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The best of times and the worst of times: empirical operations and supply chain management research

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We assess the current state of empirical research in operations and supply chain management (OSM), using Dickens' contrast between the best of times and the worst of times as a frame. The best of times refers to the future that empirical OSM research is now entering, with exciting opportunities available using big data and other new data sources, new empirical approaches and analytical techniques and innovative tools for developing theory. These are well aligned with new research questions related to the digital economy, Industry 4.0, the impact of the millennial generation as consumers, social media, 3D printing, etc. However, we also explore how it is the worst of times, focusing on the challenges and problems that plague empirical OSM research. Our goal is to show how OSM researchers can learn from the worst of times, in order to be poised to take advantage of the best of times. We introduce the research diamond as a vehicle for emphasising the importance of a balanced research perspective that treats the research problem, theory, data collection and data analysis as equally important, requiring alignment between them. By learning and addressing the issues in this period of the best of times and the worst of times, we can take advantage of the opportunities facing our field to generate research that is balanced, insightful, rigorous, relevant, impactful and interesting.

Keywords: Operations management; supply chain management; empirical study; big data; economics; behavioral operations management; Industry 4.0; theory development; assessment of research; future trends and developments

It was the best of times, it was the worst of times, it was the age of wisdom, it was the age of foolishness it was the epoch of belief, it was the epoch of incredulity, … it was the spring of hope, it was the winter of despair … (Charles Dickens: *A Tale of Two Cities*)

Introduction

Although written to describe Paris and London before and during the French revolution, these same words might also have been written to describe the state of empirical operations and supply chain management (OSM) research today. Like the world described by Dickens, empirical OSM research is undergoing a period of profound change that significantly affects both theory and practice. Empirical research methodologies have become widely accepted as valid for investigating some types of research problems, and OSM researchers are well trained in them and poised to take up this challenge. In this sense, it is the best of times.

Yet, some have questioned whether empirical approaches will continue to play an important role in OSM research in the future. There is an abundance of empirical OSM research that exhibits issues relating to the balance between the research problem, theoretical lens, data collection strategy and data analysis strategy that can cause it to be viewed as unimportant, irrelevant or untrustworthy. In this sense, it is the worst of times. While the future promises OSM empirical researchers exciting opportunities to do impactful research of interest to researchers and practitioners, potentially an age of wisdom, it is also a time of significant issues. These issues are not insurmountable; however, thus we present solutions from a compilation of sources, providing a spring of hope for empirical OSM researchers.

OSM is undergoing significant changes, due to a number of developments that are rapidly converging, including advances in technology related to the advent, acceptance and spread of Internet of Things (IoT) and smart devices,

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increased importance of social media, changes in robotics that have simplified their use, deployment and costs, as well as increasing their range of applicability, improvements in 3D printing that have simultaneously reduced costs and enhanced its range of applicability and many other important areas. In addition, there has been an explosion of big data (BD), along with associated analytics. Finally, there are changes in the marketplace itself. Millennials are replacing baby boomers as the major market segment and drivers of demand. They bring with them new demands that have OSM implications, including expecting a personalised customer experience, caring about the values of the companies they buy from, expecting their technology to work, valuing collaboration and co-creation and desiring convenience and speed, without cost (Solomon 2014). There is confusion and concern in both the practitioner and researcher worlds regarding what the future of OSM will look like and how it will operate. This creates demand from practitioners for rigorous, relevant research, which academics are well positioned to deliver, provided that that it is appropriately structured, driven by interesting research questions, grounded in relevant theory and properly executed.

Consequently, the time is right for the OSM profession to take stock of its empirical research in this highly dynamic environment, with a goal of reengineering our skills in light of the changes taking place. Thus, our research question is what can OSM researchers do to improve their empirical research, in order to ensure that it is interesting, relevant and trustworthy in the present and future? We provide recommendations to prevent this from becoming an age of foolishness or a winter of despair. We build our observations on our combined experience of over 70 years as researchers, reviewers, associate editors and editors, using a diamond-shaped model as the framework, in order to emphasise the importance of a balanced perspective. In the following sections, we focus on the four points of the research diamond, describing both issues (winter of despair) and opportunities (spring of hope) associated with each.

