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Axiomatic Theories and Improving the Relevance of Information Systems Research

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Abstract. This paper examines the fact that a significant number of empirical studies in behavioral information systems (IS) theory research engage in confirmative testing of self-evident axiomatic theories without yielding highly relevant knowledge for the IS community. To measure how pervasive such testing of axiomatic theories is, we conducted a horizontal analysis using 666 hypotheses from 72 representative behavioral IS theories and discovered that more than 60% of the hypotheses could be regarded as axiomatic theory elements. To further investigate the pervasiveness of repetitive testing of axiomatic theories, we vertically analyzed 1,301 hypotheses from 148 articles in three theory categories: technology acceptance model, diffusion of innovation theory, and institutional theory. These analyses revealed that 68.1% of these hypotheses were axiomatic and that 74.6% of them were inherited from general truths beyond the IS domain. In order to shift the research emphasis toward enhancing the relevance of IS research outcomes without sacrificing methodological rigor, we propose four complementary IS research approaches: (1) identifying disconfirming boundary conditions, (2) measuring the relative importance of axiomatic causal factors, (3) measuring the stage of progression toward visionary goals when the nature of the axiomatic theory can be extended to future visions, and (4) engaging in the conceptual design of visionary axiomatic goals. We conclude with a discussion about why so many scholars devote substantial effort to reconfirming axiomatic theories and suggest avenues for more relevant research outcomes.

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Keywords: axiomatic theory • information system theory • research methodology • design science

1. Introduction

Although much research in information systems (IS) employs the empirical testing of theories as the primary means of knowledge advancement, we argue that a significant number of behavioral studies confirmatively test self-evident axiomatic theories without effectively creating new knowledge. This issue is a persistent problem of relevance in IS research as identified by Benbasat and Zmud (1999). Although many authors have offered suggestions for improving the relevance of IS research outcomes, balancing rigor and relevance still remains an unsolved challenge (Straub and Ang 2011).

This phenomenon seems to be becoming more serious because tenure and promotion at university business schools increasingly require publications in top research journals, often discounting more practically oriented publications (Lee and Mohajeri 2012). Although the top research journals demand a demonstration of rigor, the objective evaluation of relevance is anything but straightforward. This phenomenon is not limited to the IS community alone but is a common problem of academic research in many other business disciplines (BusinessWeek 1990).

Nevertheless, it is not easy to discuss this issue because there is no consensus on the definition and

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scope of theories (Bichler et al. 2016). In this study, we limit our scope primarily to the behavioral IS theory research, which mainly contributes to the establishment of cause-and-effect knowledge by testing hypotheses using empirical and experimental data. Therefore, other types of theories—such as theories in computer science and economics, which usually adopt deductive reasoning or have mathematical proofs—are beyond the scope of this argument. Thus, the IS theories in this paper without qualification henceforth imply behavioral IS theories.

To develop a framework of enhancing relevance without sacrificing rigor, we argue that a nonnegligible amount of behavioral IS research attempts to test axiomatic theories without effectively creating relevant knowledge. Thus, the first purpose of this research is to define the concept of axiomatic theories and measure its pervasiveness. We define the concept of an axiomatic theory in IS research as *a theory within the IS domain that is acceptable as self-evident truth without the need for further empirical testing*. To investigate the nature of axiomatic theories, we define three types of axiomatic theories depending on the source of justification and its extensibility to future vision: *basic*, *inherited*, and *visionary*. Basic axiomatic theory is axiomatic in a particular domain, such as the IS domain. Inherited axiomatic theory is axiomatic in a more general domain that includes the IS domain, and visionary axiomatic theory is extensible toward visionary axiomatic goals.

To examine the pervasiveness of confirmative testing of axiomatic theories in behavioral IS theory research, we conducted both horizontal and vertical analyses. Horizontal analysis measures the pervasiveness of axiomatic theory across a broad range of IS theories, and vertical analysis dynamically measures the pervasiveness of a particular theory category over time. To observe the dynamic nature of research within a specific theory, we conducted vertical analyses for three well-known theories: *technology acceptance model* (TAM), *diffusion of innovation theory* (DOI), and *institutional theory*.

For this explorative study, we evaluated 666 hypotheses for horizontal analysis and 1,301 hypotheses for vertical analysis and discovered that 63.7% of the theory elements in the horizontal analysis and 68.1% in the vertical analysis were axiomatic and that this phenomenon is persistent over time. This statistic is congruent with the intuitive statement of the business school dean of Case Western Reserve University, Scott Cowen—"as much as 80% of business school research is irrelevant" (*Business Week* 1999, p. 62).

Our next research question is how to generate complementary research approaches in the context of axiomatic theories that are capable of rigorously generating relevant knowledge. For this purpose, we propose four complementary approaches.

1. *Identifying disconfirming boundary conditions* rather than repetitively confirming axiomatic theories within an implicit boundary,
2. *Measuring the relative importance of axiomatic causal factors* to support specific decision-making models rather than merely identifying multiple causal factors in general terms,
3. *Measuring the stage of progression toward visionary goals* (when an axiomatic theory can be extended toward a visionary goal) regarding a sample data set as a representation of a moment in the stage of progression rather than viewing the data as a means of testing excessively general axiomatic theories, and
4. *Engaging in the conceptual design of visionary axiomatic goals* instead of repetitively testing general axiomatic theories.

The remaining sections are organized as follows. Section 2 reviews the literature on typology of relevance and theory building/testing in contrast to the knowledge-creation aspect of axiomatic theories, considering the distinction between prescriptive and descriptive knowledge. Section 3 introduces three types of axiomatic theories—basic, inherited, and visionary—and presents illustrative examples.

Section 4 surveys the pervasiveness of axiomatic theories in leading IS journals using both a horizontal analysis and three vertical analyses. For the horizontal analysis, we selected 72 representative IS theories published in *Information Systems Research* (*ISR*) and *Management Information Systems Quarterly* (*MISQ*). We based our three vertical analyses on 1,301 hypotheses drawn from 148 articles.

Section 5 proposes the four complementary research approaches mentioned in the context of axiomatic theories. Section 6 discusses why testing axiomatic theories remains a pervasive and persistent practice and offers suggestions to challenge IS researchers to engage in more relevant research.

2. Relevance, Theory Test, and Axiomatic Theories

To understand the locus of axiomatic theories in the literature on relevance and theory building/testing, we review previous studies on this topic and identify their pertinence to our work.

2.1. Axiomatic Theories in the Typology of Relevance

Benbasat and Zmud's (1999) seminal study focuses on the topic of relevance from the perspective of practical contributions. Mohajeri and Leidner's (2017) recent work discusses the pluralistic nature of relevance and classifies the typology of relevance according to four perspectives: applicability, knowledge-production transfer, value, and empowerment. We align with the

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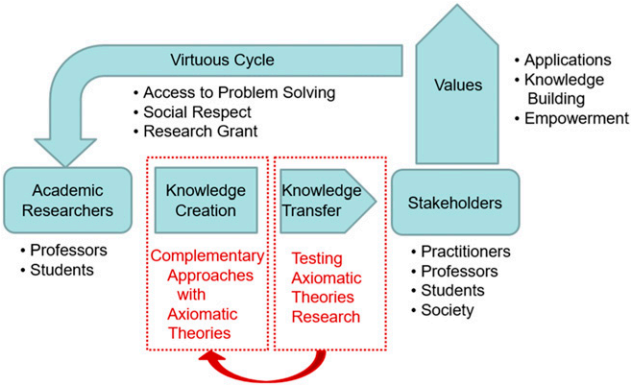
Figure 1. (Color online) The Knowledge Creation and Transfer Cycle



pluralistic view of relevance and propose a virtuous cycle of research, depicted in Figure 1, based on four factors that determine relevance: *knowledge creation*, *knowledge transfer*, *stakeholders*, and *value*. This cycle recalls the knowledge-management cycle (Nonaka 1991) in which typical stakeholders are practitioners, professors, students, and society. The value of knowledge includes applications in problem solving and empowerment in leadership as well as building knowledge that helps human thinking. In this framework, the value of knowledge is not limited by its relevance to practitioners.

Benbasat and Zmud (1999) consider papers not of interest to IS practitioners to be irrelevant and argue that to improve relevance by facilitating knowledge transfer, papers should be shorter, employ more figures and illustrations, use everyday language, and include less discussion about literature and study methods and more conceptual descriptions and prescriptions. These suggestions concern the knowledge-transfer aspect. These authors also propose four key dimensions of relevance, stating that relevant papers should be *interesting*, *applicable*, *current*, and *accessible*. The first three dimensions relate to the topics of knowledge creation, and the accessibility aspect concerns knowledge transfer. Finally, Benbasat and Zmud (1999) offer nine comprehensive recommendations in terms of topic selection, the paper's purpose, the paper's readability, and the editorial process. However, although they implicitly consider the four dimensions of relevance, they do not sufficiently clarify how to maintain rigor while pursuing relevance. To improve the relevance of academic papers to practice, Roseman and Vessey (2008) propose that reviewers conduct applicability checks with practitioners on the research objects according to three dimensions: *importance*, *accessibility*, and *suitability*; however, the editorial process of most academic journals thus far has not enforced the importance of practitioner applicability checks.

Robey and Markus (1998) argue that the papers can meet the standards of both rigor and relevance by employing four strategies: *cultivating practitioner sponsorship*, *adopting new research models*, *producing consumable research reports*, and *supporting nontraditional research outlets*. Darke et al. (1998) stress the importance of qualitative case studies to simultaneously address rigor, relevance, and pragmatism. Grover and Lyytinen (2015) argue that IS research should push the edges of either rich inductive inquiries using extensive data sets or novel genuine theorizing around the conceptual relationships between information technology (IT) and social behaviors. For the purposes of this paper, we limit the scope of our literature review to closely related themes, although we do recognize the greater depth, breadth, and value of papers belonging to this topic (Leidner 2018).

