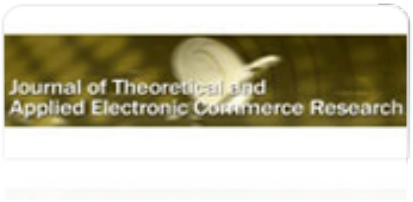

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Data-Driven Innovation through Open Government Data

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Abstract

The exponentially growing production of data and the social trend towards openness and sharing are powerful forces that are changing the global economy and society. Governments around the world have become active participants in this evolution, opening up their data for access and re-use by public and private agents alike. The phenomenon of Open Government Data has spread around the world in the last four years, driven by the widely held belief that use of Open Government Data has the ability to generate both economic and social value. However, a cursory review of the popular press, as well as an investigation of academic research and empirical data, reveals the need to further understand the relationship between Open Government Data and value. In this paper, we focus on *how* use of Open Government Data can bring about new innovative solutions that can generate social and economic value. We apply a critical realist approach to a case study analysis to uncover the mechanisms that can explain how data is transformed to value. We explore the case of Opower, a pioneer in using and transforming data to induce a behavioral change that has resulted in a considerable reduction in energy use over the last six years.

Keywords: Open data, Open government data, Big data, Innovation, Value, Generative mechanisms, Critical realism, Opower

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1 Introduction

Data have become part and parcel of modern times. We only have to imagine a world without Google searches, online weather forecasts or GPS technologies to realize the current impact of data on our lives. The use of technology and the subsequent generation and utilization of digital data have become ubiquitous, virtually taken for granted. The impact of these technologies is evolving continuously with the creation of new content, connectivity, analysis software and infrastructure. We have recently observed a radical trend towards networked behavior such as crowdsourcing and co-creation, driven by (among others) the emergence of the open-source software community, the general use of social networks and increased availability of Open Government Data (OGD). One of the most disruptive aspects of these changes is the transformation from a largely dichotomous world of the market and the state, to an open, interconnected world where the traditional roles of, and relationships between, sectors are changing. These complex interdependencies are forcing us to re-think how economic and social value is generated and appropriated [3], [32].

The number of OGD initiatives has grown from two to over three hundred in the period 2009-2013, and membership in the Open Government Partnership has gone from eight to fifty-nine countries in two years. Over 280 government data catalogs have been published and over a million datasets have been released by governments around the world, spawning new businesses and social projects. OGD is commonly seen as a driver of efficiency and a vehicle for increasing transparency, citizen participation and innovation in society. The hope is that OGD will eventually lead to the generation of substantial value. For instance, the European Commission launched an Open Data Strategy for Europe in December 2011, which is expected to deliver around $53 billion boost to the EU's economy each year [20]. The strategy resulted in EU Open Data rules being formally adopted in June 2013, including directions regarding charging rules, licensing, search on data portals and interoperability. In May 2013, U.S. president Barack Obama signed an executive order, making open and machine readable the new default for government information in the USA. It is expected that open data will bring benefits to a wide range of domains, including health, energy, education, public safety, finance and global development [75].

However, despite the potential significance of OGD, many feel that it is supported mainly by anecdotal evidence and that OGD is still far from living up to its true potential. A common assumption when opening government data is that simply supplying more data freely and in more formats will lead to more use and value creation [30]. But opening up government data is meaningful only so far as citizens and public and private organizations have not only the opportunity, but also the motivation and ability to use the data to achieve social and economic value. Lack of appropriate governance mechanisms and a lack of insight into user's perspective can explain the gap between the promises of open data and what has actually been realized [36]. Moreover, there is uncertainty as to how the value of the data will be regarded and how it should be evaluated [30]. The economic and social impacts of open-data policies remain largely unclear, and there are relatively limited empirical data available on the effects of the various policy approaches leaving policy makers without the facts they need to assess and improve these policies [34], [80].

This paper addresses the question *How can use of open government data stimulate the generation of value?* Ultimately, the study aims to explore and illustrate *how* value is generated from the use of OGD, as well as to identify the main factors that enable value generation. For that purpose, we utilize the critical realist concept of mechanism as a causal structure that contingently generates observable outcomes. The generative mechanisms portray the instrumental pathways that stem from use of OGD in the context of social, technical and organizational factors, which result in the generation of value. Furthermore, we want to explain in more depth how value generation happens in the case of a private company using OGD. For this purpose, we use a case study method, grounded in the critical realism ontology and epistemology, as suggested in [12], [76]. Based on our findings, we propose a conceptual model for data driven innovation, building on the absorptive capacity model presented in [63] and the innovation value chain model [27]. Our main contribution is the conceptualization of data driven innovation and the nomological network that furthermore shows the causal links between the external and internal enabling factors in the context of organizational innovation from data, the innovation mechanism itself and the resulting value.

2 Critical Realism and Open Government Data

It is a widely held belief that use of OGD can result in the generation of considerable social and economic value. *How* this can happen, however, is not well understood. In this section we explore the unique features of OGD, discuss how these unique features can underpin some specific value propositions, and identify the mechanisms that can explain the transformation from use of data to generation of value. We build on the Critical Realism philosophy and the concept of micro-macro mechanisms, proposing that events observed in the real world can be used to uncover the underlying mechanisms that arise from an interplay of micro-level structures, decisions and actions, and in this way contribute to explaining how value can be generated.

2.1 The Unique Features of Open Government Data

The amount of data accumulating in our increasingly digital world is breathtaking. In the past two years alone the

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amount of information available in the digital universe has increased to its current rate of 2.8 ZB, a number that is expected to double every year. This increase is mainly due to the continuous digitization of nearly all media, the ubiquity of Internet access and the proliferation of mobile phones, as well as data generation from surveillance cameras and smart meters. For example, around 30 billion pieces of content are shared on Facebook every month and 235 terabytes of data were collected by the US Library of Congress in 2011 [49]. More than 30 million interconnected sensors are now deployed worldwide in areas such as security, health care, transport systems or energy control systems, and their numbers are growing by around 30% a year [49]. Smart meters collect and transmit real-time data on energy [57], and smart automobiles are now able to transmit real-time data on the state of the car's components and environment [58]. Digitization affects two important features of data: 1) By making data easily accessible to more than one person at a time, it is resulting in *non-rivalry,* and 2) Drastically reducing marginal costs incurred by reproduction and distribution, it is making *re-use* economically feasible [54], [61], [70] Furthermore, not only have we now generated all these digital data, but in many cases they are also open for use by anyone interested, allowing for even more value generation through re-use of different stakeholders.

Open data can be defined as data that are freely accessible online, available without technical restrictions to re-use, and provided under open access license that allows the data to be re-used without limitation, including across different 'fields of endeavor' (e.g., commercial and non-commercial alike) [59]. Openness changes one important feature of digital data by making them *non-excludable*. Accordingly, when opened up, digital data become a shared resource; a public good or what has been termed 'digital commons' [32]. The concept of OGD refers specifically to government data defined as "data and information produced or commissioned by government or government controlled entities" [59] that are opened up for use and re-use by public and private agents alike. In the currently used terminology, OGD does not include data that are subject to valid privacy, security or privilege limitations, as governed by other statutes.

Government data sets make up an interesting subset of open data. Public bodies are among the largest creators and collectors of data in many different domains [35]. These domains range from traffic, weather, and geographical data to statistics and data on businesses and public sector budgeting [36]. The fixed costs incurred by collecting OGD can be high, making it unfeasible for private organizations to collect such data. However, in the case of government, these data have already been collected for specific use in governmental processes. Moreover, as an integral part of public operations, they have also been paid for by taxpayers. Therefore, OGD constitute a shared resource that offers value beyond what is captured from the original intended use.

2.2 Critical Realism as a Foundation for the Study of Open Government Data

Critical realism is becoming recognized as a viable philosophical paradigm for conducting social science research. In the Information Systems discipline, we are typically confronted with a sociotechnical environment consisting of several interacting structures, each of which has the potential to impact the existing situation to generate events. This typically includes a social structure consisting of individuals, groups, and organizations, along with a set of rules and practices, technological artifacts and discursive entities such as language and culture [76]. Critical realism based research methodologies are used to identify the mechanisms that can explain such complex interactions [24]. They allow researchers to develop and support in-depth causal explanations for the outcomes of specific sociotechnical phenomena [76]. In the context of this paper, we are interested in finding the main constructs and mechanisms that are involved when actors utilize OGD to generate value. This includes structures such as legal frameworks, different data dissemination practices, use of technology artifacts, individual capabilities and various other mechanisms that can extract value from OGD.

Critical realism interrelates ontology and epistemology, that is, it conjoins assumptions about the nature of reality, and evidentiary assessment and justification of knowledge claims. On the one hand, it posits realist ontology, that is, the existence of a world independent of researchers' knowledge of it. On the other hand, critical realism embraces a fallibilist epistemology in which human beings are unable to fully understand or observe this reality, and our knowledge of it is fallible [76]. Critical realism distinguishes between the domains of the real, actual and empirical. The *real domain* consists of generative mechanisms, which refer to the functional mechanics of a particular phenomenon [9]-[10]. Through enabling or hindering change, such mechanisms give rise to events in an *actual domain*, some that are experienced, and some are not. Finally, the *empirical domain* is made up of events that are directly or indirectly observed [52]. Even though critical realists argue that there is a *real* world out there, they accept the possibility that one observing this world does not have full access to it or have the ability to observe equally all its aspects [78]. The *potentiality* of the real still exists even if it remains unexercised or unobserved. Being *real* does not necessarily imply *observable*.

