valid, reliable and up-to-date information on which new value propositions can be built. Where objects are adaptive and connected through open systems, then organizations become able to offer services utilizing customizable functions and facilities, guiding smart things to adapt to changing needs or contexts. Where objects can make autonomous decisions, connected in fully interoperable open systems, then the types of business models made possible becomes further enhanced; customers may negotiate with the smart things to make use of the flow of information and co-create value even more effectively. Finally, at the highest level of smart things, with highly autonomous, highly collaborative things connected to almost endless other data streams, fluid and flexible business models become possible. This means that the notion of a fixed service offering becomes obsolete and organizations will need to embrace the notion of constantly changing, highly personalized value propositions.

Following Fig. 1B, the structural changes experienced within and across industries are also dependent on the levels of smartness that things acquire. At the lower levels of smartness, individual organizations can continue to operate as they have before, making use of the IoE to enhance efficiency and the quality of their decision-making (Drnevich & Croson, 2013). However, once the smart things become adaptive and autonomous, highly connected to data systems across multiple domains, then we will observe changes to the underlying working and configuration of industries and institutional arrangements, much as internet banking catalyzed a shift in retail banking. Finally, at the highest levels of the smartness of things, macro-level changes will result in industry convergence, new economic patterns and the emergence of wholly new institutions.

When objects take an active part in creating value in the context of their own experience and usage, their connectivity enables resource flows, resulting in both complementarity and conflict in practice. Not all firms aim for full interoperability - Apple being a case in point - and path dependencies from existing business models based on unconnected objects can result in other conflicts that may impede further smartness from emerging. For example, it is well known that Apple devices can only print through AirPrint, Apple's specialized technology. Thus while it is technically possible to print a document on a printer that does not support such a technology, it is unclear which party, Apple or, for example, Hewlett Packard, would create the connectivity and, by so doing, carry out the necessary "institutional work" (Lawrence & Suddaby, 2006). Institutional work refers to "the broad category of purposive action aimed at creating, maintaining, and disrupting institutions". Such conflicts may be resolved through changes to business models at the micro level. At the meso level, institutional work may be conducted, i.e. actors actively changing the rules and practices. At the macro level, new institutional arrangements may then emerge, with a completely new system of rules to govern social interactions. Thus, we propose that a systemic perspective of smartness embedded in the IoE, as we present here, captures the dynamic nature of value creation and a more comprehensive view of the implications at different levels (Vargo & Lusch, 2016).

5. Discussion

The aim of this paper is to describe how smart things in the IoE may impact business models and to propose avenues for future research. In this regard, we did not only focus on the impact of the IoE on the business models of a single firm. Instead, we adopted a service ecosystem perspective that allowed us to examine how smart things affect resource flows in a networked system on micro, meso and macro levels. Using a vignette, we argued that the impact of the IoE on business models increases with higher levels of smartness. We developed a taxonomy classifying smart things based on their levels of capability and connectivity. We further proposed that smart things with an increasingly higher level of smartness will have an impact on an increasingly higher abstraction level within economies, whereby the highest levels of smartness will have implications at the macro level across industries, resulting in the emergence of new institutional arrangements. Less sophisticated smart things will also affect business models but most likely, only at the micro level of individual organizations. Drawing on our analysis, we now derive propositions about how smart things in the IoE may impact business models and the process of value creation on the micro, meso and macro levels. Taken together, the propositions can be seen as a research agenda and used as starting point for scholars to develop new knowledge about business models in the IoE that is relevant from both scientific and management perspectives.

5.1. Micro-level propositions

From a micro perspective, endowing things with smartness may radically alter not only the service provision to the customer, but also the work environment of the frontline service employee.

From a customer perspective, endowing things with smartness enables better, more customized and personalized products and services that provide improved convenience (Rust & Huang, 2014). They also enable the customer to delegate tasks, thus saving time and effort. For instance, when current connected cars, without the intervention of the customer, arrange for a needed software update, they save the customer the bother of interacting with the car maintenance firm (Porter & Heppelman, 2014). These advantages of smartness drive customer acceptance of smart objects, which is likely to improve with increasing levels of smartness. However, at very high levels of smartness, issues such as security, privacy and trust become more relevant (Papadopoulou, Kolomvatsos, Panagidi, & Hadjiefthymiades, 2017). According to our taxonomy, for example, things with a low level of smartness are only reactive while those with a high level of smartness are autonomous and able to collaborate in order to achieve their goals.