In the discussion of relevance, our concern in this paper is to enhance the knowledge-creation aspect of relevance. Although we acknowledge that research with inherited axiomatic theories may contribute to knowledge transfer for a specific IS application, the contribution to highly relevant knowledge creation is marginal, which is why we delineate the notion of inherited axiomatic theories in the next section. If the research outcome does not create new knowledge, then knowledge transfer to stakeholders does not occur. Therefore, as depicted in Figure 1, in the context of axiomatic theories, we propose four complementary approaches (described in Section 5) that shift the contribution of research to knowledge creation from knowledge transfer.

2.2. Visionary Axiomatic Theories in Cumulative Research

Benbasat and Zmud (1999) point out that the lack of a cumulative knowledge-building tradition is one reason for low relevance. In this context, we believe that it would be fruitful to examine the "grand challenges" approach in different domains, for example, in mathematics and healthcare. In mathematics, Hilbert (1901) formulated *Hilbert's program* to identify the important unsolved problems of mathematics present in 1900, which then became central to the development of 20th-century mathematics. In the healthcare domain, the Grand Challenges in Global Health program was sponsored by the Bill & Melinda Gates Foundation in 2003 (Gates and Gates 2019).

Although the nature of social scientific analysis and design for IS research is different from that of the natural sciences, IS has its own grand challenges. Limayem et al. (2011) specifically discuss the grand challenges of IS research, and Lee (2015, 2016) and the Association for Information Systems council have proposed the Grand Vision of Bright Information and Communications Technology (ICT) Initiative as a

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means of countering the widespread "dark side" of information and communications technologies. In the context of such grand visions, specific research on topics such as the Bright Internet could be conducted prescriptively (Lee et al. 2018, Shin et al. 2018), and research progress could be reported at international conferences (Bright Internet Global Summit 2018).

To create grand visions from axiomatic theories, we introduce the notion of visionary axiomatic theories, which could serve as candidates for grand visions and related goals. The proposition of stage theories toward axiomatic goals—such as Nolan's stage theory (Favaretto and Meirelles 2015)—can pave the way for cumulative research. For instance, axiomatic visions, such as "ease of use" or "usefulness" in the context of particular IS tools and services, could serve as visionary axiomatic goals, and the status of progression toward those goals defined by a stage theory would be measurable by data analysis. Conceptual design research concerning such goals could also provide opportunities for prescriptive design science research that shows "how" goals can be achieved, as stated in the work of Gregor and Hevner (2013). It is for this reason that we define the notion of visionary axiomatic theories in this paper and propose complementary approaches (type III and type IV, as described in Section 5) that could engage in design science research. The complementary approaches would be capable of creating "useful knowledge" in line with Gregor and Hevner (2013), including both descriptive "what" knowledge and prescriptive "how" knowledge. Over time, we anticipate that interplay between the production and consumption of both types of knowledge will emerge. Each will be produced in turn and will interact with prior forms of both types and will also be passed on through the other stages of the knowledge cycle.

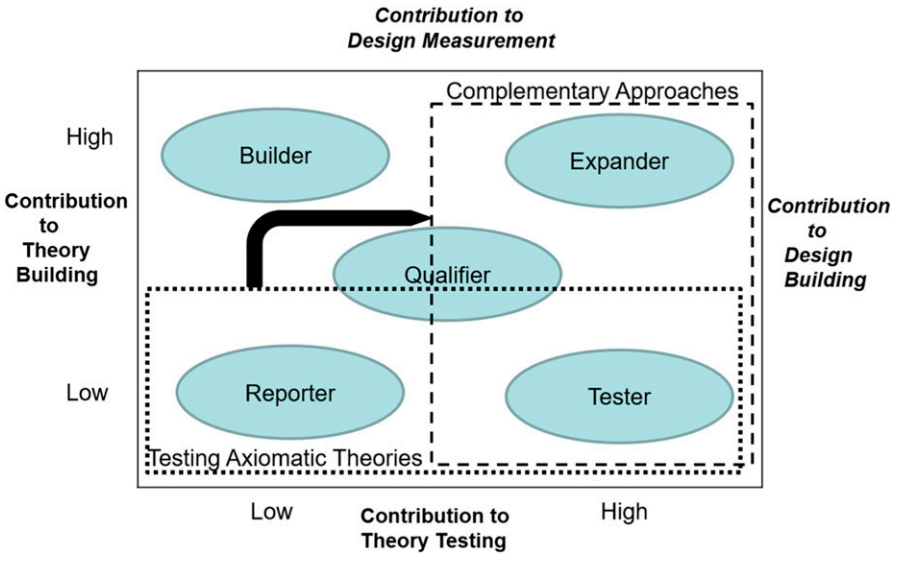
2.3. Axiomatic Theories in the Theory-Building-and-Testing Cycle

Colquitt and Zapata-Phelan (2007) comprehensively review the trend of building and testing theories via empirical studies on publications in the *Academy of Management Journal* (*AMJ*) from 1963 to 2007 (more than 45 years). They categorize contributions according to two dimensions: *theory building* (the extent to which a paper builds new theory) and *theory testing* (the extent to which a paper tests existing theory). They conceptualize five types of contributions as different combinations of two characteristics: *reporter* (low new theory and low test effect), *tester* (low new theory and high test effect), *qualifier* (medium new theory and medium test effect), *builder* (high new theory and low test effect), and *expander* (high new theory and high test effect). We offer simplified definitions of these types in Figure 2 and intend to contrast the positions of testing axiomatic theories and the complementary approaches.

According to Colquitt and Zapata-Phelan's (2007) study, reporter contributions were highest during the early years of this range but disappeared over time. Testers increased over the first 30 years but then dramatically decreased. Qualifiers have steadily grown and have constituted the largest contribution type since 1996. Builder contributions have remained fairly constant over the years, and expander contributions have enjoyed a proportional increase beginning in 1984 and, by 2007, rivaled qualifiers in prominence. These findings indicate that theory-building papers have increasingly become more associated with testing, although testing of existing theory has decreased.

Empirical studies of behavioral IS theories primarily articulate the structural relationships between independent and dependent variables and test

Figure 2. (Color online) Axiomatic Theory Testing and Goals of Complementary Approaches



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hypotheses about the causality relationships between these variables. Even though some hypotheses may be axiomatic, identifying important new factors is itself a significant contribution to theory building. Because the rigor of IS research is essential, theory building and testing tend to be intertwined, as seen in the review of *AMJ* papers discussed. In this sense, IS research studies also need to be positioned as theory testers or expanders or qualifiers. A replication study may sometimes be necessary to increase confidence in a theory.

However, if the theory is axiomatic, in particular inherited axiomatic, the benefit of repetitive testing diminishes and creates no more meaning than reporter-type contributions. To further investigate the relationship between testing and theory building, we conduct in-depth vertical analyses in Section 4. In order to improve the relevance by repositioning the IS theory research in the context of axiomatic theories, as depicted in Figure 2, we propose both the analysis approach (through complementary approaches I and II) and the design approach (through complementary approaches III and IV), as described in Section 5.

There have recently been some calls to improve relevance by addressing the topic of statistical significance. Lee and Mohajeri (2012) discuss the limits of statistical significance and the need to consider practical significance. Mohajeri et al. (2020) further distinguish the practical significance (research impressiveness to academicians) from relevance (real-world usefulness to practitioners) and demonstrate that current research papers do not sufficiently provide the necessary information for practical significance and relevance. Further, the editorial policy of *Basic and Applied Social Psychology* (*BASP*) includes an extreme prescription against research on statistical significance. Editors Trafimow and Marks (2015) announced a radical editorial policy for the journal, banning the null hypothesis significance testing procedure (NHSTP). Anticipating the legitimate concern that research quality may be degraded without data analysis, they also state, "Some might view the NHSTP ban as indicating that it will be easier to publish in *BASP*, or that less rigorous manuscripts will be acceptable. This is not so. On the contrary, we believe that the $p < .05$ bar is too easy to pass and sometimes serves as an excuse for lower quality research" (Trafimow and Marks 2015, pp. 1–2).

3. Types of Axiomatic Theories in IS Research

We now turn to defining the elements of axiomatic theory and the three types of axiomatic theories, illustrated through examples. For this purpose, we again draw on the definition of axiomatic theory in IS research as a theory in the ISs domain that is acceptable as self-evident truth without the need for empirical testing.[1]

3.1. Axiomatic Theory Elements

Because most theories are composed of more than one hypothesis identifying their structural causal relationships, we define the notion of the *axiomatic theory element* (ATE), which corresponds to an elementary statement of hypothesis or proposition. For instance, TAM theory is composed of two ATEs: Element (1) states that the perceived usefulness of an IT (an interchangeable term for IS here) has a positive effect on the attitude toward using IT when all other conditions, such as price and ease of use, are the same, and element (2), similarly, posits the positive effect of the perceived ease of use on the attitude toward using IT.

$$\text{Perceived usefulness of an IT} \rightarrow \text{positive attitude toward using the IT}, \quad (1)$$

$$\text{Perceived ease of use of an IT} \rightarrow \text{positive attitude toward using the IT}. \quad (2)$$

To distinguish these elements from the composite concept of theories, we define the term *axiomatic theory element*. In our study, axiomatic theory without qualification henceforth implies an ATE. We classify ATEs according to three types depending on the source of justification and extensibility to a vision: basic, inherited, and visionary.

3.2. Sources of Justifications

Depending on the sources of justification, the axiomatic theories of IS research can be classified into basic axiomatic theory and inherited axiomatic theory.

Type I: Basic Axiomatic Theory. Basic axiomatic theory is a kind of axiomatic theory that can be agreed on within the IS community without an empirical test. The depth and breadth of knowledge held by IS community members may vary, of course, depending on whether they are professors, students, or field practitioners. They may have learned about axiomatic theories from their daily observations, the basic nature of information systems, or through logical reasoning and commonsense within the IS field. The two elementary theories described by (1) and (2) are typical examples of basic axiomatic theory. The practitioner's concern is not testing the truthfulness of theories but designing them in ways that achieve these goals. Therefore, testing these theories is irrelevant to the needs of practitioners.