Critical realism has a strong focus on causality. Causality refers to "…the relationship between an action or thing (cause) and the outcome (effect) it generates" [76]. p. 789. Often, our ability to explain a given phenomenon requires the identification of the factors and relationships which cause it to occur. Critical realists emphasize that causality is contingent - in the sense that the observed outcome of a mechanism is contextual. Consistent regularities can arise under special circumstances in closed systems. However, open systems such as the social systems are far too complex. For example, causal mechanism M1 may be in operation, tending to bring about outcome O1. But outcome O1 is also likely to be influenced by causal mechanisms M2, M3...Mn, operating somewhere else in the social system [21]. These other confounding mechanisms may prevent or alter the realization of a particular causal effect [76]. Accordingly, we need to uncover the underlying mechanisms that offer *the ability* to generate value – and show un-

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der what circumstances value is generated, i.e., what factors enable value to materialize. This involves finding the drivers and barriers, as well as other related mechanisms, in order to explain how the value generating mechanism produced the observed impacts, and preferably why – or why not.

2.3 Enablers of Value Generation from Data

Critical realism helps uncover the mechanisms that can explain how the use of OGD generates value, given the multitude of factors that influence this potential value generation. In this way it will help us understand how an OGD initiative could result in an impressive generation of value in one country, while a similar initiative might have shown negligible impact in another. In this regard, the observed outcome should be explained in consideration with the interaction of appropriate pre-conditions as well as the transfactual operation of the mechanisms [31]. In other words, we build on the underlying premise of critical realism, that causal effects work as intended whether their operation is observable or whether it cannot be detected by those who attempt to examine it. Moreover, in line with the principle of equifinality, in most cases there are multiple possible sets of mechanisms which may have produced the outcomes being studied in a given research program [76]. Due to the complexity of the causal relationship between the utilization of OGD and value, we suggest that for the benefit of supporting policy generation, investigations of the causal paths should seek to analyze how different key mechanisms are enacted and which factors can lead to a successful outcome.

Several authors have pointed out various factors that hinder the generation of value from data. The most commonly identified barriers are: a) closed or inaccessible datasets, b) lack of comprehensive data policies, c) lack of validity, completeness and exhaustiveness of datasets, d) insufficient metadata, e) lack of consistency in cross-border access regimes, f) lack of motivation within public sector, g) lack of technical and semantic interoperability, h) lack of technical ability within public and private sectors, i) the digital divide and j) too fragmented and disparate open data community [7], [18]-[19], [26], [35]-[36], [47], [79]. It is also suggested that the following four multi-dimensional macro-level factors can help nations overcome the previously mentioned barriers to value generation [37]:

1) Capabilities, conceptualized as the collective ability of individuals and organizations to use and re-use OGD, as a function of equitable access opportunities and technology and data literacy.

2) Openness, conceptualized as a function of the general availability of government data, the accessibility of available data sources and the use of open licenses.

3) Resource governance, conceptualized as a function of leadership, data governance procedures and data dissemination skills within the public sector that is intended to increase the quality and sustainability of data resources.

4) Technical connectivity, conceptualized as a function of the technical infrastructure and the diffusion of technologies that allows users to store, access and analyze the data.

2.4 Generative Mechanisms

The concept of mechanism is a key construct and a commonly used sensemaking apparatus in many disciplines of science. Mechanisms are frequently occurring and easily recognizable causal patterns. In the context of critical realism, mechanisms are used to describe and explain causal relationship through the specifying of how central events or outcomes are produced and reproduced by the structures, actions and contextual conditions in a particular setting [74]. Following [9], [31], we define generative mechanisms as causal structures that are capable of generating observable events, Generative mechanisms can be classified on three levels: contextual or situational mechanisms (macro–micro), action-formation mechanisms (micro-micro) and transformational mechanisms (micro–macro) [29], [31]. Macro–micro mechanisms refer to how macro level constructs enable or constrain the various micro level components that subsequently may affect the generation of value. Micro-micro mechanisms relate to how specific arrangements of individual desires, beliefs, and actions may generate a specific action [29]. Micro–macro mechanisms concern how different micro level components interact in order to produce an outcome at a macro level, i.e., how the combination of different components can enable (or hinder) the generation of value from OGD. Figure 1 portrays the OGD ecosystem as recursive relationship between the contextual (macro–micro) and transformational (micro–macro) mechanisms.

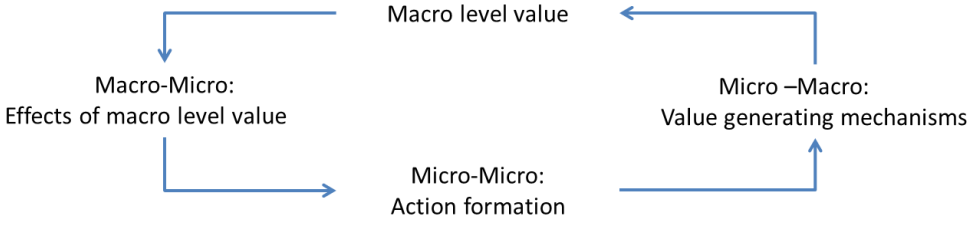

Figure 1: OGD ecosystem, extended from [31]

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We model the OGD ecosystem as a recursive loop that keeps repeating indefinitely. Subsequently, in the case of OGD, the contextual or macro–micro mechanisms explain how certain outcomes that reflect the generation of macro-level value, such as the yearly Gross Domestic Product (GDP) or the general level of education within a country, enable or constrain individuals by providing motivation, as well as affecting the opportunity and ability to generate value through use of OGD.

Next, the micro-level action-formation mechanisms [29] reflect the decisions and actions which drive individuals in the process of publishing OGD and explain subsequent decisions of actors to use the data. These mechanisms make sense of individual behavior in terms of interaction between individuals and a social aggregate [29]. While the potential generation of value seems to be the most significant motivator for opening access to government data [36], there are many other micro-level factors that can enable or hinder the actual implementation of an OGD initiative [30] and the subsequent re-use of these data. Numerous barriers for the adoption of OGD policy have been identified in [36], [79], categorized into the following areas: institutional, task complexity, use and participation, legislation, information quality and technical. For instance, one of the identified barriers stems from a risk-averse culture often found in organizations with more red tape, weak links with performance, and high involvement with elected officials [36], [79] showing the importance of strong leadership to generate value. Another set of identified barriers was focused on technical issues ranging from low information quality and unavailability of a supporting infrastructure and up to the lack of standards, fragmentation and legacy systems [36].

Finally, transformational or micro–macro mechanisms explain how the different micro level components interact in order to produce an outcome at a macro level. These mechanisms explain how the actions of a number of individuals, whose interactions with one another are enabled or constrained by their social and technical environments, are transformed into some sort of a collective outcome. This type of mechanism can be used to explain how the combination of different factors enables the actions of various individuals within or outside of the public sector, allowing them to participate in the generation of value from OGD. In the following analysis, we focus on identifying different types of such *transformational mechanisms*.

3 Value Generating Mechanisms

In this section we create a taxonomy consisting of four different mechanisms, classifying how value can be generated from OGD. We use two dimensions to categorize these mechanisms. The first dimension reflects the extent and type of value generation from use of OGD, from low to high levels of external participation. The second dimension reflects the extent and type of OGD value appropriation options, ranging from value being appropriated by dedicated participants only to value being appropriated by society in general.

3.1 Dimensions of Value

Openness is perceived as the antidote that can counteract the tendency of technology enactment to reproduce existing rules, routines, norms and power relations, despite the new and innovative capabilities introduced by these technologies. However, this perceived premise can only be fulfilled if openness changes the nature of relationships between stakeholders and governments, and enables them to link across organizational boundaries and functions [28]. Moreover, the conceptual distinction between value generation and value appropriation has been sharpened in light of the discourse on openness, technical connectivity and collaborative ventures. Value generation materializes when the utility of society´s members increases after accounting for the resources used in that activity. Value appropriation materializes when an actor is able to capture a portion of the value created by an activity [11]. The relationship between the generation and appropriation of value of multiple stakeholders in the context of alliances is increasingly viewed as being multifaceted in nature [66]. Value can be seen as a “subjective, multidimensional construct; accordingly, it is only through a multidimensional view that we get a high-fidelity picture of the value generated within alliance relationships” [23]. p. 595. However, despite the recent focus on the creation of value in collaborative settings, little is known about the underlying mechanisms [66].

Two types of value are frequently discussed in the extant literature on OGD: 1) economic value, defined as the worth of a good or service as determined by the market, most often measured relative to units of currency; and 2) social value, defined as the generated improvements in the lives of individuals or society as a whole. A recent attempt to amalgamate the concepts of economic and social value introduced the term shared value, which is meant to reconceive the intersection between society and corporate performance and involves creating economic value in a way that also creates value for society by addressing its needs and challenges [62]. Public value is another related concept in the OGD and e-government literature. The public value framework is based on the premise that public resources should be used to increase value, not only in an economic sense but also more broadly in terms of what is valued by citizens and communities [6], [53]. Based on these insights, we have developed a two-dimensional framework that is based on the *extent to which external stakeholders participate in the generation of value from OGD* as one dimension, and *the extent to which OGD initiatives are focused on generating social value* as the other dimension.