OSM empirical research today

The best of times

A review of any recent issue of *IJPR* or several other journals reveals that it is the best of times for empirical OSM research, which has come a long way since its early days (Adam and Swamidass 1989; Flynn et al. 1990). Survey research is commonly used to address interesting and important research problems, and it is well accepted by reviewers and readers. In addition, we are seeing more high quality non-survey empirical OSM research, including case research (Campbell and Sankaranl 2005; Durugbo 2013; Yeung, Lai, and Yee 2007), experiments (Su, Chen, and Ro 2017) event studies (Ni, Flynn, and Jacobs 2016) and other approaches that employ archival data (Chien, Liu, and Chuang 2017; Chong et al. 2017; Jin et al. 2016; Li and Wang 2017; Van der Spoel, Amrit, and van Hillegersberg 2017). Empirical OSM research today builds upon several well-understood theoretical lenses. Researchers are highly skilled in the design and execution of data collection strategies, and the sophistication and rigour of analysis continues to broaden and improve. However, it is important to remember that analysis is only one part of a balanced research process. While data analysis is important, it is not sufficient to compensate for an uninteresting research question, a weak theoretical lens or

Figure 1. The research diamond.

badly conceived data collection. The best research articles achieve a balance between these four elements, described below.

The research diamond

The research diamond (Figure 1), brings together the four critical elements of a balanced research paper. Although there is nothing new about any of them, we argue that many empirical OSM articles suffer from imbalance, due to researchers' preferences for theory development vs. validation or for structured data collection vs. open-ended exploration of emergent findings. The best empirical articles push beyond researchers' comfort zones to achieve a balanced treatment.

The research diamond can be envisioned as a flat, thin diamond-shaped rock that is somewhat precariously balanced on a stalagmite. The four corners of the diamond correspond to the four critical elements of a research paper. As long as it is uniformly thin and remains centred on the stalagmite, the rock will balance. However, if one of the points is thicker than the others or the rock shifts off centre, it will tip and perhaps fall. Thus, the research process should achieve balance between the research problem, theoretical lens, data collection and data analysis, which constitute an interrelated system; changes in any element affect all of the other elements. Like a gyroscope that is self-centering, research that leans too heavily towards one of the elements can quickly careen out of control. This balancing act is at the heart of an effective research process, whether it uses a theory validation or a theory development approach; the most compelling research papers tightly integrate all of these elements.

The research problem

The research problem is the issue or question addressed. An unbalanced research paper that focuses heavily in data analysis isn't sufficient to produce a high quality research paper. It may suffer from having 'excellent tools for gaining answers, but a serious shortage of interesting questions' (Levitt and Dubner 2005). Thus, having an interesting research problem is critical in developing a research project:

> … those who carefully and exhaustively verify trivial theories are soon forgotten; whereas those who cursorily and expediently verify interesting theories are long remembered. (Davis 1971)

Issues

Buried research problem

A research problem that is muddled or obscure fails to guide the other three points of the research diamond. Examples include framing the research problem as simply a restatement of the hypotheses or failing to explicitly state what the research problem is. A reader who has to dig through a paper to find the research problem is like the little boy who found a pile of manure under the Christmas tree and happily started digging through it, shouting, 'there's got to be a pony in here somewhere!' Pony papers are not uncommon in OSM research; the research problem should be clearly stated in the first few paragraphs, rather than buried in rhetoric, in order to position the paper and guide decisions related to the other three points of the research diamond.

Uninteresting research problem

Simply stating a research problem isn't sufficient, if it the problem is uninteresting. Davis (1971) described uninteresting research questions, summarised in the first three rows of Table 1. Although developed in the context of sociology, the same issues are reminiscent of some OSM papers. For example, many 'gap' studies fall in the 'irrelevant' category; just because something hasn't been studied previously doesn't mean that it is interesting or important. Rather, OSM researchers are challenged to develop research problems characterised by the description in the fourth row of Table 1.

Conceptual oversimplification

Oversimplified constructs and relationships can mask what the real research problem is. For example, a substantial amount of OSM empirical research conceives of a supply chain as consisting of simply a customer and a supplier or perhaps a supply chain triad (Choi and Wu 2009). While researchers readily acknowledge that real supply chains are more like networks (Basole and Bellamy 2014; Bezuidenhout et al. 2012; Choi, Dooley, and Rungtusanatham 2001),

Table 1. Types of research questions.

Type	Definition	Reader reaction	OSM examples
Obvious	Questions that don't need to be asked because their answers are widely accepted or readily established through logic and reasoning	• Of course • It goes without saying • Everyone knows that	• Does lead time affect the reorder point? • How is quality management implemented in [fill in the country]?
Absurd	Challenges an entire set of assumptions, suggesting that everything we previously believed to be true is actually false	• That's crazy • That doesn't make sense	• Are economies of scale no longer relevant? • Decision makers are completely rational
Irrelevant	Questions whose results have little practical value	• So what? • Who cares? • Why bother?	• What is the impact of rounding errors after the 25th decimal place? • Do companies have different purchase motivations?
Interesting	Questions that: • Challenge taken-for-granted beliefs • Have a practical, as well as theoretical, dimension • Deny some part of present practical activity • Propose new practical activity • Depart noticeably from the mainstream, without being absurd • Present an interesting spin • Propose a perspective that departs from the ubiquitous	• That's interesting • That's important • I want to continue reading • This is really exciting	• Does trust help or hinder a supply chain relationship? • Is factory focus as efficient as we believe?