The theory of reasoned action (TRA), which states, "Beliefs influence attitudes, which in turn influence

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the intention toward a particular behavior" (Bassellier et al. 2003, p. 323), offers another example of axiomatic theory. This theory is also self-evident to rational people in ordinary business environments. Here, too, what is important is not confirming the truthfulness of this theory but discovering the boundary conditions under which this theory no longer functions.

Type II: Inherited Axiomatic Theory. Inherited axiomatic theory is a type of axiomatic theory that can be inferred from a more general axiomatic theory that encompasses the IS domain. The concept of inheritance is popular in the field of object-oriented programming and ontology (Weisfeld 2013), as depicted in Figure 3. If a more general theory is a property of a higher-level object, a lower-level object can inherit specialized theories without specific tests.

For instance, the properties of the object "IT" can be inherited from the properties of the generalized object "Devices," as expressed in (3) and (4).

$$\text{Perceived use fulness of } \textit{Devices} \rightarrow \text{positive attitude toward using } \textit{Devices}, \quad (3)$$

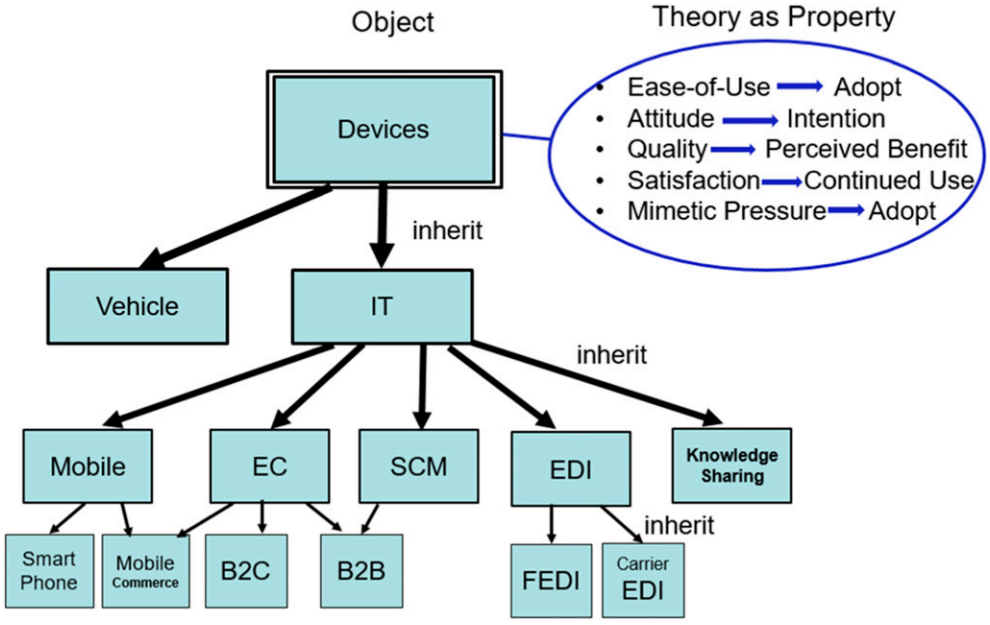
$$\text{Perceived ease of use of } \textit{Devices} \rightarrow \text{positive attitude toward using } \textit{Devices}. \quad (4)$$

Likewise, the properties of IT in (1) and (2) can pass to special application objects, such as mobile, electronic commerce (EC), supply chain management (SCM), electronic data interchange (EDI), knowledge sharing, and so forth. Thus, the axiomatic theories in (1) and (2) have the nature of both basic and inherited axiomatic theories. Therefore, confirmative tests of (1) and (2) with a special application domain within IT only create new knowledge if the study reveals a unique property or creates more specific design or measurement elements.

Other examples of inherited axiomatic theories can be found in the context of institutional theory, theory of reasoned action, and expectation confirmation theory. For instance, in the context of institutional theory (Teo et al. 2003, p. 22), the statement "greater mimetic pressures will lead to greater intent to adopt Financial Electronic Data Interchange (FEDI)" can be true for any EDI, IT, or organizational instruments. The theory of reasoned action (Bock et al. 2005, p. 91), which states, in the context of knowledge sharing, that "the more favorable the attitude toward knowledge sharing is, the greater the intention to share knowledge will be," can be generalized to any "IT" or "Devices." The expectation confirmation theory (Bhattacherjee 2001, p. 355), which states, "Users' level of satisfaction with initial IS use is positively associated with their IS continuance intention," can also be inherited from more general devices.

Therefore, repetitive confirmative testing of inheritable axiomatic theories for a specific IT application can only have meaning as reporter-type research if calling attention to a specific application is necessary. The vertical analysis reported in Section 4 demonstrates that up to 74.6% of ATEs are inherited, which is why we define inherited axiomatic theory here and propose complementary approaches I and II in Section 5.

Figure 3. (Color online) Nature of Inherited Axiomatic Theories



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3.3. Extensibility to Vision

Because the truthfulness of some axiomatic theories may be extensible to the future and be regarded as visionary, we define visionary axiomatic theory here.

Type III: Visionary Axiomatic Theory. *Visionary axiomatic theory* is a type of axiomatic theory that extends an axiomatic truth to the future as a vision even though the referent objects in the statement are not yet fully implemented, as illustrated in (5) and (6).

Perceived useful IT → will create a positive attitude toward using IT, (5)

Perceived ease of use of IT → will create a positive attitude toward using IT. (6)

These theories express beliefs concerning future IT devices, for example, next-generation smartphones that have not yet been developed. Even before the new product is developed, the vision can be accepted and can inspire the development of new technologies and products. When a theory is visionary axiomatic, the envisioned goals can enable evaluation of the stage of progression toward the goal rather than using the data to test and confirm the axiomatic theory itself. If IS researchers develop stage theories with respect to usefulness and ease of use, for example, future researchers can measure and evaluate the status of progress along these lines and identify what features of usefulness and ease of use have not yet been fulfilled. Let us call the approach toward visionary axiomatic theories that we advocate a *theory-based data-evaluation approach*, as elaborated in Section 5, in contrast to a *data-based theory-proof approach*.

Another example of visionary axiomatic theory can be found in the resource-based view of the firm in supply chain management systems and the IS success model (Seddon 1997). A vision for supply chain management (SCM) systems—for example, "IT infrastructure integration for supply chain management will impact supply chain process integration" (Rai et al. 2006, p. 228)—can be regarded as potentially true even though the specific SCM tools might not yet have been implemented. Although the case data from an immature SCM system may fail to prove this envisioned goal, this does not mean that the validity of this vision is negated. Instead, the theory should use the data to evaluate the state of SCM progress toward the eventual goal.

Wixom and Watson (2001, p. 21) examine the success factors of data warehousing implementation by testing 19 hypotheses; for instance, "A higher level of data quality is associated with a high level of perceived net benefits." Although the list of hypotheses itself is informative, each elementary statement is axiomatic. However, if the axiomatic statement can be projected into the future, it can trigger the development of a stage theory capable of evaluating the status of data quality. The identification of unfulfilled factors can lead to design science research. Because industry is interested in learning from IS research outcomes such as this, we define visionary axiomatic theory here and propose complementary approaches III and IV in Section 5.

4. Pervasiveness of Axiomatic Theories in the IS Literature

This section examines the pervasiveness of axiomatic theories in published behavioral IS theory papers by conducting a horizontal analysis and three vertical analyses using TAM theory, diffusion of innovation theory, and institutional theory. Horizontal analysis implies an evaluation of all identified IS theories and includes one representative paper from each theory category. Therefore, the first task toward a horizontal analysis is the selection of representative IS theories and papers from thousands of publications. Defining the types and scope of IS theories is not straightforward (Bichler et al. 2016). Moreover, it is impossible to clearly define the boundaries of IS research completely and to select all relevant IS research papers because of the multidisciplinary nature of the field. Nevertheless, we believe that we have identified a comprehensive sample of typical theory papers in IS journals that concern behavioral IS theories, as described in the Introduction.

4.1. Selection of IS Theories

There were three phases involved in the selection of papers for our horizontal analysis. In the first explorative phase, we began with papers drawn from the references of "Specifying Formative Constructs in Information Systems Research" by Petter et al. (2007) because this paper covers many important IS theories, which are mostly behavioral studies. The second phase examined the theories listed on the IS theory Wiki site (http://istheory.byu.edu/wiki/Main_Page), which includes a comprehensive list of theories used in behavioral IS research. Finally, we merged the lists from the two phases and eliminated redundancy.

For the second phase, we developed a Java program that crawled the Wiki site and found 2,024 published IS theory papers (as of December 14, 2017). Because the total number of papers was too large to study in-depth, we limited the journals to *ISR* and *MISQ* and selected a representative paper from each theory category. As such, we identified 97 theories associated with 358 papers. We dropped papers without formally defined hypotheses, which reduced the number to 60 theories. For each theory, we selected a

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representative paper based on the citation counts of Google Scholar as of December 14, 2017. If the most highly cited paper did not have formal hypotheses or propositions, we selected the next most highly cited paper, and so forth. In the end, we selected 52 papers representing 60 theories (with some papers addressing multiple theories) and then added 28 nonoverlapping relevant papers identified in the first phase to this number. Thus, our horizontal analysis was based on a total of 80 papers representing 72 theories and covering 666 hypotheses.

4.2. Horizontal Analysis of IS Theories

We performed the horizontal analysis by evaluating 666 hypotheses whether they are axiomatic or not and further classifying them by type. The examples of evaluation codes are demonstrated in Appendix A, and the full list is posted online at https://axiomatic-theory.github.io/. The results are summarized in Table 1. The authors' judgments were based on whether a hypothesis requires a confirmative test for knowledge building for the IS community. Table 1 is organized by paper rather than by theory because some papers are associated with more than one theory. The table lists papers according to author, published year, name of theory, number of theory elements (i.e., hypotheses or propositions) in each paper, number of nonaxiomatic theory elements (non-ATEs), number of ATEs, and their type (i.e., I, basic; II, inherited; or III, visionary). Note that some theory elements may belong to more than one type.