To provide the necessary algorithms with enough input, they need to exchange data about their environment and stakeholder interactions with other smart things in their network. It becomes apparent that in particular, the exchange of data between different smart things poses security risks such as eavesdropping, hacking, unauthorized access to data, and unauthorized access to devices (Porras, Pänkäläinen, Knutas, & Khakurel, 2018). At very high levels of smartness where customer data is potentially shared with the many connected objects and parties, customers may experience fear of data loss and privacy concerns. To develop successful IoE business models, it is therefore important to consider the trust that consumers have towards smart things but also towards the different parties who use the enormous amount of data collected by smart things (Abomhara & Koien, 2014; Andrea, Chrysostomou, & Hadjichristofi, 2016). Prior research recommends that businesses should communicate in a transparent way, what kind of data are collected and for which purposes this data is used by different parties (Roman, Najera, & Lopez, 2011). Furthermore, it has been suggested that users should be able to decide for themselves which data they want to share. However, for businesses this represents a challenge in developing flexible business models that still work if consumers allow smart things to collect only a selection of the requested data. Concerns about the security of data transmission and the usage of that data by firms may decrease customer acceptance of smart things (Rust, Kannan, & Peng, 2002), making an inverted U-shape relation between smartness level and customer acceptance likely.

Proposition micro level 1: *There is an inverted U-shape relation between the level of smartness and customer acceptance, with low acceptance for very low and very high levels of smartness.*

From a frontline employee perspective, smart things that complement the operations of human employees can be highly valuable tools because they enable the employees to do their jobs better or with less effort. Smart technology can free up time for other tasks, particularly those in which humans excel, such as building relationships with customers. This expectation is in line with previous literature showing that adoption of IT technology leads to improved customer service and adaptability to customer requirements (e.g. Ahearne, Jones, & Mathieu, 2008).

However, to what extent this advantage can be realized is critically dependent on how smart the technology is. With lower smartness levels, employees have to put a lot of time into preparing all the data and systems for the smart thing, hence becoming its assistant. Medical professionals for instance may have to spend significant time to collect patient data and make them accessible to the system. Once the things achieve a higher level of smartness, they can prepare their own input and leave the people to interpret, create, and handle their tasks fruitfully (Huang & Rust, 2018; Lingo & Bruns, 2018). With very high levels of smartness, frontline service employees may feel that they lose agency and decision-making power to the smart object taking over the functions and decisions they used to make, triggering fear of job loss (Huang & Rust, 2018). Once again, we propose an inverted U-shape relation between the level of smartness and acceptance by frontline service employees.

Proposition micro level 2: *There is an inverted U-shape relation between the level of smartness and acceptance by frontline service employees, with low acceptance for very low and very high levels of smartness.*

5.2. Meso-level propositions

It is also important to note that IoE business models are not static. Instead they are continually being enacted through the resource integration practices of the actors. Indeed business models "*define the resources that an individual market actor possesses and the ways that actor can interact with other actors—and their resources*" (Storbacka & Nenonen, 2011, p. 247). In the IoE, resource flows from connected and smart things often include data flows that dictate how connectivity creates value and how the business models that integrate data create complementarity or conflicts at the meso level.

While business models may create conflicts at the meso level, changes of the institutions, and therewith the system of rules governing interactions, are often instigated by humans. Human capabilities have the capacity to mitigate risks and moderate the effect of smartness to ensure value creation occurs, and they are also able to do the institutional work required to develop new arrangements (Lawrence & Suddaby, 2006). For example, connecting cameras, door bells and mobile phones at the micro level can result in a home security system but this may not be acceptable to insurance companies, whose business models rely on risk mitigation according to known industry standards at the meso level. However, through human use and re-use of connected objects, meso-level norms emerge that may then result in business models adapting at the micro level. Thus, an understanding of the IoE must include the role of humans, as they play a key role in the way the service ecosystems evolve (Ng & Wakenshaw, 2018; Vargo & Lusch, 2016). Humans therefore play a dual role; that of a moderator of connected business models at the meso level as well as an instigator of conflicts to business models at the micro level, driven by their need to appropriate connected resources to aid value creation. This duality of being perpetrator of conflicts as well as the moderator of risks is an important component of the IoE.