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3.2 Opening the Black Box

A distinction between black box explanations and mechanism-based explanations is made in [29]. The way in which two sets of events or variables are linked to one another is expressed with the mechanism, M: I → M → O. What characterizes black box explanations is that the link between input (I) and output (O) is assumed to be devoid of structure, or whatever structure there may be is considered to be of no interest, and thus the researcher tests only the reduced model that contains a direct link between I and O [29]. We, however, want to make a distinction between the value that is generated (outcomes observed) and the transformative mechanisms that can explain *how* this value generation materializes. We argue that identifying these mechanisms is likely to reveal instrumental pathways by which a set of actions is related to the creation of a value [28].

Furthermore, non-commonsensical explanations require mechanisms of some generality [29]. In order to identify the main archetypes of possible transformational mechanisms that explain how OGD may be used to generate value, we conducted a wide literature search that was focused on the various operational definitions of open government data. We found that two distinct ideologies drive most open government data initiatives: the *Reuse of Data* perspective and the *Open Government* perspective. We thus reviewed the respective tensions and contributions of these two unique streams. The literature on reuse of data is mostly focused on the economic value of government data, often in connection to the European PSI-directive [35]. The literature on Open Government is mostly making reference to the Obama´s 2009 Open Government Directive, and, in a more generalizable term, is directed towards examining how government policy can utilize OGD to generate additional social (or public) value in collaborative settings [8], [44].

Building on Harrison et al. [28], we ultimately adopt four general mechanisms to highlight how OGD can be used to generate value. Two mechanisms highlight the Open Government focus: *transparency of government* and *citizen participation/collaboration* [7], [28], [44] and another two highlight the reuse focus: *efficiency/effectiveness* and *innovation* [22]. [26], [34]. In Figure 2, we present a framework that can be used to develop and describe different value generation strategies, each of which has the goal of stimulating one of the general mechanisms in order to generate value. The strategies are framed from the data provider perspective, which in the case of OGD is the public sector. The framework has two dimensions. One dimension, indicating the extent to which external stakeholders (i.e., actors in the private sector) generate value from the data, therefore spans the boundaries between the public and private sectors. In the right hand column of the matrix, the private sector is actively engaged in using OGD to generate firsthand value, while in the left hand column the public sector is the more active stakeholder in value generation (while the value might be appropriated by both sectors). The other dimension, indicating the extent to which OGD initiative is focused on generating social value, ranges from strategies that are focused mainly on generating economic value (with a relatively marginal social value component) to strategies that are focused mainly on generating social value (with a relatively marginal economic value component).

Each of the four general mechanisms has the capacity to generate a mix of social and economic value, although in different proportions. The economic value that is more apparent in the lower half of the matrix is generally measured in monetary terms. Social value generation is, on the other hand, not necessarily measureable in monetary terms; hence, it may reflect intangible value. While this framework can provide a continuous spectrum of different value generating strategies, we use it to highlight four discrete paths that can provide a foundation for four archetypical value generation strategies, thereby reducing complexity and highlighting four modalities of using OGD to generate value.

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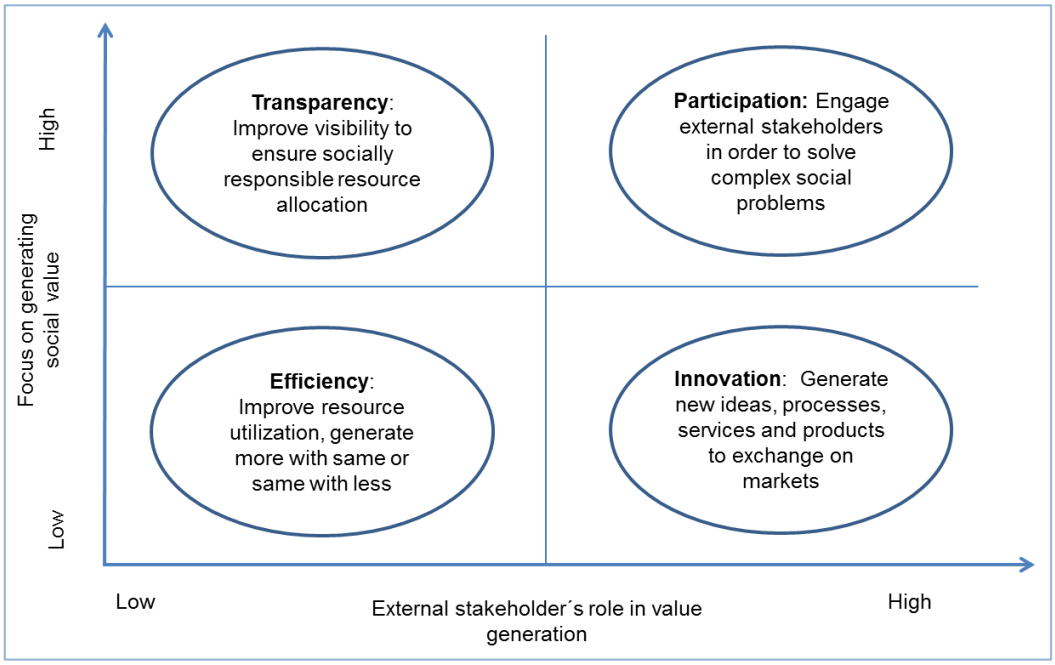

Figure 2: The open government data value generation framework

Next, we briefly review each of the general mechanisms in order to show how the use of OGD can generate value

3.2.1 Transparency Mechanisms

Transparency mechanisms are designed to reveal relevant information that is being generated, managed and stored by a particular entity, including information about its own decision processes, procedures and performance. However, opening access to selected public documents does not necessarily contribute to a transparent government [25], [73]. In fact, a government can pay lip service to open data by providing access to politically neutral topics, even though its operation in general remains deeply opaque and unaccountable [73]. Agents, whose access to information is increased, must also have the ability to process the information, and the opportunity and incentive to act on that information [39]. Accordingly, we cannot conclude that open access to government data is in itself a comprehensive measure of transparency. Rather, transparency mechanisms can enable value generation if they reduce information asymmetry. Information asymmetry refers to situations in which one has more or better information than another while they are participating in transactions, negotiations or communications. Information asymmetry can cause all sorts of socially undesirable results and behaviors. One particular prevalent outcome of information asymmetry is corruption. Corruption (defined in the context of government as misuse of public power for private benefits) has long been seen as a hindrance to socio-economic development. Corruption has been shown to have negative effects on GDP growth, human development and health outcomes. It can destroy social capital and has been shown to negatively impact people's life satisfaction [33], [65]. Improved transparency can reduce information asymmetry and result in more equitable resource allocation, leading to the creation of social and economic value.

3.2.2 Participation Mechanisms

Participation mechanisms are designed to enable and encourage public participation in government through voluntary contributions of ideas and other resources. These mechanisms provide citizens with an opportunity to influence public policy, and subsequently enhance the ties between government officials and their constituency [44]. Public participation often provides opinions through citizens' engagement as well as ideas and solutions through crowdsourcing [44]. It has been argued that more involved democratic participation is likely to lead to superior social outcomes because of participation's role in aggregating information and preferences [5]. The relationship between participation and OGD is essentially twofold: First, in order for citizens to participate, either by voicing their opinions towards policy making or by participating directly in public projects, they must have access to information about the particular issue that is being addressed. Second, their contributions lead to the generation of new data. Citizen participation in public administration decision-making has been on the rise, as many government agencies have taken advantage of Internet-based applications to communicate with constituents [38]. Participation mechanisms are designed to lower the barriers to participation for those willing-but-unable, and to make participation more attractive to those able-but-unwilling [4]. Participation mechanisms generate value through the synergies created from openness and sharing, allowing the public sector to draw from a larger pool of resources, consequently improving society's ability to solve difficult social problems.

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3.2.3 Efficiency Mechanisms

Efficiency mechanisms are designed to improve resource utilization in order to minimize waste and maximize the outcome value, using the same amount of resources. The importance of efficient use of public resources for economic growth, stability and general well-being has been brought to the forefront by a number of developments over the past decades [1]. As a consequence of increasing government intervention in affairs, such as child care, education, and health services, it is the public sectors that have faced mounting difficulties in managing efficiently the administrative bureaucracy. Moreover, increasing cross-boundary interactions and higher levels of information exchange between citizens and government have increased the total amount of government data collected and stored. These trends call for more efficient processing of data in order to provide the expected services [15]. Efficiency can be gained by cutting processing costs, making strategic connections between and among government agencies, and creating empowerment. We propose that the public sector can use open data to deliver public services more efficiently while safeguarding the quality of services, for instance, by allowing citizens to access and manage their own data or by reusing data within the public sector, thereby enabling automation of processes across governmental levels. As a result, resources can be moved from non-value adding tasks to value-adding tasks, positively affecting the generation of value.