To reduce the risk of author bias, we aimed to be conservative, classifying theories as nonaxiomatic if the judgment among authors was not unanimous. Because others may make different judgments, we do not intend to claim that our judgments are completely objective. However, we do believe that our judgments and views are objective enough to serve as a basis for discussion and further study.

The horizontal analysis identified 424 (63.7%[a])[2] of the 666 theory elements as basic axiomatic theory. Of the 424 axiomatic theory elements, 73 (17.2%[b]) were classified as inherited axiomatic theory (type II), and 105 (24.8%[c]) were of the visionary axiomatic theory type (type III). Thirty papers (37.5% of 80 papers) used exclusively ATEs, and 69 papers (86.3% of 80 papers) included at least one ATE. Only 11 papers (13.8%) did not have any axiomatic elements.

Clearly, many theory papers attempted to empirically test ATEs. Nevertheless, we do not intend to undervalue the causal structural propositions of the theories and the need for initial empirical tests that were necessary to build the theory. However, we do have concerns about the repetitive testing of axiomatic theories, which we examine in the following vertical analyses.

4.3. Vertical Analyses with Three Theories

During the second phase of our horizontal analysis, we identified several theories that are represented in more than 50 papers: diffusion of innovation theory, adaptive structuration theory, sociotechnical theory, technology acceptance model, critical social theory, institutional theory, game theory, structuration theory, contingency theory, self-efficacy theory, and transaction cost economics. Because of their prevalence, all these theories would potentially make good candidates for vertical analysis. To create a manageable sample for our vertical analyses, however, we selected three extensively studied theories from this group that include multiple formal hypotheses: TAM theory, diffusion of innovation theory, and institutional theory. Our primary source of papers representing these three theory categories was the Wiki site. However, because the Wiki site did not include papers published after 2006, we also included papers published on these theory topics between 2007 and 2018 in *ISR*, *MISQ*, the *Journal of the Association for Information Systems*, and the *Journal of Management Information Systems*. This procedure yielded 1,301 hypotheses from 148 papers: specifically, 719 hypotheses from 79 papers on TAM, 382 hypotheses from 44 papers on diffusion of innovation theory, and 200 hypotheses from 25 papers on institutional theory (summarized in Table 2).

Of 1,301 hypotheses, 886 (68.1%[d]) hypotheses were axiomatic, 74.6%[e] inherited, and 16.3%[f] visionary. The diffusion of innovation hypotheses were most axiomatic at 74.6%, institutional theory hypotheses were next at 72.0%, and TAM theory hypotheses were least axiomatic at 63.6%. Because the number of papers relating to each theory was not the same, we also performed an analysis using the normalized weight of all theories. The normalized axiomaticity in the vertical analysis was 70.1%,[g] which is a bit higher than the nonnormalized percentage of 68.1%. Both of these are a bit higher than the horizontal analysis result of 63.7%[a]. The diffusion of innovation theory had the highest inherited axiomatic percentage (92.6%), and TAM theory had the highest visionary axiomatic percentage (27.8%). As such, different theories can have significantly different compositions of axiomatic types.

4.3.1. Persistence of Axiomaticity. We also investigated the dynamic trend of the axiomaticity level for each theory by observing the distribution over time. We found no statistically significant time effect for the level of axiomaticity for any of the three theory categories, nor did we find any significant effect for the aggregated average across all three categories. Appendix B shows the statistics for the time-effect analysis. According to this finding, the phenomenon of testing axiomatic theories is persistent over time,

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Table 1. Horizontal Analysis: Number of Axiomatic Theory Elements (ATEs) by Type

Authors (year)	Name of theory	Number of theory elements	Number of non-ATEs	Number of ATEs	Number of ATEs by type		
					I	II	III
Agarwal and Karahanna (2000)	Flow theory	7	1	6	6	6	6
Ahuja and Thatcher (2005)	Self-efficacy theory	9	7	2	2	—	—
Ang and Straub (1998)	Transaction cost economics	3	1	2	2	—	—
Arnold et al. (2006)	Technology dominance	8	5	3	3	—	—
Bassellier et al. (2003)	Theory of reasoned action	2	2	—	—	—	—
Bharadwaj (2000)	Resource-based view of the firm	2	—	2	2	2	2
Bhattacherjee (2001)	Expectation confirmation theory	5	—	5	5	5	1
Bhattacherjee and Premkumar (2004)	Cognitive dissonance theory	1	—	1	1	—	—
Bock et al. (2005)	Theory of reasoned action	9	2	7	7	7	—
Brown and Venkatesh (2005)	Theory of planned behavior	8	7	1	1	—	—
Chau and Tam (1997)	Technology-organization-environment framework	7	3	4	4	2	—
Chidambaram (1996)	Information processing/organizational information processing/punctuated equilibrium	2	—	2	2	—	—
Choudhury and Sampler (1997)	Theory of administrative behavior	5	1	4	4	—	—
Compeau and Higgins (1995)	Social learning theory	14	—	14	14	6	—
Compeau et al. (1999)	Social cognitive theory	11	—	11	11	7	—
Daft et al. (1987)	Media richness theory	3	—	3	3	—	—
Davis (1989)	Self-efficacy theory/TAM	2	—	2	2	2	2
DeLone and McLean (1992)	IS success model	5	—	5	5	—	1
Dennis et al. (2008)	Media synchronicity theory	10	4	6	6	—	—
Dimoka et al. (2012)	Signaling	6	—	6	6	6	—
Enns et al. (2003)	Influence behavior	7	5	2	2	2	—
Gattiker and Goodhue (2005)	Information processing theory	13	2	11	11	—	6
Gefen et al. (2003)	Theory of trust/technology acceptance model	12	4	8	8	4	3
Goodhue and Thompson (1995)	Task-technology fit	3	3	—	—	—	—
Griffith et al. (1998)	Socio-technical theory	6	—	6	6	—	—
Griffith et al. (2003)	Transactive memory theory	19	5	14	14	—	—
Hong et al. (2004)	Central capacity/associative network model	15	2	13	13	—	—
Jarvenpaa et al. (2004)	Punctuated equilibrium theory	8	2	6	6	—	—
Johnston and Warkentin (2010)	Protection motivation theory	7	4	3	3	1	—
Kankanhalli et al. (2005)	Social exchange theory	10	2	8	8	—	—
Karahanna et al. (1999)	Adaptive structuration/cognitive dissonance/diffusion of innovations	3	2	1	1	—	—
Karimi et al. (2004)	Task-technology fit	8	3	5	5	—	—
Keil et al. (2000)	Prospect theory	7	7	—	—	—	—
Kettinger and Lee (2005)	SERVQUAL	2	2	—	—	—	—
Kim and Michelman (1990)	Competitive strategy	3	—	3	3	—	1
Kim et al. (2005)	TAM/theory of planned behavior	2	—	2	2	—	—
Ko et al. (2005)	Absorptive capacity theory	13	2	11	11	—	—
Koh et al. (2004)	Psychological contracting theory	2	—	2	2	—	—
Leidner and Kayworth (2006)	Organizational culture theory	14	3	11	11	—	—
Lewis et al. (2003)	Technology acceptance model	8	2	6	6	—	—
Liang et al. (2007)	Absorptive capacity theory	6	—	6	5	5	1
Liang and Xue (2009)	Technology threat avoidance theory	20	11	9	9	1	—

Table 1. (Continued)

Authors (year)	Name of theory	Number of theory elements	Number of non-ATEs	Number of ATEs	Number of ATEs by type		
					I	II	III
Lilien et al. (2004)	Cost-benefit framework of cognition/fit-appropriation model	13	4	9	9	—	9
Lim et al. (2000)	Theory of impression management	2	1	1	1	—	1
Lowry et al. (2016)	General strain theory	10	—	10	10	—	—
Majchrzak et al. (2000)	Structuration theory	4	3	1	1	—	—
Majchrzak et al. (2005b)	Cooperative learning theory	2	—	2	2	—	—
Majchrzak et al. (2005a)	Critical social theory	1	1	—	—	—	—
Malhotra et al. (2004)	Social contracting theory	8	—	8	8	—	—
Malhotra et al. (2005)	Organizational knowledge creation	12	12	—	—	—	—
McKeen et al. (1994)	Contingency theory	5	—	5	5	—	—
Melville et al. (2004)	Agency theory/game theory	11	5	6	6	—	2
Nissen and Sengupta (2006)	Behavioral decision theory	12	4	8	8	—	8
Pavlou and Gefen (2004)	Institution-based trust/trust transference	12	—	12	12	—	10
Pavlou and Gefen (2005)	Cognitive dissonance theory	15	2	13	13	—	—
Pavlou et al. (2007)	Lemon market	19	4	15	15	5	4
Potter and Balthazard (2004)	Cognitive load theory	4	4	—	—	—	—
Rai et al. (2006)	Resource-based view of the firm	10	—	10	10	—	10
Ray et al. (2005)	Resource-based view of the firm	7	7	—	—	—	—
Salaway (1987)	Organizational learning theory	24	24	—	—	—	—
Sambamurthy et al. (2003)	Dynamic capabilities	9	2	7	7	—	7
Straub and Welke (1998)	General deterrence theory	2	—	2	2	—	—
Subramani (2004)	Transaction cost economics	8	6	2	2	—	—
Sussman and Siegal (2003)	Elaboration likelihood model of informational influence	8	—	8	8	—	—
Tanriverdi (2005)	Knowledge-based theory of the firm	2	—	2	2	—	2
Te'eni (2001)	Task closure theory	33	33	—	—	—	—
Teo et al. (2003)	Institutional theory	12	—	12	12	11	—
Vance et al. (2015)	Accountability theory	7	—	7	7	—	5
van der Heijden (2004)	Technology acceptance model	2	—	2	2	—	—
Venkatesh and Morris (2000)	Feminism theory	8	8	—	—	—	—
Venkatesh et al. (2003)	Theory of Planned Behavior (TPB), Theory of Reasoned Action (TRA), Unified Theory of Acceptance and Use of Technology (UTAUT)	9	8	1	1	—	—
Vessey and Galleta (1991)	Cognitive fit theory	5	3	2	2	—	—
Wasko and Faraj (2005)	Social capital theory	14	1	13	13	—	—
Watson (1990)	Garbage can theory	2	—	2	2	—	—
Weill (1992)	Portfolio theory	4	3	1	1	—	1
Wixom and Todd (2005)	Technology acceptance model	19	2	17	17	—	—
Wixom and Watson (2001)	IS success model	19	—	19	19	—	19
Yi and Davis (2003)	Social learning theory	10	1	9	9	—	—
Zhu and Kraemer (2005)	Technology-organization-environment framework	10	5	5	5	—	4
Zigurs and Buckland (1998)	Multiattribute utility theory	5	5	—	—	—	—
Total		666	238	424	424	73	105
Percent		100	36.3	63.7[a]	100	17.2[b]	24.8[c]

and there is no indication that the level of testing axiomatic theories declines naturally. We now move to a discussion of the vertical analysis results for each theory.