Proposition meso level: *Institutional work at the meso level moderates the positive relationship between the level of smartness and firms' ability to successfully develop and apply new business models.*

5.3. Macro-level propositions

As a third perspective in this discussion, we consider key research challenges at the macro level, as the IoE and smart things alter value ecosystems within industry sectors as well as between industry sectors. The taxonomy proposed in this paper demonstrates that as connected things acquire higher levels of smartness (see Fig. 1), multiple constituents within and between industry sectors become part of a single IoE network, making use of shared data and developing fluid and flexible business models. This leads to industry convergence (Sick, Preschitschek, Leker, & Bröring, 2019), new networked business models (Adner, 2017; Bankvall et al., 2017; Oskam et al., 2018), and new service ecosystems (Hacklin, Battistini, & von Krogh, 2013). Established industry boundaries become blurred and fragmented and industries no longer exist in separate spheres. New industry outsiders enter markets and define new paradigms, often in the form of IoE-enabled services instead of - or alongside - physical products. This implies not only that individual organizations must embrace the emergence of smart things and adapt their business models, their operations and their value ecosystems, but also that whole sectors or economies must do the same concurrently. So a key challenge appears to be guiding organizational decision-making about which networks to participate in, and how to find the right partners for value co-creation. Such a move into unknown territory brings significant difficulties in aligning institutional arrangements between hitherto unconnected sectors (Besharov & Smith, 2014).

Despite these imminent transitions, many firms struggle to recognize the dynamics of IoE-enabled industry convergence and its related challenges and opportunities (Kim, Hyeokseong, Kim, Lee, & Suh, 2015). The disruption resulting from industry convergence creates a complex, fluid and uncertain environment, where enduring strategic choices are hard to make (Hacklin et al., 2013). For example, car manufacturers produce smart cars, which creates intra-industry connectivity between automotive actors: petrol stations, maintenance companies, parking garages, car sharing firms and traffic information providers. However, the IoE will also enable inter-industry connectivity, connecting cars with city planners, restaurants, healthcare providers, home delivery services, and so on. This example demonstrates that car manufacturers have to develop fluid and flexible business models that determine how they can co-create value within an emerging open, interoperable global network. Such strategies have to be focused on developing services that add value through sharing skills, resources and knowledge with other actors (Barrett et al., 2015). Established and 'narrow' intra-industry institutional arrangements are threatened by this development.

Proposition macro level 1: *The IoE, and its related smart things, will result in industry convergence and blurring industry boundaries*.

The taxonomy shown in Fig. 1 indicates that the highest levels of smartness of things in the IoE are brought about by connected things exhibiting an ability to adapt to unknown or unexpected circumstances, to act autonomously and to collaborate with other constituents. In turn, this implies that networks of organizations too will need to develop and apply related strategic competences, to have flexible organizational structures, relationships and processes, and to adapt quickly as new data-driven insights emerge. Apart from new entrants, most firms are limited by path dependencies (Wirtz et al., 2010), making large-scale or rapid changes highly challenging. We can expect that the firms that are most able to follow a path of stakeholder management towards a networked business model will be best placed through mutual benefit-sharing agreements.

Proposition Macro 2: *Networked business models, as opposed to single-firm business models, will become more prevalent and more successful in the IoE*.