3.2.4 Innovation Mechanisms

Innovation mechanisms are designed to generate new or significantly improved products (goods or services), work processes, business practices, and organizational methods [56]. Recent technological developments have provided firms with the ability to collect, manage, and use different types of data in multiple ways to innovate, and subsequently create value [49]. Following [69], we assume that innovation can have economy-wide effects. Innovation brings about novel combinations of resources, new production methods, as well as new products and services, which, in turn, can lead to the transformation of markets and industries, thus increasing value [69]. Numerous studies have confirmed the relationship between macro-level business innovation and economic value. The social impacts of new innovations have, however, been much less discussed and analyzed, with the possible exception of [41], who separates economic and non-economic consequences of technological innovations. The concept of social innovation is generally directed at improving the quality and/or quantity of life [60]. Social and business innovation can, however, overlap, as business innovation - while mostly dealing with profitable new ideas - can also result in social value generation. Going forward, we view data-driven innovation as business innovation, based to a large degree on exploiting data, and capable of generating positive economic and social impacts.

4 Research Design

In general, the case study is a preferred method when (a) *how* or *why* questions are asked, (b) the investigator has little control over events, and (c) the focus is on a contemporary phenomenon within a real-life context [72]. The inquiry should rely on multiple sources of evidence where data (e.g., interviews, observations, documents and archival records) should converge in a triangulating fashion. Strong triangulation of data sources is important to establish the necessary reliability and validity of a research study [72]. The case study also benefits from the prior development of theoretical propositions to guide data collection and analysis [72]. Here we apply a single-case study, spanning a period of eight years. We used a prior model of OGD value generating mechanisms to guide us in the data collection and analysis [37].

A Critical Realist-based case study is an iterative process. To abstract from specific empirical instances to mechanisms, one must distinguish general and essential conditions that underpin the phenomenon from incidental and nonessential conditions, i.e., spurious effects [12]. Accordingly, we first need to identify the structural components of the mechanism in order to understand how these components interact in order to produce the emergent outcome. Next, we need to identify and analyze the outcome tendency. And finally, we must identify the context that influences the outcome [12]. This study employed the methodological principles offered in [12], [76]. These principles include: (1) Explication of events; (2) Explication of structure and context; (3) Retroduction; (4) Empirical corroboration; (5) Validation of explanatory power. These principles do not recommend specific case study methods, but rather identify essential elements needed to derive theoretical statements of generative mechanisms [76].

The first principle suggests a “thick description of case *story* including actions and outcomes” [76]. p. 796. This is done by describing the sequence of events that links the initial conditions to the observed outcome. The second principle involves describing the structural entities, constituent parts, contextual conditions existing in the case, as well as identification of the relationships among the entities. The third principle involves using retroduction to identify and elaborate on the tendencies of contextual factors and mechanisms that may have interacted to generate the observed outcomes. Retroduction is the mode of inferential reasoning that reconstructs the conditions for the occurrence of an empirical phenomenon and seeks to identify the generative mechanisms *that generalize beyond the immediate instance of the phenomenon* [9], [17], [67]. The fourth principle involves analytical validation of the proposed mechanism based on case data and assessment of explanatory power of each mechanism relative to alternative explanations. Finally, the fifth principle involves employing multiple approaches to support the causal analysis based on a variety of data types and sources, analytical methods, investigators and theories [76].

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4.1 Field Site

Recognizing the paucity of in-depth field studies on the *use* of OGD, our strategy was to deepen this understanding by studying one particular case in depth. We sought to identify an organization that could give us a unique and exemplary source of insights on this topic. After going through a number of cases where OGD was used to generate value, we chose the case of Opower which is a relatively mature company that has used OGD from the day it was founded. The company´s innovative use of data has spurred a great deal of attention, enabling us to collect secondary data on the company and its impacts from multiple sources. Specifically, we conducted semi-structured interviews in September 2013 with three members of Opower: a (technical) product manager, a lead analyst and an energy efficiency specialist. Interview questions were sent in beforehand and the interview was tape recorded for further analysis. Subsequent follow-up correspondence included one more employee, a senior manager, as well as in depth analysis of company documents.

As we did not have longitudinal primary data, we used secondary data to re-create the chain of events leading to the current status, including a Harvard Business Review Teaching Case [16], an economic analysis of Opower's impact on energy efficiency [2], as well as a number of published interviews and newspaper articles. Afterwards, the key informants had an opportunity to review the event description to ensure validity [72].

Opower is an energy tech company that currently works with over 90 energy utilities servicing 22 million homes. Their main mission is to help everyone, everywhere, save energy. Founded in 2007 by two college friends, Alex Laskey and Daniel Yates, the company has now grown to over 400 employees and operates in three continents. Opower was founded on a simple premise: they want to engage the millions of people who are blissfully unaware about their energy use. To do so, they provide people with information. Not only information on their own energy consumption, but compared to other similar households, putting every customer's energy use in personal perspective. Opower merges and analyzes utility and third party data streams to create individual customer profiles, and subsequently uses these profiles to generate personalized insights that are delivered through different channels. When provided with better information and suggestions on how to decrease energy consumption, people are empowered to take greater control of the way they use energy, regardless of age, income, education, or access to technology. In October 2013, the Opower home energy reports had helped people around the world save over three terawatt hours of energy and more than $350 million on their energy bills. Opower uses open data to generate economic value for their investors and their utility partners, as well as social value in the form of decreased use of energy by their residential customers, leading to monetary savings for households and reduced CO_2 emissions.

Opower uses data from the U.S. Residential Energy Consumption Survey (RECS) to understand how households are using energy. The survey provides region-specific data on end-use energy consumption patterns, such as the type and efficiency of appliances used by the consumers, the systems and energy sources they use to heat and cool homes, among other topics. Opower combines these data with data from the U.S. Census Bureau on the mix of gas and electric heating sources in a given county, to create location-specific baselines to use when analyzing an individual's home energy consumption. On top of these data, Opower has built an analytics engine to inform and motivate customers. Their platform can store and process 15-minute interval data from smart meters as well as second-level data from millions of in-home devices at large scale and high speed. This, in turn, helps Opower deliver their Home Energy Reports with tips that are personalized for individual customers, for instance, identifying and suggesting the replacement of inefficient heating or cooling systems.

5 Event Analysis

In this section we develop a description of events based on multiple sources of evidence for construct validity. Following Hansen and Birkinshaw, the three main phases of the innovation process are: idea generation, idea conversion and idea diffusion. In the following analysis, after explaining the context of the case, we cluster the chain of events according to these three main phases [27].

5.1 Case Context

Climate change has emerged as one of the most important economic policy issues of the early 21st century. The pollutants that contribute to global warming are commonly known as greenhouse gas emissions. Carbon dioxide (CO_2) is probably the best known greenhouse gas, representing 85% of all greenhouse gasses in the U.S. Electricity production is the largest single source of global warming pollution in the U.S., responsible for nearly 40% of greenhouse gas emissions. Traditionally, economists and policymakers have focused on relative prices as the primary force driving energy demand [2]. There are, however, three problems with price-based approaches to energy conservation. First, it has not been politically feasible to implement carbon taxes, at least in the U.S. Second, measuring the effects of an energy efficiency subsidy on energy use requires knowledge of the elasticities of demand for energy efficient goods. Third, while subsidies are in theory innocuous because they are transfers, they are in practice a large drain on increasingly-limited public funds. Spurred by these problems, interest has dramatically increased in non-price energy conservation programs that are informed by insights from behavioral science and evaluated via ran-

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domized trials [2].

A McKinsey report published in July 2009 estimated that there was a huge potential for energy-efficiency increases in the United States, and that a 23% reduction in energy usage was possible by 2020, resulting in large cost savings for the economy [48]. The report asserted that beyond the economics, efficiency represents an emissions-free energy resource. If captured at full potential, energy efficiency could abate approximately 1.1 gigatons of carbon dioxide emissions per year by 2020 and therefore serve as an important bridge to a future era of advanced low-carbon supply-side energy options. However, the study highlighted a number of barriers to the realization of significant efficiency gains, including large initial outlays of capital required to improve infrastructure, the fragmentation of efficiency opportunities, societal apathy and simple lack of awareness. While the overall potential for energy-efficiency gains was vast, it was spread out across industrial, commercial and residential buildings, making widespread cooperation difficult. Additionally, the incentive and motivation of individuals and corporations to take responsibility for improvements by themselves were seen as being low [48].

5.2 Idea Generation

The college friends and founders of Opower, Alex Laskey and Daniel Yates, went separate ways after graduating from Harvard but became reacquainted a few years later. They soon discovered their mutual interest in preserving the environment, both of them being inclined to join the fight against climate change. In 2006 they started to discuss potential ideas. Originally, they came up with five ideas, all of which focused on reducing emissions: two non-for-profit and three for-profit. The final idea, however, was born when Yates was examining his own energy bill and realized that he did not understand the numbers. He could not gain understanding of whether his consumption was high or low in comparison to other households, nor what he could do about decreasing his consumption. His confusion triggered the idea of providing people with understandable and relevant information about their energy consumption, complete with tips on how to save energy. He confronted Laskey with the idea, which he immediately liked. From Laskey's previous work in political polling, he knew that just about everybody agreed when asked if saving energy was important, and yet nobody knew if they were any good at it [16].