4.3.2. Vertical Analysis of TAM Theory Papers. For the vertical analysis, we identified 79 TAM papers using the aforementioned sampling method. According to this analysis, (a) 18 papers sought to confirm TAM theory with minor modifications, (b) 17 papers added new variables, (c) 7 papers added moderating variables, and (d) 15 papers studied causal factors for antecedents and consequents. Eleven papers combined parts of (b)–(d). Only six papers significantly changed the TAM model. Additionally, we observed that the technology

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Table 2. Vertical Analysis: Number of ATEs (Axiomatic Theory Elements) by Type

Theories	Number of papers	Number of theory elements	Number of non-ATEs	Number of ATEs	Number of ATEs by type		
					I	II	III
Technology acceptance model	79	719	262	457	457	299	127
Percentage			36.4	63.6	100	65.4	27.8
Diffusion of innovation	44	382	97	285	285	264	14
Percentage			25.4	74.6	100	92.6	4.9
Institutional theory	25	200	56	144	144	98	4
Percentage			28.0	72.0	100	68.1	2.7
Total	148	1,301	415	886	886	661	145
Percentage		100	31.9	68.1[d]	100	74.6[e]	16.3[f]
Normalized Percentage			(29.9)	(70.1[g])	(100)	(75.4)	(15.2)

acceptance studies evolved to incorporate the unified theory of acceptance and use of technology (UTAUT; Venkatesh et al. 2003) after it was introduced in 2003.

Of the 719 hypotheses in the TAM theory papers, we judged 457 (63.6%) as axiomatic and 262 (36.4%) as nonaxiomatic. As such, the axiomatic level of TAM theory papers was almost the same as that of the papers in the horizontal analysis. All the axiomatic elements were classified as basic (type I), 65.4% were also deemed inherited (type II), and 27.8% were judged to be visionary (type III). The level of inherited axiomatic theory statements in TAM papers appears to be significantly higher than the average derived from the horizontal analysis (15.8%). But the number of papers extensible to visionary axiomatic goals was similar to the percentage found in the horizontal analysis (24.5%).

Studies adding moderating variables, such as gender effects (Gefen and Straub 1997, Venkatesh and Morris 2000) and entrepreneur-type effects (Ndubisi et al. 2005) generate some interesting results. A forward-looking extension by Venkatesh and Bala (2008) investigates second-tier antecedents, that is, the effects of four factors (individual differences, system characteristics, social influence, and facilitating conditions) on perceived usefulness and perceived ease of use. Devaraj et al. (2008) examine the impact of user personality on technology acceptance in terms of both perceived usefulness and social norms using the five-factor model of personality (conscientiousness, extraversion, neuroticism, openness, and agreeableness), demonstrating the role of individual differences and personality in technology acceptance. Although the Devaraj et al. (2008) study employs a TAM setting, the hypotheses are not axiomatic.

Many inherited axiomatic theory papers apply TAM theory to various applications, such as enterprise resource planning (ERP) systems (Amoako-Gyampah and Salam 2004), laptops (Elwood et al. 2006), internet banking (Wang et al. 2003, Chan and Lu 2004, Pikkarainen et al. 2004), inquiry and purchasing tasks (Gefen and Straub 2000), business-to-consumer websites (Gefen et al. 2003), network environments (Gentry and Calantone 2002), web-based learning systems (Gong et al. 2004), participation in blogs (Hsu and Lin 2008), online games (Hsu and Lu 2004), microcomputer usage (Igbaria et al. 1995), personal computers (Igbaria et al. 1997), online shopping (Klopping and McKinney 2004, Vijayasarathy 2004), wireless internet (Lu et al. 2003), e-commerce (McCloskey 2003), the internet (Shih 2004, Spacey et al. 2004), software packages (Szajna 1994), and instant messaging services (Wang et al. 2004). These studies would have been more interesting had they studied the specific design parameters of usefulness and ease of use for each application and measured the degree of progression in each application rather than merely reconfirming the general validity of TAM theory. This holds true for the next two theories we discuss as well.

4.3.3. Vertical Analysis of Diffusion of Innovation Theory Papers. Diffusion of innovation theory explains how innovations are diffused through a specific population or social system over time (Rogers and Shoemaker 1971, Rogers 1995). In promoting an innovation, different strategies are used to appeal to the five different categories of adopters: innovators, early adopters, early majority, late majority, and laggards. The rate of adopting innovations is influenced by five factors: relative advantage, compatibility, trialability, observability, and complexity (Rogers 1995).

We identified a total of 65 papers employing diffusion of innovation theory through the sampling method described earlier. However, it should be noted that the level of research activity in this specific area has noticeably decreased over the last 10 years. Of these 65 papers, 4 were case-study papers, and 4 were critical bibliography articles. An additional 13 papers lacked both formal hypotheses and propositions. Thus, excluding those 21 papers, 44 papers remained for our vertical analysis. Our analysis revealed 22 papers that sought to confirm diffusion of innovation theory in various contexts with minor

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changes, 4 papers that added moderating variables, and only 6 papers that substantially extended existing knowledge pertinent to diffusion of innovation theory. Of the 382 hypotheses presented in these papers, 285 (74.6%) were axiomatic, and 97 (25.4%) were nonaxiomatic. Of the basic (type I) axiomatic elements, 92.6% were inherited (type II), and only 4.9% were visionary (type III).

A number of studies have advanced the understanding of diffusion of innovation theory. Lai et al. (2016) significantly advance the understanding of innovation diffusion by examining the effects of social behavior (technology imitation) in the context of the usual rational approach (technology evaluation) to the process of IT diffusion and also investigate how external and internal forces moderate the impact of technology imitation and evaluation on ERP adoption and assimilation. Agarwal and Prasad (1998) add a new construct—personal innovativeness—to the IT domain and analyze its moderating effects on the relationship between the perception of a new IT and the intention to use it, offering insights into how individuals adopt new ITs.

A large number of inherited axiomatic theory papers apply diffusion of innovation theory to innovation in a wide variety of areas, such as end-user computing (Moore 1987, Brancheau and Wetherbe 1990), material requirements planning (Cooper and Zmud 1990), EDI (Premkumar et al. 1994, Iacovou et al. 1995, Ramamurthy and Premkumar 1995), financial EDI (Lee 1998), motor-carrier EDI (Crum et al. 1996), the internet (Martins et al. 2004, Park and Yoon 2005), website adoption (Beatty et al. 2001), online services (Parthasarathy and Bhattercherjee 1998), virtual stores (Chen et al. 2002), virtual banking (Liao et al. 1999), mobile internet services (Xu et al. 2017), mobile commerce (Wu and Wang 2005), e-commerce (Eastin 2002, Seyal and Rahman 2003), e-newspapers (Li 2003), intranet (Eder and Igbaria 2001), software-development methodology (Hardgrave et al. 2003), software process (Fichman 2001), object-oriented programming language (Fichman and Kemerer 1997), client/server networking (Forman 2005), telecommunication technologies (Grover and Goslar 1993), multimedia message service (Hsu et al. 2007), wireless application (Hung et al. 2003), integrated services digital network (ISDN) (Lai 1997), smart card–based payment systems (Plouffe et al. 2001), remixing (Stanko 2016), and ERP (Lai et al. 2016). Again, these studies would have been more interesting had they studied the specific design parameters of innovation diffusion for each application and measured the degree of innovation diffusion in each application rather than merely reconfirming the general validity of diffusion of information.

4.3.4. Vertical Analysis of Institutional Theory Papers.

Finally, institutional theory posits that organizations face pressure to conform to rules and belief systems prevailing in the environment because the homogeneity of organizational structure and procedure helps foster the organization's legitimacy (Meyer and Rowan 1977). Organizations adopt homogeneous structures and procedures through three types of pressures: *coercive pressures* are a result of legal mandates or organizational influence, *mimetic pressures* to imitate successful standards are caused by high degrees of uncertainty, and *normative pressures* come from the similar attitudes and approaches of the professional communities and associations resulting from hiring common practices (DiMaggio and Powell 1983).

Using the same sampling method as we did for the TAM and diffusion of information theory papers, we initially collected a total of 63 papers. However, we found that far more case studies were conducted in the research of institutional theory than in the other two theories. Of the 63 papers, 19 present case studies, and an additional 19 lack formal hypotheses or propositions. We therefore excluded those 38 papers, retaining a total of 25 papers for our vertical analysis. This distribution of papers would seem to indicate that institutional theory researchers tend to focus less on confirmative theory testing than do TAM and diffusion of information researchers.

Of the 25 papers, 13 articles sought to confirm institutional theory with slight variations, 3 papers incorporated moderating variables, and 4 articles significantly extended the literature in this particular area. Our analysis of 200 hypotheses drawn from these 25 papers showed that 144 (72%) are axiomatic and 56 (28%) are nonaxiomatic. Of the basic (type 1) axiomatic elements, 68.1% were inherited (type II) and only 2.7% were visionary (type III).