Finally, at the macro level, literature has debated ways in which digitalisation, including the IoE and highly smart things, will lead to what is known as a 'winner takes all' (WTA) situation (Cennamo & Santalo, 2013; Frank & Cook, 1995; Loebbecke & Picot, 2015), which may result in wholly new institutional arrangements emerging (Hodgson, 2015; North, 1991). The IoE reduces both marginal production costs in markets, thereby increasing economies of scale, and distribution costs for digital products and services. Both of these then result in a centralization of power with a small number of market players dominating (Loebbecke & Picot, 2015). Research has shown such centralization processes to be counter-beneficial to macro-level economic well-being (Rosen, 1981), leading to worsening employment conditions, increasing power asymmetries and more social inequality. However, Cennamo and Santalo (2013) suggest that platform competition is shaped by important strategic trade-offs and that the WTA end-game will not be universally successful. Indeed, in the specific area of IoT we may see a high level of industry specialization whereby, if the costs of multi-homing are low, a more fragmented competitive landscape could emerge. This is reflected in the early period of IoT platform development which lacks any clear trend towards consolidation. Our taxonomy (Fig. 1) indicates that there is great potential to be had from smart things in the IoE, but this necessarily implies that the potential will only be realized when macro-level institutions enable all relevant parties to share data. Highly powerful monopolists can coerce other players to some extent, but we may expect new institutional arrangements to develop technical, legal and managerial solutions for each party to maintain sovereignty over its own data, to control which other parties can access it, for what purposes and at what price.

Proposition Macro 3: *At higher levels of smartness, industry sectors will succumb to the 'Winner Takes All' pattern of power centralization unless new institution arrangements emerge to enable data sovereignty solutions*.

6. Outlook

This article explores how the IoE will impact on the business world, with a specific focus on the business model. Strategic theory following the service-dominant logic (Vargo & Lusch, 2017), posits that the products and things people buy are simply carriers of competences and functionality that form a service that users apply in the context of their use situation. We have discussed how this situation will change as the IoE leads to increasing levels of smartness in the things that we buy and use. Even though the dynamics of these changes are mainly driven by technical progress such as interconnectivity, big data, artificial intelligence, and semantic interoperability, organizations and institutions also have important roles to play in influencing the way the IoE will change societies.

To date, there is a lack of theory and methodologies to help organizations make the right strategic choices as we enter the era of the IoE. Using theory-based insights from two related disciplines, and from inductive insights from a vignette, we propose a taxonomy of conceptually different levels of smartness, and we explore the implications of the IoE for business models and value creation on the micro, meso and macro levels.

Based on the suggested taxonomy and the theorizing of propositions, researchers can be guided to conduct case studies in order to more deeply examine the nature of smartness and validate its different levels as developed in our taxonomy. Case studies could also shed light on the consequences of things getting smart for companies, consumers and other stakeholders. Scales and measures to, for instance, assess the level of smartness could be developed in quantitative studies. The IoE is expected to bring about unprecedented societal change, opening up new opportunities and posing new challenges. Research from different disciplines such as economics, computer science, psychology, law and ethics is needed to better understand and influence future developments in the IoE.

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References

Abomhara, M., & Koien, G. M. (2014). Security and privacy in the internet of things: Current status and open issues. *Proceedings of the international conference on privacy and security in mobile systems* (pp. 1–8). . https://doi.org/10.1109/prisms.2014.6970594.

Adner, R. (2017). Ecosystem as structure: An actionable construct for strategy. *Journal of Management, 43*(1), 39–58. https://doi.org/10.1177/0149206316678451.

Ahearne, M., Jones, E., & Mathieu, J. (2008). High touch through high tech: The impact of salesperson technology usage on sales performance via mediating mechanisms. *Management Science, 54*(4), 671–685. https://doi.org/10.1287/mnsc.1070.0783.

Andrea, I., Chrysostomou, C., & Hadjichristofi, G. (2016). Internet of things: Security vulnerabilities and challenges. *Proceedings of the IEEE symposium on computers and communications* (pp. 180–187). . https://doi.org/10.1109/iscc.2015.7405513.

Anjum, A., Sporny, M., & Sill, A. (2017). Blockchain standards for compliance and trust. *IEEE Cloud Computing, 4*(4), 84–90. https://doi.org/10.1109/mcc.2017.3791019.

Azodolmolky, S., Wieder, P., & Yahyapour, R. (2013). SDN-based cloud computing networking. *Proceedings of the International Conference on Transparent Optical Networks (ICTON)* (pp. 1–4). . https://doi.org/10.1109/icton.2013.6602678.