Source: Based on Davis (1971).

there is a tendency to focus on small fragments of supply chains. This may be justified as learning about fragments to generalise to a broader network (Benton and Maloni 2005), but it many cases, this conceptual oversimplification is simply for the researchers' convenience.

Research problems may also be limited by researchers' methodological limitations; if survey methods are their only skill, the supply network is assumed away so that they will be able to easily apply a survey to collect data. The data collection strategy should be aligned with the research question. In the case of a supply network, a deep dive into the rich details of a few supply networks using an inductive approach would be more informative than a survey.

Overly pragmatic problems

Many interesting research problems have their roots in current events; for example, product recalls by Mattel, Toyota and others led to interesting research problems that have guided a number of papers (e.g. Hora, Bapuji, and Roth 2011; Ni, Flynn, and Jacobs 2016; Roth et al. 2008). The issue with such papers, however, is the temptation to focus too heavily on the actual event, rather than placing it in the larger context of theory. This runs the risk of a paper that reads like a consulting report, rather than a research article. This can be a particular problem for action research and engaged research (Touboulic and Walker 2016), where the researcher becomes deeply embedded in the context of a firm. Grounding practical research problems in theory helps guide the research toward generalizable conclusions that are both practical and make an academic contribution. Thus, while research problems grounded in the real world are interesting and important, maintaining balance between the four points of the research diamond is critical to developing them into strong research.

Time myopia

Time myopia is illustrated by cross-sectional research questions, which are typical of survey research. While acknowledgement of the need for longitudinal research questions is often part of a survey study's list of limitations, there may be a reluctance to actually tackle such problems. Longitudinal analysis faces the challenge of transitions between states, making standard data analysis approaches inappropriate. It is tempting to allow analytical shortcomings of survey methodology to dictate research questions, leading to the study of less interesting problems. Development of longitudinal case studies may be more tenable and better aligned with this type of research question than a survey.

Space myopia

Space myopia is related to locally focused research problems. Although OSM research is not as exclusively U.S.-focused as it was in the past, it remains mostly local; research conducted in a single country, such as China, is only generalizable to that country. Global research problems that transcend national boundaries call for comparisons between regions. There are many methodological challenges inherent in survey and case study data collection strategies that cross national boundaries (Farh, Canella, and Lee 2006; Tsui 2006), thus, as empirical OSM research moves towards truly global research problems, there will be a need to apply innovative data collection and analytical approaches.

Opportunities

Although these issues may conjure a winter of despair, we view them as opportunities to improve empirical OSM research. Thus, we pose opportunities that represent the spring of hope, helping empirical OSM research to be more significant and relevant.

Interesting research questions

An interesting research question (see the last row of Table 1) captures readers' attention.

> The first criterion by which people judge anything they encounter, even before deciding whether it is true or false, is whether it is interesting or 'boring'. (Davis 1999, 245)

An interesting research question is counterintuitive, without being absurd, challenges established theory (Bartunek, Rynes, and Ireland 2006), and causes readers to want to read farther, by proposing something intriguing (Davis 1971). Barley's (2000) rock and roll metaphor (Table 2) nicely describes characteristics of interesting research questions.

Table 2. Rock and roll metaphor for interesting research questions.

Criterion	Definition	Example
Uncomfortable	The familiar, while comfortable, isn't always interesting. An interesting research question should move beyond what is comfortable	*I love the Greatful Dead's music. Although it is very familiar, it isn't interesting to me because I don't find it to be new or unique*
Challenging	Seeing something as interesting and enjoying it aren't synonymous. Don't be afraid to tackle challenging research questions	*While I find Nirvana's heavy metal sound interesting, I don't especially enjoy listening to it*
Important	Being interesting doesn't necessarily imply being important. Focus on importance, rather than uniqueness or filling gaps	*Tiny Tim's falsetto 'Tiptoe Through the Tulips,' accompanied by a ukulele is interesting, yet imminently unimportant.* (If you don't remember Tiny Tim, you will be quickly convinced by this video: https://www.youtube.com/watch?v=zcSlcNfThUA)
Tacit	There is a tacit component to being interesting. A good research question has an interesting tacit component	*Nobody is able to replicate the sound of Jerry Garcia's guitar playing, no matter how much they study his music. The late Mr. Garcia couldn't have probably even have articulated what was unique about it*

Source: Adapted from Barley (2000).