An example of a study that extended the literature considerably in this area is the paper by Angst et al. (2017). This study not only identifies key organizational antecedents (strategic orientation, formal structure, and internal dynamics) influencing a hospital's single-sourcing versus multisourcing configuration for the electronic medical record system but also provides a novel sequence analysis approach to quantifying sourcing configurations. Another noteworthy work is the study by Dibbern et al. (2012), which analyzes the moderating effects of national characteristics (individualism versus collectivism) on the relationships between systemic effects and sourcing decisions. Dibbern et al. (2012) report that systemic impacts influence IS outsourcing decisions differently in more individualistic cultures than in collectivist ones, shedding light on how cultural differences might impact outsourcing decisions.

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As in the TAM and diffusion of information research discussed, many inherited axiomatic theory papers apply institutional theory to different contexts, such as Y2K (Cannon and Woszczynski 2002), e-commerce (Chatterjee et al. 2002, Gibbs and Kraemer 2004), e-business (Wang and Cheung 2004), business-to-business e-marketing (Son and Benbasat 2007), the criminal history system (Laudon 1985), EDI (Premkumar et al. 1997), FEDI (Teo et al. 2003), system investment and replacement (Furneaux and Awade 2017), and green IT (Hu et al. 2016). They are all important application areas, but testing the same level of inherited axiomatic theory does not seem to create critical knowledge, as discussed in relation to the other two theories.

5. Complementary Approaches for Axiomatic Theories

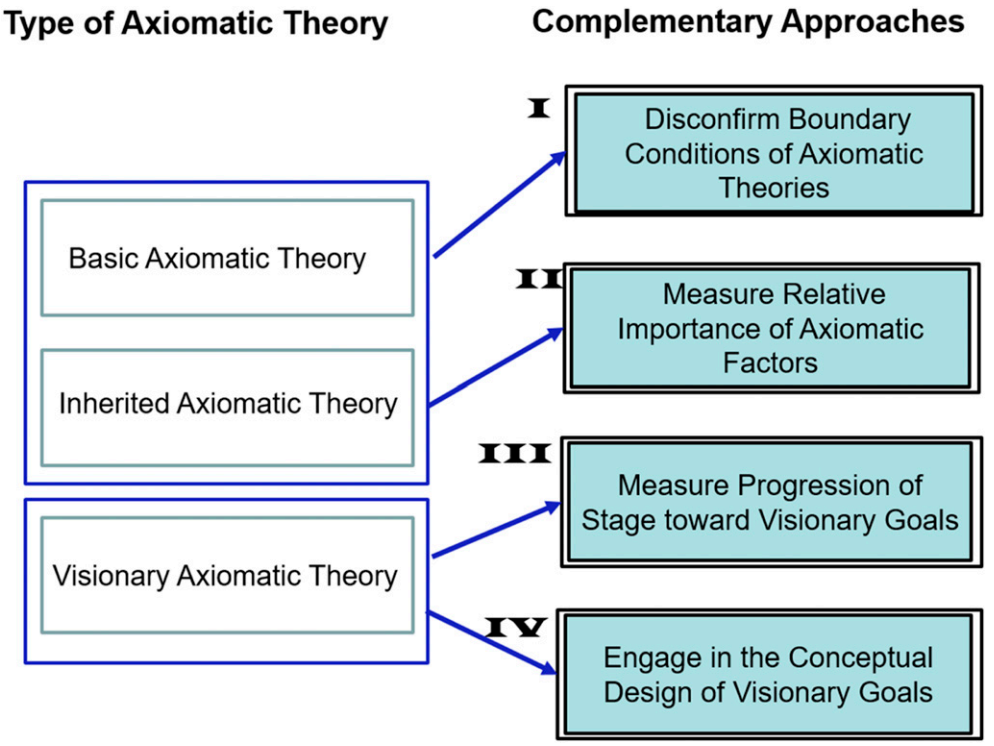
In this section, we propose four complementary research approaches. Their relationships to the types of axiomatic theory are depicted in Figure 4. The first two approaches are associated with the nature of basic and inherited axiomatic theories. We propose *identifying the disconfirming boundary conditions* (approach I) and *measuring the relative importance of axiomatic causal factors* (approach II) in decision-making models. For visionary axiomatic theories, we adopt our third and fourth complementary approaches: *measurement of the stage of progression* (approach III) and *engagement in the conceptual design* (approach IV).

5.1. Identification of Disconfirming Boundary Conditions

Bacharach (1989, p. 496) defines theory as "a statement of relations among concepts within a set of boundary assumptions and constraints." This definition implies that even an axiomatic theory may only be valid under certain implicit boundary conditions. Thus, the endeavor to identify the explicit conditions that disconfirm an axiomatic theory can create new knowledge. As the number of boundary conditions increases, the axiomatic nature of a theory becomes, accordingly, more restricted and specific. However, we found very few research papers that attempted to identify disconfirming boundary conditions. Thus, complementary approach I proposes studying the discovery of disconfirming boundary conditions of axiomatic theories rather than reconfirming the validity of axiomatic theories.

For instance, TAM theory carries the implicit assumption that "IT users = business users" and that users are "utilitarian," even though these boundary conditions are not explicitly stipulated. By extending TAM theory to other populations, such as hedonic users and game players, a boundary of the theory explicitly appears (van der Heijden 2004). In another example concerning the theory of reasoned action defining the sequence of belief, attitude, and intention, an implicit boundary condition is "people = rational decision makers." However, Sheeran (2002) discusses the role of habits and automaticity in

Figure 4. (Color online) Axiomatic Theory Types and Complementary Approaches



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human behavior. For instance, behavior in an urgent situation may be motivated more by the autonomous nervous system or habitual automatic responses rather than by conscious intentional decision making. As such, recognizing boundary conditions could help clarify the effective scope of axiomatic theories.

In some cases, moderating variables may define the boundary conditions of axiomatic theories (Dubin 1978). However, as we have observed from the vertical analysis of TAM theory papers, only four papers in this category study the effect of moderating variables. Venkatesh and Morris's (2000) study is one such example. They conclude that men are more sensitive to perceptions of usefulness and that women are more sensitive to perceived ease of use. Another example of moderating variables can be found in the paper by Becker et al. (2013), which demonstrates the influence of the user's experience level. Clearly, the knowledge generated by such studies is useful and less axiomatic than the original TAM theory.

5.2. Measurement of Relative Importance of Axiomatic Causal Factors

Even though the causal relationship of factors in a theory may be axiomatic, measuring its relative importance for decision making in comparison with other axiomatic factors presents a different issue. Thus, complementary approach II proposes studying the relative importance of axiomatic factors possibly with other nonaxiomatic factors rather than testing the validity of axiomatic factors per se.

For instance, van der Heijden (2004) studies the relative importance of usefulness, ease of use, and enjoyment for hedonic users and finds that enjoyment is more important than usefulness for this group. Although this study does not negate the axiomatic nature of usefulness itself, it demonstrates the need to study the relative importance for contexts. In the case of adopting ERP systems, small companies may not choose a highly powerful and useful ERP system if it is too sophisticated to learn and too expensive to use. Likewise, low-income consumers may not be able to afford useful and easy-to-use smartphones. As such, follow-up studies examining the relative importance in various contexts can help measure the impact of theories on real-world decision making.

In the context of TRA, a number of empirical studies have evaluated the gap between intention and actual behavior. Sutton (1998) evaluates the performance of TRA in predicting and explaining intentions and behavior. Sheeran (2002) demonstrates that the correlation coefficient is only 0.53, and the amount of variation that behavioral intention accounts for is only 28%. We believe that such studies can create far more value than merely retesting TRA in different settings.

With statistical models, Mohajeri et al. (2020) recommends that researchers should offer not only the magnitudes of effect size through the coefficients of independent variables but also the confidence intervals, interpretations of magnitude, and their rationale. They argue that 78% of papers in *MISQ* in 2015 did not offer information regarding practical significance.

The authors also recommend that it should be reported how the effect sizes of dependent and independent variables are relevant in the eyes of identified nonacademic stakeholders. Note that the other disciplines, such as the American Educational Research Association (2006) and the American Psychological Association (2010), have already mandated the reporting of confidence intervals in published papers.

Conjoined analysis may also be adopted for the measurement of relative importance (Luce and Tukey 1964). We argue that more attention should be devoted to contextual measurement research, particularly when the factors are axiomatic, because the discovered data would be capable of creating practical value, even though the methodology remains rigorous and cumulative.

5.3. Measurement of the Stage of Progression Toward Visionary Goals

Many empirical studies regard the data set as a random sample drawn from a total population that can be used to test theories. However, most surveyed data sets are collected at a certain point in time (unless it is a panel data set) with limited representativeness in terms of time, country, technology, and population characteristics. Particularly in studies using visionary axiomatic theories, the data set could be better used to evaluate the stage of progression toward visionary axiomatic goals with distinctive context labels (Jun and Lee 2001) rather than using the data merely to test the visionary axiomatic theories themselves. Thus, complementary approach III proposes adopting the theory-based data-evaluation approach in the context of visionary axiomatic theories instead of the data-based theory-proof approach, as described in Section 3.3.

As an example of the data-based theory-proof approach, recall that the data that Davis (1989) collected were used for the proof of TAM. This was a big contribution. However, if we assume that TAM was regarded as a visionary axiomatic theory, we could then use the theory-based data-evaluation approach. For this illustrative purpose, we could retrospect the data set with a view of measuring the stage of email system progression and label the context as "Year (1989), IT Tool [Email Tool (PROFS), File Editor (XEDIT), Graphics Systems (Chart-Master, Pen-draw)], Region (Canada, USA), Users (IBM Laboratory, MBA Students)" to distinctively define the nature of the data.

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These data could then be contrasted with a new study done in subsequent years with specific design goals, such as "filtering malicious spam email" for email systems. The data collected at different points in time could measure the progression made and diagnose the features that remain unsatisfied. This example illustrates what we mean by research on IS progression stages. The research on this kind of progression stage may adopt the intervention research approach (Siponen and Baskerville 2018) by explaining how and why the progression causes a difference in achieving the visionary goals.