Baily, K. D. (1994). *Typologies and taxonomies. An introduction to classification techniques.* Thousand Oaks, CA: Sage.

Bankvall, L., Dubois, A., & Lind, F. (2017). Conceptualizing business models in industrial networks. *Industrial Marketing Management, 60*(1), 196–203. https://doi.org/10.1016/j.indmarman.2016.04.006.

Barrett, M., Davidson, E., Prabhu, J., & Vargo, S. L. (2015). Service innovation in the digital age: Key contributions and future directions. *MIS Quarterly, 39*(1), 135–154. https://doi.org/10.25300/misq/2015/39:1.03.

Bench-Capon, T. J. M. (1990). *Knowledge representation: An approach to artificial intelligence.* Academic Press.

Benner, M. J., & Tripsas, M. (2012). The influence of prior industry affiliation on framing in nascent industries: The evolution of digital cameras. *Strategic Management Journal, 33*(3), 277–302. https://doi.org/10.2139/ssrn.1721005.

Besharov, M. L., & Smith, W. K. (2014). Multiple institutional logics in organizations: Explaining their varied nature and implications. *Academy of Management Review, 39*(3), 364–381. https://doi.org/10.5465/amr.2011.0431.

Blum, B. I. (1994). A taxonomy of software development methods. *Communications of the ACM, 37*(11), 82–94. https://doi.org/10.1145/188280.188377.

Cennamo, C., & Santalo, J. (2013). Platform competition: Strategic trade-offs in platform markets. *Strategic Management Journal, 34*(11), 1331–1350. https://doi.org/10.1002/smj.2066.

Cohen, P. R., & Feigenbaum, E. A. (Eds.). (2014). The handbook of artificial intelligence (Vol. 3). Butterworth-Heinemann.

Doganova, L., & Eyquem-Renault, M. (2009). What do business models do? Innovation devices in technology entrepreneurship. *Research Policy, 38*(10), 1559–1570. https://