Parsimony

The research problem should provide a simple, clean causal model with a strong theoretical rationale for the *why* underlying each link. For example, Hora and Klassen (2013) used only two constructs in their vignette-based experiment on knowledge acquisition during large scale, low frequency losses. This allowed them to develop a rich, detailed rationale for each hypothesis, leading to clear, concise and memorable conclusions. In contrast, OSM models often contain 10–15 constructs with 20 or so links between them, causing readers to have difficulty recalling the most important findings or even what the focal construct was.

Framing of research questions

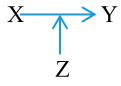
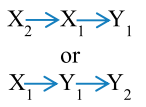
A research question should have a single focal construct, which is its most memorable and interesting element (Whetton 2009), illustrated in the first two rows of Table 3. In both examples, psychological trust is the focal construct; it is the independent variable in the first example and the dependent variable in the second. Thinking about what the focal construct is can be helpful in developing a logical and concise research question, as well as framing the theory to support it.

Contribution to knowledge

A good research problem makes a contribution to knowledge. Huff (2009) provides a useful list of ways that research can make a contribution to knowledge, in the order of increasing diversity and doubt.

- *Speculation:* A curious or provocative idea or phenomenon that cannot be explained by current theory.
- *Assertion:* A new subject explains things (or is explained by things) that researchers should know more about.
- *Clarification:* Expansion of knowledge about an interesting construct by providing details about its composition or causal connections.
- *Reiteration:* Reinforcement that improves understanding of an interesting construct.
- *Adjustment:* Misunderstood or overlooked phenomena indicate that a construct has different components or causal relationships than previously believed.

Table 3. Development and improvement of theoretical propositions.

Focal construct	Framing	OSM example
Framing		
Independent variable	Given the importance of Y, you'll be interested to learn about my proposed new antecedent X_a	Given the importance of competitive performance, you will be interested to learn about my proposed new antecedent, psychological trust
Dependent variable	Given the importance of X in this research conversation, you'll be interested to learn about my proposed new consequent Y_a	Given the interest of the OSM research community in lean, you will be interested in learning about its effect on psychological trust
Improvement		
Add a Z-moderator		Given this conversation's acceptance of X → Y, you'll be interested in my proposal that Z operates as a moderating condition
Add a Z-mediator		Given this conversation's acceptance of X → Y, you'll be interested in my proposal that Z operates as a mediating factor
Add an X		Given this conversation's acceptance of X → Y, you'll be interested in my proposal that the explanation of Y is significantly enhanced by the addition of X_2
Add a Y		Given this conversation's acceptance of X → Y_1, you'll be interested in my proposal that X also explains Y_2
Build out a proposition into a complex model		Given this conversation's acceptance of X → Y, you'll be interested in my proposal to 'graft on' an antecedent condition (X_2) or subsequent outcome (Y_2)

Source: From Whetton (2009).

- *Negation:* A new construct is more important or significant than a standard construct.
- *Synthesis:* A broader explanatory framework resolves apparent contradictions between two interesting constructs and shows how both are important.
- *Redirection:* A different subject is more interesting and more significant than a standard subject.
- *Rebuttal:* Argues or provides evidence that reestablishes that a construct is interesting and significant, although some scholars have had doubts about its importance and significance.

Metaphors

Just as Barley's (2000) rock and roll metaphor helps define the nuances of the 'interesting' construct, metaphors can be used to help a wide range of readers understand a challenging research construct (Foropon and McLachlin 2012). An easily visualised metaphor, like scouts hiking on a trail (Goldratt 1992), develops understanding of difficult-to-comprehend constructs like the interaction between dependent events and statistical fluctuations. For example, Wu, Melnyk, and Flynn (2010) used a kitchen as a metaphor for subtle distinctions between operations practices, capabilities and resources. We employ a number of metaphors in this paper, including a hammer, a pony, bread dough, rock and roll, a large flat rock and a gyroscope. Examples of OSM metaphors include a sandcone (Ferdows and DeMeyer 1990), a funnel (Clark and Wheelwright 1993), boiling frogs (Cattani et al. 2006), a canary cage (Clark and Wheelwright 1993) and rocks in a river.