As another example, recall that Rai et al. (2006) examine the causal impact of IT-SCM infrastructure on supply chain process integration with data from manufacturing and retail organizations in 2006. If a follow-up SCM stage theory were developed, the test data could measure the stages of SCM progression rather than simply retesting the postulated axiomatic hypotheses in different settings. This approach would enable the establishment of an SCM knowledge base that could be used to support comparative studies that may take place in different time, location, and industry settings. Such studies could then diagnose the stage of progression toward achieving the ideal goals of IT-enabled supply chain integration and identify what should be the new design for SCM in the context of new emerging technologies such as artificial intelligence.

As such, each application domain would have unique and specific measurements for its stage theory research based on domain knowledge. This kind of IS application-specific research would be cumulative and also informative to practitioners. The comparative study, in conjunction with previous studies, could diagnose differences between domains and could reveal some behavioral limiting factors associated with particular companies, industries, and countries.

Although the financial community has access to a massive financial database and the medical community maintains knowledge bases such as the Cochrane Library (www.cochranelibrary.com) that can be used to study and share information for the good of society, the IS community has no such reliable IS research knowledge base other than published papers and case studies themselves. An accumulated case database with context labels would be capable of supporting academicians and practitioners in their IT-related research and could aid decision making customized to specific applications, industries, countries, and so forth. As such, visionary axiomatic goals could guide the development of a platform for cumulative IS knowledge building that would create a useful research environment supporting studies of the relationship between various types of IT investments and business performance (Sircar et al. 2000).

5.4. Engagement in Conceptual Design of Visionary Axiomatic Goals

We argue that visionary axiomatic theory can also be used as a guide for design science research (Hevner et al. 2004), generating the design goals on which artifacts could be built. Thus, complementary approach IV proposes generating design goals from visionary axiomatic theories, possibly with stage theories that could guide design improvements of new IS products and services. The outcomes of complementary approach IV would pave the road for the progression stage measurements of complementary approach III. Two approaches could sometimes be pursued together, offering an example of interaction between prescriptive and descriptive knowledge, as described in Section 2.2.

As an example of complementary approach IV, suppose that we adopt usefulness and ease of use as visionary axiomatic goals, which could then serve as the foundation for deriving prescriptive design goals. If a visionary axiomatic goal were then not yet fully satisfied, designers could identify the gap between the goal and the current status and identify what kind of design artifact would be necessary to fulfill the goal. IS researchers might include organizational factors as well as technical factors in order to distinguish the IS research from pure technological development. Axiomatic design methodology (Suh 2001) could be adopted as a means of systematically associating design goals with design factors, which are often called *design parameters*.

In the case of an email system, suppose that two goals (such as supporting the "memory management of email addresses" and "filtering malicious spam email") influence the usefulness of email systems in the context of 2019. These are the goals toward which stage theories could be proposed. Because these goals were not recognized when Davis (1989) studied TAM theory, identification of new design goals is important to create the foundation of new design artifacts. In the measurement research of email systems in the context of 2019, users may be quite satisfied with the memory management of email addresses (assume that the user satisfaction level is 8 of 10, for instance) but not quite satisfied with the capability of filtering malicious spam email (assume that the user satisfaction level is 6 of 10). These kinds of application-specific visionary axiomatic goals—for example, the usefulness of email systems—could be defined more clearly, and the stage of progression at certain points in time could be measured by subsequent studies of complementary approach III.

Based on the gap between the current status and ideal goals, the goal of improving the "filtering of malicious spam email" could potentially be designed through adopting Bright eMail, a system that aims to

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eliminate the sources of malicious spam email. In this regard, an example from the vision-driven Bright Internet research underlying Bright eMail (Lee 2019) is useful: The Bright Internet adopts a vision of a preventive cybersecurity paradigm (in contrast to the current protective self-defensive paradigm) through five visionary goals (*origin responsibility*, *deliverer responsibility*, *identifiable anonymity*, *privacy protection*, and *global collaboration*). The visionary principles are justified by logical reasoning and analogical social norms, but no implemented system currently exists (Lee 2015). As the research progresses, the design parameters have become increasingly specified (Lee et al. 2018), and a Bright Internet 1.0 test bed has been designed in cooperation with multiple industry partners who have established the Bright Internet Project Consortium (www.brightinternet.org). One of its functions includes Bright eMail, which aims to preventively eliminate the emission of malicious email from origin sites. As such, designing Bright eMail can be regarded as an example of complementary approach IV, and measuring its performance in terms of the goal of filtering malicious spam email can be regarded as an example of complementary approach III.

By researching such vision-oriented problems, IS design research can prescribe the requirement of technical development research. This kind of academic research also has the capacity to serve as a forerunner to industry, creating useful knowledge for practitioners as well as academicians. For instance, the industry partners of the Bright Internet Project Consortium intend to create new businesses based on the research outcomes of the test bed project. The societal vision–oriented futuristic research requires not only technology development and business models but also policy development because the problems extend beyond the business domain alone (Lee 2016). It is noteworthy that futuristic research also requires a priori experimental analyses for feasibility studies as well as a posteriori empirical justification studies. In this regard, the design research needs to work complementarily with analytical measurement research that is described in complementary approach III.

6. Discussion and Conclusion

This paper identifies a problem with IS theory research, in particular the behavioral research that repetitively conducts empirical tests of axiomatic theories. We offer four complementary approaches for the purpose of yielding more relevant research outcomes in this context. These four approaches by no means serve as an immediate solution to all IS relevance problems, but they should be helpful for cultivating new types of research paradigms. These approaches are not totally new, but we argue that IS researchers need to pay more attention to them.

One question that remains, however, is why so many scholars engage in the empirical testing of axiomatic theories even though the effectiveness of knowledge creation engendered by this method is relatively low. We take a stab at an answer to this question.

6.1. Reasons for the Empirical Testing of Axiomatic Theories

IS departments in business schools experience intense ranking pressure based primarily on the number of papers reported by the *Financial Times* and impact factors related to citation counts, which both have an impact on funding and recruitment success. On an individual level, tenure and promotion decisions increasingly require the publication of papers in top journals. IS researchers, under the mandate of "publish or perish," are keenly aware of the need to answer journal reviewers' questions, which almost invariably include "What is the theoretical contribution?" and "What is the empirical evidence that validates your propositions?" Seeking to answer these common and anticipated questions with minimum risk, an author may choose the stereotypical recipe of using a well-established reference theory as a base and then adding some variables, adopting a different application setting, constructing hypotheses, collecting a reasonable number of data points, and employing rigorous statistical analysis. Topics of this sort are usually inspired by extant literature—which often relies on axiomatic theories—rather than on real-world problems, thus resulting in repetitive empirical testing of axiomatic theories. Though the IS field is full of intelligent and respectable scholars, researchers seeking to survive the gauntlet of tenure or promotion are given little incentive to take research risks.

6.2. Guidance for More Relevant Research

The next question then is how to help scholars escape from the trap of repetitive testing of axiomatic theories. In this regard, journal editors and senior scholars should give signals or guidance that could eventually lead to a research paradigm shift or, at least, to an expansion as, for example, the *Journal of Basic and Applied Social Psychology* has done. Creating new complementary research paradigms—of course, not limited to what we propose here—should be genuinely encouraged during the review process of journals and conferences. Providing the grand vision of research goals and key-stage theories could also offer guidance for junior researchers. The systematic development of such goals by senior researchers

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should also be regarded as an important research contribution that could serve as a solid foundation for creating highly relevant future IS research opportunities. As a field, we should collectively create an environment that fosters solving fundamental social and business problems through IS research. Merely seeking business-level productivity and competitiveness is not enough because recent challenging IS problems emanate from beyond the business boundaries (Lee 2016). The solution must be two-pronged: we must seek to prevent the intellectual waste generated by safe but less fruitful research while also creating new research opportunities in order to cultivate the prosperity of the IS community and increase its impacts on society.

6.3. Further Studies on Axiomatic Theories

We have only just scratched the surface of the issues surrounding axiomatic theories because we have only examined 80 representative theory papers from 72 theory categories and 148 in-depth papers from TAM theory, diffusion of innovation theory, and institutional theory categories. There is much work still to be done on this topic. Future research may collect the judgments of axiomatic theories based on a large number of people in the IS community. Additional vertical analysis may be conducted as "research on research relevance" (Mohajeri and Leidner 2017, p. 5790). It is our hope that many studies will use the proposed complementary approaches introduced here. We believe that behavioral research can uncover new research opportunities by discovering boundary conditions and measuring the relative importance of axiomatic factors in practical business decision-making problems.

Design science researchers in the IS field would also be able to create research opportunities by defining and evaluating the design goals for key IS applications by adopting visionary axiomatic theories. They could also study the measurement of progression stages toward visionary axiomatic goals and build a common IS knowledge platform based on their research outcomes with the context-labeled case databases, which could develop into a cumulative research and consulting platform. Academic societies, such as INFORMS and AIS, need to establish such platforms for the future of the IS community.

Indebted to the previous research efforts and outcomes contributed by talented IS scholars, we are now ready to take the next steps toward creating more relevant outcomes for the IS community and amplifying the social value generated by IS research.