doi.org/10.1016/j.respol.2009.08.002.
Drnevich, P. L., & Croson, D. C. (2013). Information technology and business-level strategy: Toward an integrated theoretical perspective. *MIS Quarterly, 37*(2), 483–509. https://doi.org/10.25300/misq/2013/37.2.08.
Foss, N. J., & Saebi, T. (2017). Fifteen years of research on business model innovation: How far have we come, and where should we go? *Journal of Management, 43*(1), 200–227. https://doi.org/10.1177/0149206316675927.
Frank, R., & Cook, P. (1995). *The winner-takes-all society.* New York: Free Press.
Fredette, J., Marom, R., Steinert, K., & Witters, L. (2012). The promise and peril of hyperconnectivity for organizations and societies. The Global Information Technology Report. World Economic Forum. https://www3.weforum.org/docs/GITR/2012/GITR_Chapter1.10_2012.pdf (Accessed November 21 2019).
Furubotn, E. G., & Richter, R. (2005). *Institutions and economic theory: The contribution of the new institutional economics.* Ann Arbor, MI: The University of Michigan Press.
Gambardella, A., & McGahan, A. M. (2010). Business-model innovation: General purpose technologies and their implications for industry structure. *Long Range Planning, 43*(2–3), 262–271. https://doi.org/10.1016/j.lrp.2009.07.009.
Ghallab, M., Nau, D., & Traverso, P. (2004). *Automated planning: Theory and practice.* Amsterdam: Morgan Kaufmann.
Glass, R. L., & Vessey, I. (1995). Contemporary application-domain taxonomies. *IEEE Software, 124*, 63–76. https://doi.org/10.1109/52.391837.
Greenwood, R., Raynard, M., Kodeih, F., Micelotta, E. R., & Lounsbury, M. (2011). Institutional complexity and organizational responses. *Academy of Management Annals, 5*(1), 317–371. https://doi.org/10.1080/19416520.2011.590299.
Hacklin, F., Battistini, B., & von Krogh, G. (2013). Strategic choices in converging industries. *Sloan Management Review, 55*(1), 65–73.
Hippert, H. S., Pedreira, C. E., & Souza, R. C. (2001). Neural networks for short-term load forecasting: A review and evaluation. *IEEE Transactions on Power Systems, 16*, 44–55. https://doi.org/10.1109/59.910780.
Hodgson, G. M. (2015). On defining institutions: Rules versus equilibria. *Journal of Institutional Economics, 11*(3), 497–505. https://doi.org/10.1017/S1744137415000028.
Huang, M. H., & Rust, R. T. (2018). Artificial intelligence in service. *Journal of Service Research, 21*(2), 155–172. https://doi.org/10.1177/1094670517752459.
Kaldeli, E., Lazovik, A., & Aiello, M. (2016). Domain-Independent planning for services in uncertain and dynamic environments. *Artificial Intelligence, 236*(7), 30–64. https://doi.org/10.1016/j.artint.2016.03.002.
Keen, P., & Williams, R. (2013). Value architectures for digital business: Beyond the business model. *MIS Quarterly, 37*(2), 643–647.
Kim, N., Hyeokseong, L., Kim, W., Lee, H., & Suh, J. H. (2015). Dynamic patterns of industry convergence: Evidence from a large amount of unstructured data. *Research Policy, 44*(9), 1734–1748. https://doi.org/10.2139/ssrn.2519054.
Kleinaltenkamp, M. (2018). *Institutions and institutional arrangements. The SAGE handbook of service-dominant logic.* Sage.
Lawrence, T., & Suddaby, R. (2006). Institutions and institutional work. In S. R. Clegg, C. Hardy, T. B. Lawrence, & W. R. Nord (Eds.). *Sage handbook of organization studies* (pp. 215–254). London: Sage.
Leonetti, M., Iocchi, L., & Stone, P. (2016). A synthesis of automated planning and reinforcement learning for efficient, robust decision-making. *Artificial Intelligence, 241*, 103–130. https://doi.org/10.1016/j.artint.2016.07.004.
Lingo, E., & Bruns, H. (2018). Big data and creative work: optimization within the collective creative process. Academy of Management Global Proceedings. https://journals.aom.org/doi/10.5465/amgblproc.surrey.2018.0096.abs (Accessed November 21 2019).
Loebbecke, C., & Picot, A. (2015). Reflections on societal and business model transformation arising from digitization and big data analytics: A research agenda. *Journal of Strategic Information Systems, 24*(3), 149–157. https://doi.org/10.1016/j.jsis.2015.08.002.
Maglio, P. P., & Spohrer, J. (2008). Fundamentals of service science. *Journal of the Academy of Marketing Science, 36*(1), 18–20. https://doi.org/10.1007/s11747-007-0058-9.