Paradoxes

A paradox presents two contrary perspectives; taken separately, each is incontestable (Poole and Van de Ven 1989). Davis (1971) provided a set of generic paradoxes, summarised in Table 4. A paradox can be resolved through a shift in perspective or by posing the problem differently; thus, a paradox can be useful in developing interesting research questions. Options for dealing with a paradox include:

- Live with it
- Use temporal separation to explain it (e.g. firms at different stages of development will respond differently)
- Use managerial separation to explain it (e.g. what people at the operational level think about is different from what people at higher levels think about)
- Revise the theory to accommodate the paradox (Poole and Van de Ven 1989)

For example, Powell's (1995) research built on the function paradox: Total Quality Management (TQM) resulted in high performance for some firms, but not others. Westphal, Gulati, and Shortell (1997) addressed this using temporal separation, proposing that early TQM adopters were motivated by economic factors, while later adopters were motivated by customer pressure, resulting in customised vs. standardised TQM implementation. However, in revisiting this paradox, Benner and Veloso (2008) argued that both early and late adopters were motivated by economic factors, and Kennedy and Fiss (2009) dismissed Westphal, Gulati, and Shortell's (1997) two-sample approach, noting that there were equivocal outcomes related to the economic benefits of innovation adoption. In other words, both early and lagged beneficiaries exist. Thus, a paradox can lead to a research problem that inspires a stream of subsequent research.

Theoretical lens

Thoughtful application of theory guides addressing the research problem in a manner that allows knowledge to be systematically accumulated (Amundson 1998; Van de Ven 2007), helping researchers generate coherent explanations, rather than data dredging (Hambrick 2007; Weick 1989, 1995; Whetton 1989). As noted by Van de Ven (2007), nothing is as practical as good theory. Theory provides a way to 'make sense of what would otherwise be inscrutable or unmeaning empirical findings (Gaile, Clarke, and Huff 2009, 286).' It is what makes a field like OSM a science, rather than a set of practices or an art, providing a roadmap for investigating the research problem, elucidating relevant constructs and expected relationships between them, and avoiding extraneous constructs and relationships.

Theory is independent of the data collection approach; whether a survey, case research, direct observation, action research or an experiment is used, it should be guided by theory or used as a means to develop theory. *Theory validation*, the approach used in OSM survey and experimental research, applies existing theory, through replication or to a novel context; it is a deductive approach. In contrast, *theory development* is inductive, focusing on developing unique theory that proposes new constructs and relationships or makes very major modifications to existing theory, often

Table 4. Generic research paradoxes.

Paradox	Description
Organisation	• What seems to be an organised (structured) phenomenon is in reality an unorganised (unstructured) phenomenon • What seems to be an unorganised (unstructured) phenomenon is in reality an organised (structured) phenomenon
Composition	• What seem to be assorted heterogeneous phenomena are in reality composed of a single element • What seems to a single phenomenon is in reality composed of assorted heterogeneous elements
Abstraction	• What seems to be an individual phenomenon is in reality a holistic phenomenon • What seems to be a holistic phenomenon is in reality an individual phenomenon
Generalisation	• What seems to be a local phenomenon is in reality a general phenomenon • What seems to be a general phenomenon is in reality a local phenomenon
Stabilisation	• What seems to be a stable and unchanging phenomenon is in reality an unstable and changing phenomenon • What seems to be an unstable and changing phenomenon is in reality a stable and unchanging phenomenon
Function	• What seems to be a phenomenon that functions ineffectively as a means for the attainment of an end is in reality a phenomenon that functions effectively • What seems to be a phenomenon that functions effectively as a means for the attainment of an end is in reality a phenomenon that functions ineffectively
Evaluation	• What seems to be a good phenomenon is in reality a bad phenomenon • What seems to be a bad phenomenon is in reality a good phenomenon
Correlation	• What seem to be unrelated (independent) phenomena are in reality correlated (interdependent) • What seem to be correlated (interdependent) phenomena are in reality unrelated (independent)
Co-existence	• What seem to be phenomena that can exist together are in reality phenomena that cannot exist together • What seem to be phenomena that cannot exist together are in reality phenomena that can exist together
Co-variation	• What seems to be a positive co-variation between phenomena is in reality a negative co-variation between phenomena • What seems to be a negative co-variation between phenomena is in reality a positive co-variation between phenomena
Opposition	• What seem to be similar (nearly identical) phenomena are in reality opposite phenomena • What seem to be opposite phenomena are in reality similar (nearly identical) phenomena
Causation	• What seems to be the dependent phenomenon in a causal relation is in reality the independent phenomenon • What seems to be the independent phenomenon in a causal relation is in reality the dependent phenomenon

Source: From Davis (1971).

through case studies or action research. In the following sections, we describe issues with both OSM theory validation and theory development research, as well as proposing opportunities for improving each.