Consequently, the founders started gathering external information on the topic of environmental sustainability. During this process they came across Robert Cialdini, Regents' Professor Emeritus of Psychology and Marketing at Arizona State University, who for over 30 years had studied how people were persuaded by social norms [16]. Cialdini and colleagues had discovered that providing high-energy consuming households with prescriptive normative information regarding the average home energy usage in their neighborhood, constructively decreased energy consumption. In contrast, for households that were initially low in their base rates of energy consumption, the same descriptive message produced a destructive boomerang effect, leading to increased levels of energy consumption. Interestingly, adding an injunctive component to the message (a smiley token) proved reconstructive by buffering this unwelcome boomerang effect, meaning that for people who were initially low in energy consumption, the same descriptive normative information combined with an injunctive message of approval led to continued consumption at the desirable low rate, rather than a significant move toward the mean. Moreover, despite concerns that normative interventions would only have an effect for a short time, the longer-term results indicated that the effects of the normative messages continued to be strong even four weeks after the initial intervention [2], [55], [68].

After reading about Cialdini and colleagues´ work, the founders saw an opportunity to partner with electrical and gas utility companies to gain access to consumers' energy-usage data, and create a program to drive efficiency gains. In order to do so, they would use data on individual consumption, compare them to data on average energy consumption, and use insights from Cialdini's work on normative influences to create incentives for people to change their behavior. They approached Cialdini and offered him a role as chief scientist in their new venture to help provide the most effective normative messaging possible, which he accepted [16].

5.3 Idea Conversion

The founders next discussed their ideas with politicians in the Texas state legislature and found that early interest in their concept was high [16]. A legislature that implemented incentives for utilities to decrease consumption was consequently passed. Afterwards, Yates and Laskey decided to approach a number of potential utilities customers to validate demand for the information-based product. In short, the founders managed to raise $1.5 million in seed capital and then $15 million from venture capitalists, and a startup company was born. Over the next few months, Opower worked out a four-stage framework for customer interaction; analyze, engage, measure, and sustain [2], [16]. The process began with an analysis of the customers' energy-usage habits by sifting through data from the utility, while also pulling in data from other (open) sources that provided insight into the demographics, family type and income levels of customers.

Each report contained two key features: The first was the Action Steps Module, which gave consumers information about steps they could take to conserve energy. This included recommendations to improve home energy efficiency, such as attic insulation, installation of energy-efficient lighting and replacing appliances. However, the primary suggestions centered on simple changes in usage behavior such as turning off electronics and lighting when not at home. The second feature of the home energy report was a Social Comparison Module, as shown in Figure 3. The

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module provides visual graphics to illustrate a customer's energy consumption relative to customers in households with roughly equivalent square footage, drawing on property data and data from the Residential Energy Consumption Survey (RECS). The Social Comparison Module, coupled with the action steps, makes it relatively easy for customers to understand what they need to do in order to reach parity with their neighbors. To reinforce *good behavior* the reports include smiley tokens alongside a good score. This idea is based on Cialdini's findings: people do not want to just save energy; they want to be acknowledged for their efforts [16].

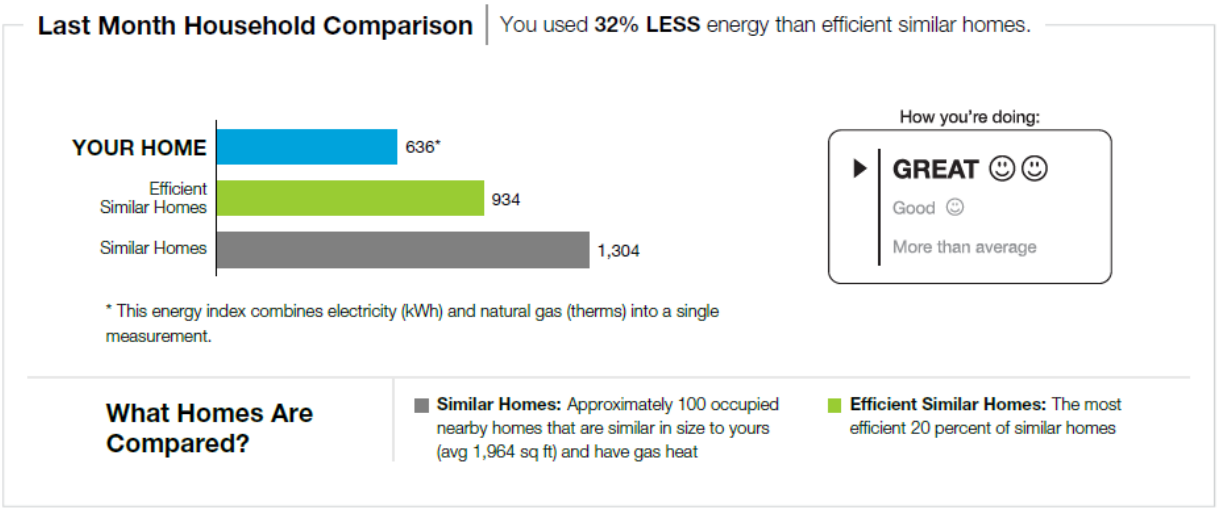

Figure 3: Social comparison module

In 2007, Laskey and Yates ran a pilot study on 35,000 homes. At the start of the program, they split the households into two groups with similar demographic profiles, consumption patterns, weather, energy prices and economic conditions. The test group received the home energy reports, while the control group did not. Afterwards, they analyzed the consumers' energy-usage data and applied a rigorous methodology to measure and verify the results from the targeted reports against a control group [16]. Subsequently, Opower ran a large-scale data analysis over time with replicable results, in accordance with EPA guidelines for energy-efficiency programs. The electrical utility companies saw an almost immediate 1.5% to 3.5% savings in energy usage in those households that received the personalized report. While the numbers seemed low, a Time magazine article put the potential for these savings into perspective by translating them to the net impact of CO_2 emissions saved if the product would be used nationwide, stating that society would be cutting carbon and saving money at the same time. The founders were most excited about the potential scalability of the idea. The utility companies could extend the program to nearly 100% of their customer base and maintain the program's cost effectiveness. The program cost utilities just $0.03 per kilowatt-hour of energy saved, while providing a savings of 75 gigawatt-hours per 100,000 households, far exceeding the success of other energy-efficiency programs that utility companies had implemented [16].

5.4 Idea Diffusion and Impact

Opower's first client partner was Sacramento Municipal Utility District. In 2008, Opower (actually the company's name was Positive Energy until 2009) went to Illinois and then Minnesota, deploying their first Automatic Meter Reading (AMR) solution. In 2009, the company started servicing Colorado, Massachusetts and Virginia, implemented an online customer portal and started to use a data services layer for the first time. Also in 2009, the founders were invited to the White House to discuss with President Obama what companies in the U.S. were doing to combat global warming. Shortly thereafter, BusinessWeek named them one of 50 Tech Start-Ups to Know About and Opower was featured in a front-page story in the New York Times. In 2010, they went to California, hired their 100th employee, and deployed an advanced meter infrastructure. President Barack Obama visited the Opower headquarters in 2010, highlighting in his speech how their accomplishments were making homes more energy efficient, saving people money, generating jobs and putting America on the path to a clean energy future. At that point in time, Opower reported 100 gigawatt hours of energy saved and $10 million saved by households. Soon after, a Time Magazine article was published, effectively disseminating the idea of how people´s behavior could be modified by informing them about their choices and how this behavioral change had the ability to generate both monetary and CO_2 savings.

One year later Opower went overseas and set up in the UK, reporting 500 gigawatt-hours and $50 million dollars saved! In 2011, Opower came to New York and in the same year won the two largest Smart Grid deployments in the U.S. In 2012, Opower went live with their new Energy Social App and reported one terawatt hour of energy saved. In October 2013, this number was up to three terawatt hours, which is the equivalent to around 30% of the energy produced by solar energy technologies in the U.S. every year. This translates to over 4.6 billion pounds of CO_2 abat-

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ed and about $350 million saved on household energy bills. An independent economic research paper from 2011 evaluated the effects of the Opower Home Energy Reports and found that the Average Treatment Effects (ATE) of Opower's programs ranged from 1.4 to 3.3% of baseline usage, with an unweighted mean ATE of 2.0% [2]. The evaluation also showed that treatment effects increased markedly as a function of pre-treatment usage, although not even the lowest consumption households increased usage in response to the treatment. The analysis concluded that this experiment showed how the simple act of informing users, a treatment that had no effect on relative prices, could persistently affect usage by as much as an 11- 20% short run price increase or a 5% long run increase would have accomplished! [2].

6 Structural and Contextual Analysis

In this step we need to identify the components of social and physical structure, contextual environment, along with the relationships among them [76]. The key components are the real objects of the case, for example, persons, organizations and systems. They constitute structures, i.e., networks of objects with causal powers [12].