Majchrzak, A., Markus, M. L., & Wareham, J. (2016). Designing for digital transformation: Lessons for information systems research from the study of ICT and societal challenges. *MIS Quarterly, 40*(2), 267–277. https://doi.org/10.25300/misq/2016/40:2.03.
Marinova, D., de Ruyter, K., Huang, M. H., Meuter, M. L., & Challagalla, G. (2017). Getting smart: Learning from technology-empowered frontline interactions. *Journal of Service Research, 20*(1), 29–42. https://doi.org/10.1177/1094670516679273.
Massa, L., Tucci, C. L., & Afuah, A. (2017). A critical assessment of business model research. *Academy of Management Annals, 11*(1), 73–104. https://doi.org/10.5465/annals.2014.0072.
Mintzberg, H. (1985). *Structure in fives: Designing effective organizations.* Sage.
Miorandi, D., Sicari, S., De Pellegrini, F., & Chlamtac, I. (2012). Internet of things: Vision, applications and research challenges. *Ad Hoc Networks, 10*(7), 1497–1516. https://doi.org/10.1016/j.adhoc.2012.02.016.
Ng, I. C. L. (2014). *Creating new markets in the digital economy: Value and worth.* Cambridge University Press.
Ng, I. C. L., Scharf, K., Pogrebna, G., & Maull, R. (2015). Contextual variety, Internet-of-Things and the choice of tailoring over platform: Mass customisation strategy in supply chain management. *International Journal of Production Economics, 159*, 76–87. https://doi.org/10.1016/j.ijpe.2014.09.007.
Ng, I. C. L., & Wakenshaw, S. Y. L. (2017). The Internet-of-Things: Review and Research Directions. *International Journal of Research in Marketing, 34*(1), 3–21. https://doi.org/10.1016/j.ijresmar.2016.11.003.
Ng, I. C. L, & Wakenshaw, S. Y. L. (2018). Service ecosystems: A timely worldview for a connected, digital and data-driven economy. The SAGE Handbook of Service-Dominant Logic, Sage. https://doi.org/10.4135/9781526470355.n12.
Ng, I. C. L., & Vargo, S. L. (2018). Service-Dominant (S-D) Logic, service ecosystems and institutions: Bridging theory and practice. *Journal of Service Management, 29*(4), 518–520. https://doi.org/10.1108/josm-07-2018-412.
Nickerson, R. C. (2013). A method for taxonomy development and its application in information systems. *European Journal of Information Systems, 22*(3), 336–359. https://doi.org/10.1057/ejis.2012.26.
Nickerson, R. C., Varshney, U., Munterman, J., & Isaac, H. (2007). Towards a taxonomy of mobile applications. *Proceedings of the American Conference on Information Systems* (pp. 338–343). .
North, D. C. (1990). *Institutions, institutional change, and economic development.* Cambridge: Cambridge University Press.
North, D. C. (1991). Institutions. *Journal of Economic Perspectives, 5*(1), 97–112. https://doi.org/10.1257/jep.5.1.97.
Okhuysen, G., & Bonardi, J. P. (2011). Editor's comments: The challenges of building theory by combining lenses. *Academy of Management, 36*(1), 6–11. https://doi.org/10.5465/amr.2011.55662498.
Oskam, I., Bossink, B., & de Man, A. P. (2018). The interaction between network ties and business modeling: Case studies of sustainability-oriented innovations. *Journal of Cleaner Production, 177*, 555–566. https://doi.org/10.1016/j.jclepro.2017.12.202.
Papadopoulou, P., Kolomvatsos, K., Panagidi, K., & Hadjiefthymiades, S. (2017). Investigating the business potential of internet of things. *Proceedings of the Mediterranean Conference on Information Systems* (pp. 1–14). .
Pinyol, I., & Sabater-Mir, J. (2013). Computational trust and reputation models for open multi-agent systems: A review. *Artificial Intelligence Review, 40*(1), 1–25. https://doi.org/10.1007/s10462-011-9277-z.
Poggi, A., Lembo, D., Calvanese, D., De Giacomo, G., Lenzerini, M., & Rosati, R. (2008). Linking data to ontologies. *Journal on Data Semantics, X*, 133–173. https://doi.org/10.1007/978-3-540-77688-8_5.
Porras, J., Pänkäläinen, J., Knutas, A., & Khakurel, J. (2018). Security In the internet of things-A systematic mapping study. *Proceedings of Hawaii International Conference on System Sciences,* 3750–3759. https://doi.org/10.24251/hicss.2018.473.
Porter, M., & Heppelman, J. E. (2014). How smart connected products are transforming competition. *Harvard Business Review, 94*(1–2), 1–23.