Theory validation

Theory validation research builds upon deductive reasoning, which draws upon a positivist worldview (Huff 2009). It assumes that it is possible to accept or reject claims and that observations of phenomena do not vary significantly between observers. Theory is validated by comparison and selection among different theories, typically analysing data collected through surveys, experiments or some types of archival data. A theory validation approach applies the research diamond by beginning with formation of abstract generalisations to develop a research problem that is used to make a theoretical statement that one class of phenomena will be connected in some way to another class (Huff 2009). Logical deduction and operationalisation of the constructs form the base for implied empirical statements, which are tested by collecting observations to see whether they hold or not.

Theory validation issues

Insufficient understanding of what theory is. Although it may seem self-evident, the distinction between a literature review and a theoretical lens is not always clear, driving some OSM empirical researchers to the winter of despair. A literature review positions research in the extant literature and, as such, is a necessary part of a good research paper. However, it doesn't provide a roadmap for addressing the research problem, specify key constructs and relationships between them or describe how the research advances scientific knowledge. Much what OSM authors describe as theory is actually literature review; effective use of an appropriate theoretical lens is a hallmark of the best research papers.

Wrong theory. Because OSM doesn't have a large body of unique theory, researchers borrow established theory from fields with a richer theoretical base. Commonly cited theories in empirical OSM research that have their roots in other fields include the resource based view (Barney, Wright, and Ketchen 2001), transaction cost economics theory (Williamson 1975, 1981), agency theory (Jensen and Meckling 1976), institutional theory (DiMaggio and Powell 1983), social network theory (Granovetter 1973), complex adaptive systems theory (Bezuidenhout et al. 2012; Pathak et al. 2007) and behavioural economics (Tversky and Kahneman 1974). However, there is a tendency to select theories (the resource based view is a particular favourite), without considering their alignment with the research problem. While some OSM research papers apply RBV very effectively, many more do not; it is not a one-size-fits-all lens for all research problems.

Forced theory. Theory, while usually referred to by OSM empirical researchers, it isn't always employed to guide their research. When a theoretical lens is added *post hoc,* after empirical data has been collected and analysed, it appears forced (Gaile, Clarke, and Huff 2009). This primarily descriptive approach simply reiterates what a theory states, but fails to capitalise on its power to ground a research problem in a systematic field, then use it to guide data collection and analysis. Using a theoretical lens to guide research is challenging. It is like kneading bread dough; it must be thoroughly worked in order to yield insights, along with some resting periods for reflection, allowing insights to 'rise.' However, with the same amount of kneading, pie dough would become tough and break apart, thus, good bakers avoid overworking pie dough. OSM researchers often treat theory as though it were pie dough, avoiding overworking it. However, it is only through thoroughly working theory, along with reflecting upon it, that important insights result.

Overreliance on economics-based theories. OSM validation research applies several economics-based theories, such as RBV, transaction cost economics theory and agency theory, which assume that decision-making is driven by an optimality goal and that behaviour occurs in a state of equilibrium and rational determination (Bromiley 2005). However, optimisation may be impossible because of missing information or the complexity of real world research problems (Simon 1979). Thus, many economics-based theories have not performed well in an OSM context (Bromiley 2005), suggesting the need for theory development, rather than theory validation, for some research questions and the need for applying other theory bases.

Misapplied theory. Sometimes an appropriate theory is applied, but it is not applied properly, resulting from a tendency to repeat what was learned from other authors' descriptions of the theory, rather than reading the original theoretical exposition. This is akin to reading the *Cliff Notes* version of a classic piece of literature, rather than reading the actual book; while popular among high school students trying to outsmart their English teachers, it isn't a good approach to mastering theory or ferreting out the elements that will help guide investigation of a particular research problem.

Terminology issues. Terminology issues arise when drawing upon theory in other fields. For example, in applying organisational information processing theory (OIPT) (Galbraith 1973, 1977) to supply chains, Koufteros and Marcoulides (2006) struggled with the dilemma of remaining true to OIPT by referring to 'organisational subunits,' vs. reflecting the language of supply chain management by referring to 'supply chain members' or 'customers and suppliers.' Using the language of supply chain management risked losing the connection to OIPT, however, using the language of OIPT could make the research inaccessible to the supply chain research community.

Sloppy operationalisation. A hallmark of science is its precision of key constructs. Empirical OSM researchers' tendency towards jargon ('confused, unintelligible language', http://www.merriam-webster.com) and definitional sloppiness causes confusion and difficulty generalising their results to broader theory. For example, capabilities, distinctive competencies, competitive priorities, competitive advantages and resources are sometimes used interchangeably. Other sets of problematic terms include risk, uncertainty and complexity; collaboration, integration and strategic alliances; and fit,

alignment and consensus. There are at least 15 definitions of resilience, ranging from a reactive (post-disruption) capability (Christopher and Peck 2004; Sheffi and Rice 2005) to a proactive, preventive capability (Ponomarov and Holcomb 2009).