In the process of idea generation, the founders showed proficiency in the use of external sources [27], as they not only took the results from behavioral science to heart, but went right to the source and recruited one of the researchers that had conducted the experiments. We need to conceptualize the *openness* of the founders and their willingness to use external information in their development of an idea. A company´s absorptive capacity captures the ability of a firm to recognize the value of new, external information, assimilate it and apply it to commercial ends, which is critical to its innovative capabilities [14]. Opower's primary value proposition is based on generating information and insights from various sources of data. As said earlier, their mission is to use information to empower end users to take control of their own energy use. The fact that Opower could assimilate external knowledge, as well as being able to combine externally available data with internal data for new insights, indicates the company's high level of absorptive capacity. We propose that this absorptive capacity has positively influenced data-driven innovation, which is reflected in the many innovative technical solutions Opower has built around use of these data, such as their patent pending analytics engine.

We gathered from our interviews that Opower is not dependent on the data acquired from public sources, being free of charge, at least not in the current context. However, being spared from cumbersome payment processes and complex licensing issues has significantly simplified the use of these data, and decreased transaction costs. Furthermore, while Opower has gathered an impressive amount of data on energy use from smart meters that could be aggregated to hypothesize about general use behavior, they still prefer to use the RECS survey. Partly because it comes from an independent and respectable source, and partly because it contains micro data that allow the company to manipulate very granular information and extract insights that suit their unique needs. Opower is also using other types of OGD, for instance weather data, geographic data and demographic data. The general availability of different datasets clearly benefits the company. In general, their impression is that the more availability of high quality, sufficiently granular data, the better. Regarding accessibility, Opower has experienced that links to websites containing datasets have been changed or even taken down, making it difficult to maintain a library of content across multiple years. Therefore a central repository would prove beneficial for the company.

While external data sources offer massive potential for commercial use, they are outside the control of the organization consuming them, and thus their quality may be unknown and their supply uncertain [19], introducing a certain amount of risk for the private sector users. After analyzing which factors affected the use of OGD in the Opower case, we identified two types of risk. The first has to do with data management within the public sector, which must consider the quality of data, the management of risk, including security and privacy considerations, as well as the data stewardship processes. What Opower perceives as the biggest issue with using data supplied by the government is that the granularity is in some cases not as desired, the data are not updated frequently enough and in some cases new types of information are based on old survey data. Therefore, the quality of the data itself and the data stewardship processes are an issue for Opower. Privacy and security related considerations are still relatively unexplored as potential barriers to the generation of value from OGD, especially as the datasets released do by definition not include data that are subject to valid privacy, security or privilege limitations, as governed by other statutes. However, when combined with other types of data, such as readings from smart meters, the potential threat to privacy is certainly a risk that Opower has acknowledged. That said, worries about breach of privacy are not recognized as a barrier to value generation in the case of Opower.

The second risk involves the sustainability of the resource. While Opower is not entirely dependent on any specific governmental data-source, it would certainly be inconvenient for the company if the quality of data used would deteriorate or if data should cease to be collected due to an unsustainable business model. The sustainability of open government data as a resource is highly dependent on the attention an OGD initiative receives from politicians. The U.S. government has shown substantial interest in opening government data, highlighted by the president's executive order from May 2013, making open and machine readable the new default for government information. The executive order is to be the manifestation to the longstanding commitment to release and leverage data in support of enhanced transparency and accountability, improved government services, and a stronger economy [75].

For Opower as a data analytics company, one of the most important factors is their own technological infrastructure.

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Their cloud-based technical platform enables Opower to sift through vast amounts of data, amongst other readings from smart-meters that are imported every 15 minutes. They utilize a high frequency storage for storing data from 50 million homes. In addition to the storage, they also utilize an energy analytics engine that analyses 35 billion events per month and makes 1,500 calculations per second. The engine combines internal customer interaction data with data from external sources, i.e., data sourced from the utilities companies and open government data. The data analytics engine is what gives Opower the ability to compare thousands of different homes' smart meter reads to find tiny fluctuations that indicate that certain homes are over-heating or over-cooling at certain thermostat set-points. The third major component is the interaction engine which generates 35 billion reports every month. While still highly dependent on the paper based reports, Opower is constantly evolving new channels using modern platforms, such as web-based portals and applications for smart phones and tablets.

The company´s ability to analyze digital information is, of course, highly dependent on the infrastructure in the operating country, such as the availability of smart meters in homes and the general telecommunications infrastructure that allows them to access and transfer these massive amounts of data to the company´s internal (cloud based) data storage. The utilities adoption of modern interaction channels is also a factor. Originally, Opower only used paper based reports, but with evolving technology they have continued to develop new, more cost-effective channels. However, paper based still remains the company's main channel due to several reasons. For instance, there is a lack of correct email addresses in the utilities customer databases, and people are still being more responsive to paper based messaging than to email based. Moreover, the new technology enabled channels are dependent on the degree to which the utilities use technology to engage with customers. In a recent white paper (Is Mobile Turning into a Missed Opportunity?), Opower compares utilities' use of web-based and mobile-based technologies to that of banks, concluding that the utilities sector in the U.S. still has a long way to go to catch up.

7 Retroduced Mechanisms

The principle of retroduction, the core of the critical realist explanatory model, is derived from the ontological assumption of emergence and epistemological focus on explanation. The objective is to identify the most complete and logically compelling explanation of the observed events given the specific conditions of the contextual environment [76]. If there are existing mechanisms in the theoretical knowledge of a field, they are adapted to fit the specifics of the given case. However, if no existing mechanisms are adequate to explain the phenomena being studied within a specific context, a new mechanism is proposed [76]. This type of activity can be divided into two sub-steps [12]: (1) identify the contextual elements and (2) look for mechanisms. Retroduction can be seen as being some sort of a thought trial to identify and describe the elements of the causal mechanism and the contextual influences responsible for its activation [76].

7.1 Contextual Enabling Factors

In the following sections we conceptualize the factors that we can identify as having enabled value generation from OGD in the case of Opower. Consequently, we identify which of the value generating mechanisms discussed in section 3.2 might explain how the use of OGD is being transformed to value in this case.

7.1.1 Absorptive Capacity

The presence of valuable external sources of knowledge does not imply that the flow of new ideas and external knowledge into firms is a self-governing or easy process. External knowledge can only be assimilated and integrated with the firm's (internal) knowledge base when the firm has internal competencies that facilitate such processes. Absorptive capacity captures the ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends, thereby being critical to its innovative capabilities [14]. Modern information technologies perform an important role in the development and maintenance of a firm's absorptive capacity. Absorptive capacity has been conceptualized as a multidimensional construct that consists of three distinct yet interrelated capabilities: identification of valuable external knowledge, assimilation or transformation of valuable external knowledge, and application of assimilated external knowledge [42], [63]. While a firm's absorptive capacity is dependent upon prior related knowledge [14], the predominant theoretical view is that absorptive capacity is an organizational capability, not an asset [42], [63].

In order to conceptualize the firm´s absorptive capacity, we use findings from previous research. A firm's ability to absorb valuable external knowledge depends on its level of prior related knowledge [14]. Yet, in addition to its knowledge base, a firm needs to develop structures and processes that facilitate knowledge absorption. Prior research finds that two types of organizational capabilities impact absorptive capacity: coordination capabilities and socialization capabilities. Coordination capabilities enhance knowledge exchange across intra- and inter-organizational boundaries, whereas socialization capabilities capture a firm's ability to produce a shared ideology that offers organizational members a collective identity [63]. However, empirical findings give an indication that for digitalized data-driven innovation, the firm's IT-specific absorptive capacity matters more than its general absorptive capacity [40]. IT capabilities allow firms to use technology to develop external relationships and collect knowledge from the external environment, as well as to increase knowledge application capability [63]. In the context of creating business value, we conceptualize absorptive capacity as a multi-dimensional construct, where IT capabilities and

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complementary organizational capabilities (coordination and socialization) positively influence a firm's ability to identify, assimilate, transform and apply valuable external knowledge [63].

7.1.2 Openness

The increasing importance of data, often termed big data, has been widely discussed in the media as well as in academic circles. However, one very important enabler for the generation of value from data seems to get much less attention, namely, openness. Openness has been identified as a driver of value from social technologies: the greater the degree of openness, the easier it is for an industry to capture the value from social technologies [50]. There still is, however, very little agreement about exactly what *open* means or how openness can facilitate the generation and appropriation of value from data. Big and open data share the commonality of using data in new, technology-intensive ways to gain insights [46]. It is suggested that openness is a factor that combines unrestricted availability with accessibility and technical interoperability [71]. Openness implies that organizations get the opportunity to integrate large and small volumes of data from internal and external sources to yield new insights. Accordingly, we conceptualize openness of data as a multidimensional construct, reflecting the availability of data, the technical accessibility of data as well as the legal dimension of openness (use of open licenses), [18], [22], [37].

7.1.3 Resource Governance

When opened up, government data become a common, shared resource, available for use within an open network of public and private stakeholders. However, this resource is still governed by the public sector as the main collector of the data. Therefore, we include resource governance as a construct intended to reflect the importance of proper governance mechanisms for the ability to generate value from this resource. Based on [37], we conceptualize resource governance as a multi-dimensional construct that encompasses not only data management, but also the promotion of equitable and sustainable provision of the data. Sustainable systems are those that meet current needs of many individuals involved in producing and using a common resource without compromising the ability of future generations to utilize the resource [32]. Ongoing analysis of more than 900 major change initiatives in the public sector indicates that 61% of these initiatives do not yield the hoped-for impact, and that a major factor in such cases is a lack of the skills, mind-sets and behaviors critical to sustaining change [51]. Resource governance must fit with, and respond to, a dynamic strategy that supports evolving national goals, and creates sustained institutional reforms. Key to any benefits, whether economic or social, is managerial leadership and political support [7], [51].