Appendix A. Examples of Identifying Axiomatic Theory Elements

A.1. Horizontal Analysis of ATEs

		ATE type		
Paper title and source	Non-ATE	I	II	III
(2000): "Time Flies When You're Having Fun: Cognitive Absorption and Beliefs About Information Technology Usage," *MIS Quarterly* 24(4): 665–694				
H1: Perceived usefulness of an information technology has a positive effect on behavioral intention to use the information technology.		✓	✓	✓
H2: Perceived ease of use of an information technology has a positive effect on behavioral intention to use the information technology.		✓	✓	✓
H3: Perceived ease of use of an information technology has a positive effect on the perceived usefulness of the information technology.	✓			
H4: After controlling for self-efficacy perceptions, cognitive absorption with an information technology has a positive effect on the perceived ease of use of the information technology.		✓	✓	✓
H5: After controlling for self-efficacy perceptions, cognitive absorption with an information technology has a positive effect on the perceived usefulness of the information technology.		✓	✓	✓
H6: Computer playfulness has a positive effect on cognitive absorption with an information technology.		✓	✓	✓
H7: Personal innovativeness has a positive effect on cognitive absorption with an information technology.		✓	✓	✓

Appendix A. (Continued)

(2005): "Moving Beyond Intentions and Toward the Theory of Trying: Effects of Work Environment and Gender on Post-Adoption Information Technology Use," *MIS Quarterly* 29(3):427–459		
H1a: Quantitative overload negatively influences trying to innovate with IT.		✓
H1b: Qualitative overload negatively influences trying to innovate with IT.		✓
H2: Perceived autonomy positively influences trying to innovate with IT.	✓	
H3: The relationship between autonomy and the trying to innovate with IT will be stronger in men than in women.	✓	
H4: The relationship between overload and trying to innovate with IT will be stronger in women than in men.	✓	
H5a: Autonomy interacts with quantitative overload to positively influence individual's trying to innovate with IT.	✓	
H5b: The above interaction effect will be stronger in women than in men.	✓	
H6a: Autonomy interacts with qualitative overload to positively influence individual's trying to innovate with IT.	✓	
H6b: The above interaction effect will be stronger in women than in men.	✓	
(1998): "Production and Transaction Economies and IS Outsourcing: A Study of the U.S. Banking Industry," *MIS Quarterly* 22(4):535–552[a]		
H1: The higher the comparative production cost advantage offered through IT outsourcing, the greater is the degree of IT outsourcing.		✓
H2: The less the transaction costs involved in hiring outsourcers, the greater is the degree of IT outsourcing.		✓
H3: The less the financial slack, the greater the degree of IT outsourcing.	✓	
(2006): "The Differential Use and Effect of Knowledge-Based System Explanations in Novice and Expert Judgment Systems," *MIS Quarterly* 30(1):79–97		
H1: Knowledge-based system (KBS) users will be more likely to adhere to the recommendation of a KBS when explanations are provided.		✓
H2: When using a KBS with explanation facilities, novices will choose more feed-forward explanations than experts.	✓	
H3: When using a KBS with explanation facilities, experts will choose more feedback explanations than novices.	✓	
H4: When using a KBS with explanation facilities, novices will choose more declarative knowledge explanations than experts.		✓
H5: When using a KBS with explanation facilities, novices will choose more initial problem-solving strategy-based explanations than experts.	✓	
H6: When using a KBS with explanation facilities, experts will choose more procedural knowledge explanations than novices.		✓
H7: Experts that use feedback explanations when using a KBS with explanation facilities will be more likely to adhere to the recommendation.	✓	
H8: Experts that choose more feedback explanations when using a KBS with explanation facilities will be more likely to adhere to the recommendation.	✓	

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Appendix A. (Continued)

(2003):"The Influence of Business Managers' IT Competence on Championing IT," *Information Systems Research* 14(4):317–336			
H1: IT knowledge in business people positively influences their intentions to champion IT in their organizations.	✓		
H2: IT experience in business people positively influences their intentions to champion IT in their organizations.	✓		
(2000): "A Resource-based Perspective on Information Technology Capability and Firm Performance: An Empirical Investigation," *MIS Quarterly* 24(1):169–196			
H1: Superior IT capability will be associated with significantly higher profit ratios.	✓	✓	✓
H2: Superior IT capability will be associated with significantly lower cost ratios.	✓	✓	✓
(2001): "Understanding Information Systems Continuance: An Expectation-Confirmation Model," *MIS Quarterly* 25(3):351–370			
H1: Users' level of satisfaction with initial IS use is positively associated with their IS continuance intention.	✓	✓	
H2: Users' extent of confirmation is positively associated with their satisfaction with IS use.	✓	✓	
H3: Users' perceived usefulness of IS use is positively associated with their satisfaction with IS use.	✓	✓	✓
H4: Users' IS continuance intention is positively associated with their perceived usefulness of IS use.	✓	✓	
H5: Users' extent of confirmation is positively associated with their perceived usefulness of IS use.	✓	✓	
(2004): "Understanding Changes in Belief and Attitude Toward Information Technology Usage: A Theoretical Model and Longitudinal Test," *MIS Quarterly* 28(2):229–254[b]			
RQ1: Do IT users' beliefs and attitude toward IT usage change over time as they experience IT usage first-hand?[c]	✓		
H1: Beliefs (Forward-looking)—(+)→ Beliefs (Modified)			
H2: Beliefs (Forward-looking)—(−)→ Disconfirmation			
H3: Beliefs (Forward-looking)—(+)→ Satisfaction			
H4: Beliefs (Forward-looking)—(+)→ Attitude (Initial)			
H5: Disconfirmation—(+)→ Beliefs (Modified)			
H6: Satisfaction—(+)→ Attitude (Modified)			
H7: Attitude (Initial)—(+)→ Attitude (Modified)			
H8: Beliefs (Modified)—(+)→ Attitude (Modified)			
H9: Beliefs (Modified)—(+)→ Intention (Modified)			
H10: Attitude (Modified)—(+)→ Intention (Modified)			

Notes. Full examples are shown in https://axiomatic-theory.github.io/. H, hypothesis; P, proposition; RQ, research question.

[a] Firm (bank) size was also tested but not hypothesized.

[b] We adopted the first research question (RQ) of three RQs in the paper because it represents the research model (figure 1) of the paper sufficiently.

[c] The authors did not present their research hypotheses explicitly. For your reference, the following hypotheses are derived from figure 1 of their paper.

Appendix B. Time-Effect Analysis of Axiomaticity

B.1. Annual Distribution Table of Axiomaticity Over Time

Year	TAM	DOI theory	Institution theory	Aggregated average
1984		0.83		0.83
1985	0.57		0.93	0.75
1986				
1987		0.83		0.83
1988		0.14		0.14
1989	1.00			1.00

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Appendix B. (Continued)

Year	TAM	DOI theory	Institution theory	Aggregated average
1990		0.53		0.53
1991	0.80			0.80
1992				
1993		0.60		0.60
1994		0.68		0.68
1995	0.86	0.93		0.89
1996	0.40	1.00		0.70
1997	0.36	0.69	1.00	0.69
1998	0.72	0.61		0.66
1999	0.41	0.78		0.60
2000	0.46			0.46
2001	0.79	0.76	0.83	0.79
2002	0.79	1.00	0.70	0.83
2003	0.49	0.94	0.85	0.76
2004	0.81	1.00	0.52	0.78
2005	0.57	0.83		0.70
2006	0.55			0.55
2007	0.38	0.89	0.70	0.65
2008	0.54	0.33		0.44
2009	0.81			0.81
2010	0.90		0.17	0.53
2011				
2012			0.62	0.62
2013	1.00		0.86	0.93
2014	0.67			0.67
2015				
2016		0.50	1.00	0.75
2017		0.57	0.67	0.62
Average	0.66	0.72	0.74	0.69
Standard deviation	0.21	0.23	0.24	0.17

Note. TAM, technology acceptance model; DOI, diffusion of information.

B.2. Annual Distribution Charts of Axiomaticity Over Time

Figure B.1. (Color online) Axiomaticity of TAM Theory

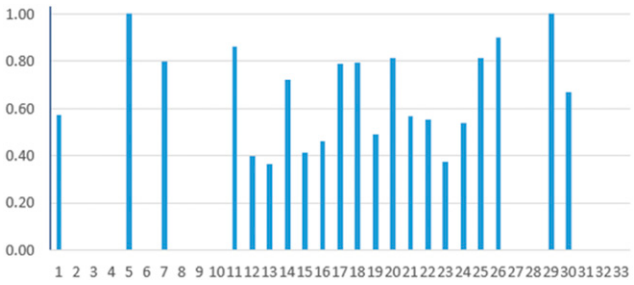


Figure B.2. (Color online) Axiomaticity of Institutional Theory

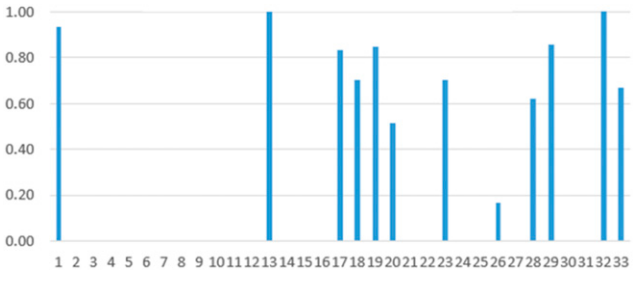


Figure B.3. (Color online) Axiomaticity of Diffusion of Innovation Theory

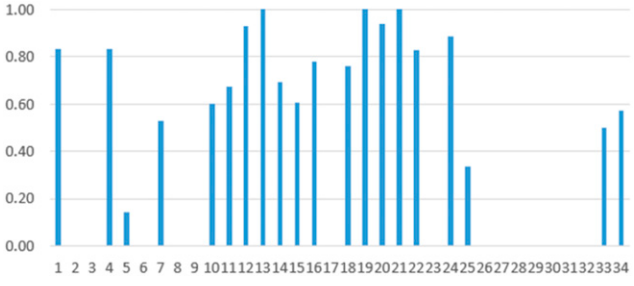
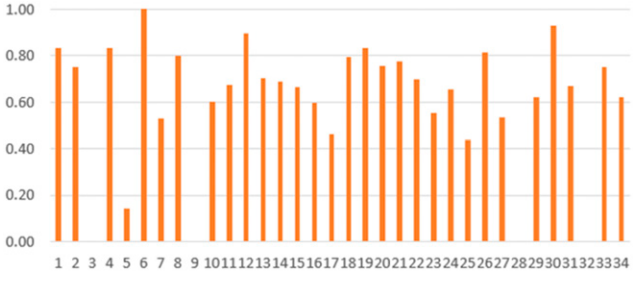


Figure B.4. (Color online) Aggregate Average of Axiomaticity



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Endnotes

[1] While our paper was still under revision, Bandodkar (2015) used the term *axiomatic theory* and presented his own view as to whether studying axiomatic theory is valuable or whether it stagnates IS research at the Americas Conference on Information Systems. But the issues he raised were totally different from the issues we present in this paper.

[2] The superscripts (e.g., [a], [b], [c]) refer to the numbers indicated in the final rows of in Tables 1 and 2, respectively.

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