Oversimplification of assumptions. Although Occam's Razor states that, among competing theories, the one with the fewest assumptions should be selected (Gauch 2003), it is important that simplification of assumptions does not compromise analysis and results. Much OM research builds upon the implicit assumption that relationships are linear, for example, implying that, as the number of suppliers is reduced, performance should improve. Yet, an inverted-U relationship is more realistic; too many or too few suppliers can adversely affect performance (Choi and Krause 2006). In another example, some operations strategies are failure preventers (a step function), while others are success producers (an exponential relationship) (Rajan 1985). Relaxing the assumption of linearity can lead to exciting theoretical developments, such as order winners and order qualifiers, which follows a step function (Hill 2000).

Generalisation to a different unit of analysis. Unit of analysis issues are challenging when applying theory that was originally developed for a different field. Many of the areas from which OSM researchers borrow theory focus on individuals, while OSM research focuses primarily on firms, raising generalizability issues (Yukl and Falbe 1991). For example, there is a strong theoretical foundation on power in the organisational behaviour literature, where it is viewed as a manager's personal characteristic (Tannenbaum 1968). However, supply chain power is a characteristic of the relationship between a source and target firm (Sullivan and O'Connor 1985). The behavioural research on intraorganisational power primarily focuses on communities of governmental, political, recreational and religious organisations that do not necessarily engage in economic interaction (Hickson et al. 1971), so its applicability to supply chain power is limited. Thus, there is a question of whether the theory base on individual power base can be extended to the independent, yet interdependent, members of a supply chain (Huo, Flynn, and Zhao, 2017).

Theory validation opportunities

Although there are many issues with OSM theory validation research, there are also a number of means for remedying them.

Broader perspectives. Huff's (2009) description of scholarship as a conversation is useful in finding relevant theory to guide a theory validation project. Clues about a relevant theoretical conversation can be found in biographical information about scholars, association sites, informal interactions at conferences, co-citation in formal publications, being open-minded about the potential applicability of theories from other disciplines, staying alert to new developments at conferences and so forth. The research diamond suggests reflection upon the research question, then actively seeking an appropriate theoretical lens, trying several alternative theories before deciding which is the best fit. This process necessarily involves making challenging decisions about unit of analysis and terminology adoption vs. adaptation issues.

Go to the source. In developing a meaningful research question using deductive reasoning, we have found tremendous value in returning to the source, reading the original exposition of a theory. Subtleties and nuances that other researchers may have not noted can be potentially useful in providing an effective theoretical lens. We have found this to be very helpful in moving beyond superficial application to actively working the bread dough of a theory.

Consider behavioural theories. Moving beyond economics-based theories can open a new window of potentially relevant theoretical lenses to OSM empirical researchers. Behavioural theories view decision-making as a social process influenced by the actions of others. Because it is people who ultimately make OSM decisions, constructs such as bounded rationality, routines, aspirations, satisficing, trust and selective perception are important. Behavioural theories provide a useful and exciting complement to economic theories (Bendoly, Donohue, and Schultz 2006; Croson et al. 2013; Hill et al. 2009; Riedel and Schildberg-Hörisch 2013) by taking the perspective that people are not the rational, economically-driven operators that economics-based research assumes (Tversky and Kahneman 1974). Rather, they are satisficers (Bromiley 2005; Simon and Newell 1972), who search available alternatives until an acceptable threshold has been met.

Positive positioning. Theory validation research should be a no-lose proposition, rather than a source of fear that the research will be a failure if the hypotheses are not supported. If a strong theoretical foundation is used as the lens, then all potential outcomes should be equally attractive. On the one hand, if a well-accepted theory is found to be relevant to

a new context, this is interesting and provides further validation of the theory. On the other hand, if it is found to not be relevant in a different context, this is perhaps even more interesting. Rather than feeling defeated, researchers should instead regard this situation as an opportunity to make a unique contribution to the scientific knowledge about the relevance of a theory in various contexts.

Competing theories. Another win–win use of theory is to frame a research problem in terms of competing theories. Because of the imprecision inherent in the social sciences, there can be alternative theoretical explanations for the same research problem. For example, Hui et al. (2004) tested whether two-factor theory or fairness heuristic theory was a better fit for quality management. Testing competing theories provides a powerful and interesting foundation for low-risk research; the results will inevitably support one theoretical explanation better than the other, ensuring a positive outcome.