Furthermore, data management must ensure that the data is of sufficient quality. Unknown, inconsistent or unsatisfactory quality of OGD leads to substantial risks for validity and relevance. It is also important to give the correct context to the data, as government data are in many cases collected or created for specific purposes, and thus could be misleading if taken out of that context [19]. Accordingly, use could be stimulated if more information about the way open data are collected and processed were to be provided by including metadata [80]. The security of information must also be considered. There is an ongoing debate regarding possible privacy risks in relation to the use of OGD, and even greater concerns have been voiced regarding the implementation and adoption of smart meters in homes. However, in a recent study, perceived privacy risk was not found to be a significant influence on smart meter adoption intentions [77]. This *privacy paradox* is well known in research and may result from users' perceptions regarding the sensitivity of information disclosed [77]. It is important that resource governance sufficiently addresses all concerns regarding information privacy; otherwise these concerns might adversely affect the mechanisms that can transform OGD to value.

7.1.4 Technical Connectivity

The current trend towards a massive increase in the generation of data, as well as wider access to different kinds of data, has important implications for both public and private organizations. This trend is supported by recent advances in technology: the technical ability to manage and openly disseminate big and small datasets; the ability to analyze, mash up and make sense of different types of data; and the networking capabilities to access and link data from various sources. Research suggests that the scale and scope of changes brought on by use of data are set to expand greatly as series of technology trends accelerate and converge. To capture value from data, public and private organizations will have to deploy technologies that can help individuals and organizations to integrate, analyze, visualize and consume the growing torrent of available data [49]. Technical connectivity is conceptualized as a multidimensional construct that describes the availability of technologies that allows users to store, access and combine the data. The construct consists of three dimensions: 1) the infrastructure that facilitates data exchange between government agencies, private sector firms and the public 2) dissemination of software, including data organization management software, as well as analytics and discovery software and 3) access via multiple platforms, such as mobile and web-based platforms.

7.2 Identifying Mechanisms

We can identify one macro-micro level mechanism that explains the *why* of value generation in this particular case. We can call it the motivational effects of value generation or the motivation mechanism. While the hope of generating economic value is a well-established reason for any innovation, the social value aspect plays a somewhat bigger role in this case. The Opower case illustrates how the general awareness of global warming and the prospect of generating social value by increasing energy efficiency influenced and motivated both policy makers and Opower founders.

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While the founders were both contemplating for-profit and non-for-profit ideas, there is one unintended benefit they received from going the for-profit way while pursuing a social-goal: The economic value generated has helped the company attract talents that might have proved difficult without the financial resources they gained. This includes sought-after technical skills that have enabled the company to evolve their use of technology for data analytics and dissemination purposes. But most employees are equally attracted to the company´s mission: To help everyone, everywhere save energy. The generation of social and economic value has not only positively influenced the capabilities of the company, it has also brought awareness of the generative power of data to policy makers (referencing Obama's visit to Opower headquarters), utilities companies and the general public

Our main focus here, however, is to explain the *how* of value generation. If we start by trying to fit the case of Opower to Figure 2, we can see that the value is mostly generated by stakeholders outside of the public sector. While the public sector provides the data and is responsible for creating the incentives that make utilities willing to sacrifice a part of their income in order to achieve more energy efficiency, the main value generation happens from small changes in the energy use of 22 million households, which collectively amounts to considerable savings in energy use. This indicates that the value generating mechanisms are located on the right side of the matrix. If we look at the vertical dimension, we have to determine whether this case presents a purely social focus, a purely capital one or somewhere in between. As Opower is a privately owned company that is returning a healthy return on investment to their shareholders, they do not present a purely social, not-for-profit organization. However, Opower is a double bottom-line company, and their primary mission is to help people save energy. This mission is what drives the company and they have shown amazing results, motivating people around the world to increase energy efficiency, which have resulted in a considerable reduction in CO_2 emissions. The archetypical value generating mechanism that seems to be most illustrative of the Opower case is the innovation mechanism in the lower right hand corner; however, in the case of Opower, the precise mechanism might lie closer to the middle due to the company's strong emphasis on social value generation.

In the real world, there is rarely a single mechanism that explains a certain outcome. We could say that Opower's analysis of data and clear presentation of results has increased transparency of information, which, in turn, has affected the energy use behavior of households and motivated the utilities companies to be more socially responsible in their resource allocation. Using a similar logic, use of OGD has encouraged households and utilities to be more efficient in their use of energy. However, in both cases these are second-order mechanisms that depend on Opower´s innovative use of technology to transform raw data into valuable information. This indicates a potential synergy caused by interplay between different mechanisms, resulting in enhanced value generation. Finally, while Opower is certainly using government provided information, we could not identify any explicit collaboration between the public sector and the company on either the data itself or any finding based on the data. Our conclusion is that in this case the main mechanism that can explain value generation is what we call (socially motivated) *data-driven innovation*.

7.3 The Data-Driven Innovation Mechanism

Firms are increasingly procuring knowledge from external sources in their innovative activities [43]. Many models have been developed to explain how firms can exploit external knowledge, ranging from simple free riding to consulting with lead users to utilization of public sources of knowledge [13]. A central part of the innovation process concerns the way firms go about organizing their search for new ideas that have commercial potential. New models of innovation have suggested that many innovative firms have changed the way they search for new ideas, adopting open search strategies that involve the use of a wide range of external actors and sources to help them achieve and sustain innovation [43]. Empirical results strongly suggest that firms with more open knowledge search strategy, having access to a larger number of information sources that can provide ideas and resources, tend to be more innovative [43], [45]. Accordingly, a lack of openness of firms to their external environment may indicate that managers over emphasize internal sources and under emphasize external sources.

The end-to-end process from idea generation to business growth can be represented as an innovation value chain, comprising three main phases: idea generation, idea conversion and idea diffusion [27]. Within these three main phases, six linking tasks are necessary for the innovation chain [27]. The first phase represents the firms' efforts to acquire the different types of knowledge necessary for innovation, involving three linking tasks: in-house idea generation, cross-pollination and external sourcing [27]. The next phase is the process of transforming this knowledge into new products, services, business processes or behavioral innovations. This activity involves two linking tasks: screening and funding of new ideas and developing new ideas into viable products, services or businesses. This activity may again involve a combination of firms' internal and external resources. The final stage in the innovation value chain is the diffusion of firms' innovations: spreading developed ideas within and outside the company. Empirical research shows a clear causal link from knowledge sourcing through innovation to business growth and productivity [45], [64].

When data have been made available and accessible, current knowledge may be synthesized with different types of open data, and used for generating new knowledge, ideas and value propositions. Available technologies can be used to convert the data into information that is further used in product-, process- or behavioral innovations. These innovations are then diffused to society to form and establish new structures and generate different kinds of value. Finally, the new structures provide the foundation for new data and new innovation, and the loop repeats itself. Information and data are the basic currency across this whole ecosystem. The basic belief behind making the data

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available to external uses without restrictions to use is that the owner or custodian of data may not be best placed to understand the potential future uses of the data they hold. Waste and the destruction of value could occur if government set rules of access to information which fails to recognize the requirements of unforeseen users and uses. That is, too tight rules of engagement may unintentionally constrain the beneficial use by third parties or eventual end-users in the data-driven innovation process.

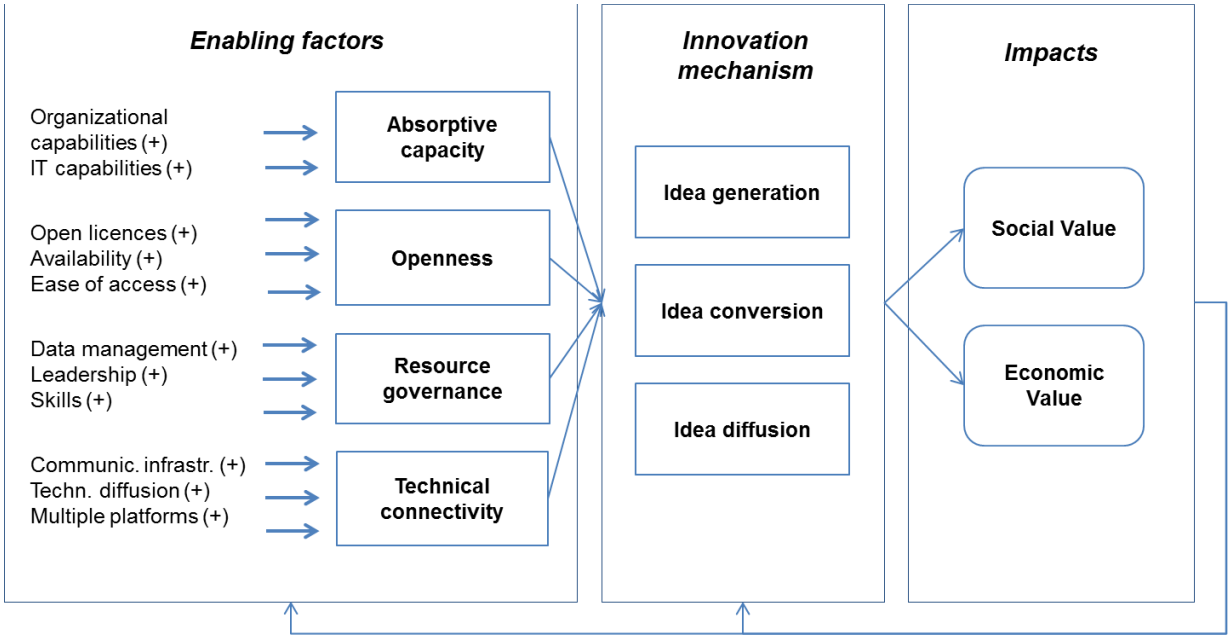

Figure 4: Conceptual model of the data driven innovation mechanism

Figure 4 shows the conceptual model for the data driven innovation mechanism. The four multi-dimensional enabling factors are all capable of positively influencing the innovation mechanism, although to a different degree, depending on the contextual environment. To illustrate, while strong leadership within government might have a huge influence on the impact of an OGD initiative in the beginning stages, the influence might be less for the more mature initiatives.