Rijsdijk, S. A., & Hultink, E. J. (2009). How today's customers perceive tomorrow's smart products. *Journal of Product Innovation Management, 26*(1), 24–42. https://doi.org/10.1111/j.1540-5885.2009.00332.x.
Roman, R., Najera, P., & Lopez, J. (2011). Securing the internet of things. *Computer, 44*(9), 51–58.
Rosen, S. (1981). The economics of superstars. *The American Economic Review, 71*(5), 845–858.
Russell, S., & Norvig, P. (2009). *Artificial intelligence: A modern approach.* Prentice Hall Press.
Rust, R. T., Kannan, P. K., & Peng, N. (2002). The customer economics of internet privacy. *Journal of the Academy of Marketing Science, 30*(4), 455–464. https://doi.org/10.1177/009207002236917.
Rust, R. T., & Huang, M. H. (2014). The service revolution and the transformation of marketing science. *Marketing Science, 33*(2), 206–221. https://doi.org/10.1287/mksc.2013.0836.
Shi, W., Cao, J., Zhang, Q., Li, Y., & Xu, L. (2016). Edge computing: Vision and challenges. *IEEE Internet of Things Journal, 3*(5), 637–646. https://doi.org/10.1109/JIOT.2016.2579198.
Sick, N., Preschitschek, N., Leker, J., & Bröring, S. (2019). A new framework to assess industry convergence in high technology environments. *Technovation, 84–85*, 48–58. https://doi.org/10.1016/j.technovation.2018.08.001.
Storbacka, K., & Nenonen, S. (2011). Markets as configurations. *European Journal of Marketing, 45*(1/2), 241–258. https://doi.org/10.1108/03090561111095685.
Teece, D. J. (2012). Dynamic capabilities: Routines versus entrepreneurial action. *Journal of Management Studies, 49*(8), 1395–1401. https://doi.org/10.1111/j.1467-6486.2012.01080.x.
Teece, D. J., Pisano, G., & Shuen, A. (1997). Dynamic capabilities and strategic management. *Strategic Management Journal, 18*(7), 509–533. https://doi.org/10.1002/(SICI)1097-0266(199708)18:7 < 509::AID-SMJ882 > 3.0.CO;2-Z.
Tesauro, G., Gondek, D. C., Lenchner, J., Fan, J., & Prager, J. M. (2013). Analysis of Watson's Strategies for Playing Jeopardy!. *Journal of Artificial Intelligence Research, 21*, 205–251. https://doi.org/10.1613/jair.3834.
Turber, S., Vom Brocke, J., Gassmann, O., & Fleisch, E. (2014). Designing business models in the era of internet of things. *International Conference on Design Science Research in Information Systems, 17–31*. https://doi.org/10.1007/978-3-319-06701-8_2.
Vargo, S. L., & Akaka, M. A. (2012). Value cocreation and service systems (re) formation: A service ecosystems view. *Service Science, 4*(3), 207–217. https://doi.org/10.1287/serv.1120.0019.
Vargo, S. L., & Lusch, R. F. (2004). Evolving to a new dominant logic for marketing. *Journal of Marketing, 68*(1), 1–17. https://doi.org/10.1509/jmkg.68.1.1.24036.
Vargo, S. L., & Lusch, R. F. (2016). Institutions and axioms: An extension and update of service dominant logic. *Journal of the Academy of Marketing Science, 44*(1), 5–23. https://doi.org/10.1007/s11747-015-0456-3.
Vargo, S. L., & Lusch, R. F. (2017). Service-dominant logic 2025. *International Journal of Research in Marketing, 34*(1), 46–67. https://doi.org/10.1016/j.ijresmar.2016.11.001.
Westerlund, M., Leminen, S., & Rajahonka, M. (2014). Designing business models for the internet of things. *Technology Innovation Management Review, 4*, 5–14. https://doi.org/10.22215/timreview/807.
Wirtz, B. W., Schilke, O., & Ullrich, S. (2010). Strategic development of business models: Implications of the Web 2.0 for creating value on the internet. *Long Range Planning, 43*(2–3), 272–290. https://doi.org/10.1016/j.lrp.2010.01.005.

Xu, L. D., He, W., & Li, S. (2014). Internet of things in industries: A survey. *IEEE Transactions on Industrial Informatics, 10*(4), 2233–2243. https://doi.org/10.1109/TII.2014.2300753.

Yang, L. T., Di Martino, B., & Zhang, Q. (2017). Internet of everything (editorial). *Mobile Information Systems, 2017*, 1–3.

Zott, C., & Amit, R. (2010). Business model design: An activity system perspective. *Long Range Planning, 43*(2–3), 216–226. https://doi.org/10.1016/j.lrp.2009.07.004.

Zott, C., Amit, R., & Massa, L. (2011). The business model: Recent developments and future research. *Journal of Management, 37*(4), 1019–1042. https://doi.org/10.2139/ssrn.1674384.