The innovation mechanism itself is not inherently different from any generic innovation mechanism, other than in this case; the innovation is to a large degree based on the use of data. The impacts of the data-driven innovation can range from generation of internal economic value, measured as company revenue or profits, to the generation of more widely appropriated economic and social value. Although we have conceptualized innovation as business innovation, which is most often characterized by the drive towards economic value generation, the social benefits resulting from the innovation can be even more profound, as in the case of Opower. This chain of events explains how the use of a particular resource – OGD - in a specific company, and in the context of certain macro level structures, can result in the generation of macro-level value. Finally, the generation of economic and social value can further positively affect some of the micro level constructs we present in the model, resulting in a virtuous cycle of openness, innovation and value generation.

8 Empirical Corroboration

We need to ensure that the proposed mechanism of data-driven innovation offers the causal and explanatory power to explain how value is generated from the use of OGD. In an open system there are a number of mechanisms at play. After identifying a certain mechanism, we can identify others by asking how the context influences the triggering of the mechanism [12], [67].

The original driver behind the whole Opower adventure was the founder's interest in preserving the environment. The founders originally came up with five ideas, three non-for-profit and two for-profit. After discussing these ideas among themselves and with others, they agreed upon explaining the energy bill, an idea they termed *Energy Bill 2.0.* In an attempt to generalize this finding, we have suggested that a trigger for the OGD value generating mechanisms is the motivational aspect of social and economic value – rainbows and carrots. Furthermore, the value generated also supports the company´s aspirations after the fact. Opower has not encountered problems in hiring people with the right technical and data analytics skills, even though there is a reported shortage of those skills in the market. One potential reason for this is the company´s somewhat unique combination of economic and social value generation. The economic value enables them to provide good salaries and a working environment where employees get an opportunity to learn how to use the latest technologies. The social value generation attracts those that are passionate about creating an impact, changing the world for the better. We therefore suggest one contextual macro-

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micro mechanism: the mechanism of *motivation*.

However, the case highlights two other elements that have proved to be important to the process of idea generation and conversion: 1) The apparent lack of information on the energy bill and 2) Cialdini's findings on how information about people's neighbors had an effect on their behavior. We propose that in order to be able to utilize Cialdini's finding and the available OGD to their benefit, the company needed to possess a good degree of absorptive capacity. Moreover, as Cialdini's findings predict, people need information, not only about their own behavior but as compared to the behavior of others. Therefore, Opower needed access to aggregate data on consumer behavior as well as data on energy consumption in individual homes. The technical infrastructure enabled them to collect, store, merge and analyze data from different sources. These two factors together explain Opower´s *ability* to innovate from external datasource. Absorptive capacity can only benefit a company if it has access to valuable and re-useable external information sources. The *opportunity* for data-driven innovation arises from the fact that Opower had access to the data they needed from the U.S. government and that the data was of sufficient quality and sustainability (a trusted resource) for them to use.

We have suggested that the archetypical mechanism that can best explain the value generation in the case of Opower is the mechanism of innovation, where novel combinations of resources and new methods of analysis lead to the generation of a new service, which, in turn, leads to the transformation of the energy market, thus increasing value [69]. We propose that in the case of Opower, the innovation is in essence based on utilizing a specific resource, namely, data. We use the term *data-driven innovation* to generalize this finding to include any innovation that is, to a large degree, based on utilizing data to generate value. The value generated for the entrepreneurs and the government has been economic in nature, i.e., the establishment of a growing company which leads to profits for the investors, new jobs for employees and higher tax payments to the government. Opower has had a 280% five-year revenue compound annual growth rate, and in October 2013 there were almost 100 available positions posted on their webpage. Furthermore, Opower has generated social value, as reduced CO_2 emission contribute to environmental sustainability, which again can lead to a collective improvement in the lives of individuals, benefitting society as a whole.

9 Discussion and Conclusion

The aim of this research was to develop a framework for the generative mechanisms that explain *how use of OGD can stimulate the generation of value,* and then use these mechanisms to explain how a private company can generate economic and social value by using OGD. We constructed a framework based on a review of the OGD and value literature, using general and established mechanisms to explain how use of OGD as a resource can result in generation of value. The framework is based on two dimensions that are intended to capture the impact of openness: First, how openness is enabling external stakeholders to contribute to the generation of value from OGD as a resource and second, how society as a whole can appropriate value in the presence of openness. Using the framework, we identified four different archetypical generative mechanisms, each of which represents a particular type of cause-and effect relationship between OGD and value. Subsequently, we used a critical realism based research approach to analyze the case of Opower. We propose that a mechanism of data-driven innovation fits the Opower case and has the ability to explain how Opower used OGD to generate value and what contextual enabling factors were involved. We suggest that our analysis has shed light on how the potential value generation motivated the idea, how the lack of information triggered the idea of innovating from data, and how the interplay of four multi-dimensional factors enabled the innovation, which ultimately led to the generation of economic and social value. Finally, we propose that the resulting value generation has, in turn, positively influenced, not only the company´s own ability to generate even more value but also policymaker's interest in OGD, thus increasing our understanding of the value of data.

The contributions to knowledge are as follows: a) The two-by-two framework with the four archetypical generative mechanisms can be used to explain the complex relationship between openness, data and value, b) the illustration of the potential virtuous cycle within the OGD ecosystem and c) the conceptual model of data-driven innovation, where we suggest a nomological network of constructs that illustrates how OGD can be used to generate value. The contribution to practice is the strategic framework which can help governments position and prioritize their strategic OGD goals and the identification of factors that can enable the generation of value from OGD through the innovation mechanism. We furthermore believe that the insights offered in this study can be applied to guide OGD initiatives that have the goal of driving innovation in the private sector. One hypothetical example of such use could be a public body planning a new OGD strategy. A discussion about the initiative's goals should include what kind of value should be generated (sought after impacts) and how. After reflecting on the different levels of interactions between stakeholders, the difference between social and economic value and value generation vs. appropriation of value, the public body in question could compare its current status (for example, strong in creating internal efficiency but weak in maintaining two-way relationships with external stakeholders) to the desired status and subsequently start a discussion on how to move from the current to the desired state.

A limitation of the study is that we use only the first four principles suggested in [76], as the fifth principle includes using multiple methods to perform validation of explanatory powers. While principle 5 is out of the scope of this particular paper, our aim is to continue to test our conceptual model using a variety of methods in future work. Furthermore, as the paper analyses only one case study, our ability to generalize our findings is somewhat limited. It is well

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known that OGD come in different types and structures, the use of the data varies greatly and the contextual circumstances vary between countries and even individual initiatives. More cases should be analyzed to reflect on the generalizability of this model. An interesting way to achieve this could be to follow the method used in [31] where the authors examine which *configurations* of identified enabling factors actually lead to an observed successful outcome in different cases [31]. A further limitation is that while we focus on the enabling factors and the interplay between them, as well as the mechanism of data driven innovation, we did not really analyze the possible interplay between the innovation mechanism and the other generative mechanisms, other than reflecting on how the innovation mechanisms would have triggered second-order transparency and efficiency mechanisms. We suggest that an in-depth analysis of this relationship might present an opportunity for future research.

We propose that openness is in itself an important enabler of the generation of value from data, as openness enables both the generation and appropriation of value, not only by the organization that produces or collects the data, but also by external stakeholders. However, while openness might be seen as the necessary condition in this context, it is insufficient on its own. Governments should increase the usability and re-usability of their data by focusing on resource governance, where the aim is to ensure the quality and sustainability of the resource and to minimize risk for external users. On the demand side, companies need to possess the right capabilities as well as having access to technical platforms that enable them to link disparate data sources and transform these data to valuable information products and services. Finally, we suggest that the act of opening data and treating them as a shared resource available for use by anyone has the ability to contribute to a synergistic relationship between different mechanisms, thus contributing to the simultaneous generation of economic and social value.

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