Theory development

Because theory development seeks to propose new constructs or relationships between them to modify or develop new theory, it is well aligned with qualitative data, collected via interviews (Laihonen and Pekkola 2016; Samson and Gloet 2014; Sezen, Karakadilar, and Buyukozkan 2012), observation and engaged approaches (Touboulic and Walker 2016) such as action research (Baker and Jayaraman 2012; Carvalho, Scavarda, and Lustosa 2014; Danese and Vinelli 2009; Ross, Jayaraman, and Robinson 2007). It uses an inductive approach, building on an interpretivist perspective (Huff 2009), where meaning is linked to specific observations in specific settings. Thus, theory development uses the research diamond in a different way than theory validation. Rather than beginning with a research question supported by theory and using it as the basis for designing the data collection and analysis strategy, theory development begins with data collection. Through various analytical approaches that are frequently qualitative, themes emerge, which are the basis for developing new constructs, proposing new ways in which constructs are related and using them to modify existing theory or develop new theory. Inductive approaches are based on listening to the story that the data tells, which can be challenging for researchers who are accustomed to using a deductive approach to approach data based on a predetermined theoretical framework. Inductive approaches are also appropriate for taking an initial cut at BD (e.g. Shah and Liu 2006), helping to avoid becoming distracted by its volume and variety of constructs.

Theory development issues

Lack of theory development. Theory development can seem intimidating, especially in a field such as OSM, where theory is primarily borrowed from other fields. What is called theory development in OSM frequently isn't. Pointing out the limitations to a theory's range of application is not sufficient to make a theoretical contribution (Hambrick 2007; Sutton and Staw 1995; Weick 1995; Whetton 1989). When research positioning focuses primarily on questions of *what* and *how* a proposition may be improved or another construct added, this doesn't develop new theory. Similarly, a focus on questions related to *who* and *where* simply apply an old theoretical model in a new setting.

Making a theoretical contribution lies in the *whys* (Whetton 2009), which are the theoretical glue that holds a model together, specifying the dynamics that underlie a model and providing a compelling case for why they should be believed. While the *whys* are the most fruitful avenue for theory development, they can also be the most challenging (Whetton 2009).

Inappropriate application of deductive reasoning. Theory validation is inherently backward-facing as it applies deductive reasoning to move from abstract concepts to empirical testing. Because of this, the best that can be expected from theory validation is validation of existing theory. While this may be appropriate in some contexts, it is not appropriate for research that seeks to reveal new insights and develop theory. Rather, inductive approaches are appropriate when the goal is theory development. These require the use of different data collection and analysis strategies (Eisenhardt 1989; Miles, Huberman, and Saldanha 2014; Yin 2013). For example, grounded theory (Glaser and Strauss 1967) employs the following steps:

- Extensively describe a situation, without using specialised academic vocabulary.
- Code the description to create first-level substantive categories.
- Modify and improve the codes, as additional data is collected, categorised and compared.
- Conclude empirical observations when further new categories are not required to account for further observations.

Theoretical insights emerge as the categories stabilise and their relationships become apparent. Examples of OSM research employing grounded theory include Dowlatshahi (2005), Chiarini and Vagnoni (2015), Narasimhan, Narayanan, and Srinivasan (2010) and Binder and Clegg (2006).

Unnecessary model complexity. The models that empirical OSM researchers develop are often overly complex, with a large number of constructs and proposed relationships between them. This can make it very challenging to fully explain each of the *whys* within page limitations. In other fields, theoretical models are often simpler, containing only a few constructs. This allows each construct to be thoroughly developed and the *why* behind each proposed relationship to be strongly justified. Parsimonious, well justified theory is preferable to complex, superficial theory, however, this may require a mindset change among researchers and reviewers.

Unnecessary model symmetry. In developing theoretical models, OSM researchers seem to have a preference for symmetry. However, a model should only be symmetric if there is theoretical justification. For example, if there is no justification for the assumption that customers and suppliers will perceive a focal firm's power in the same way, then the model shouldn't be symmetric. This is related to our previous statements about complexity; if a relationship (link) can't be clearly theoretically justified, then it shouldn't be included.

Restriction to macro perspective. Most OSM research focuses on the macro (plant or firm) level of analysis (Rothaermel and Hess 2007). The implicit assumption that firms at the same level will perform in similar ways often results in a performance paradox, where two firms that are seemingly identical at the macro level exhibit very different performance patterns. This phenomenon is supported by the mixed findings of research that indicates some firms have significantly benefited from developments such as MRP (Orlicky 1975), TQM (Ebrahimpour 1985), Six Sigma (Delsanter 1992), or Lean (Krafcik 1988), while other similar organisations have not (e.g. Bhasin and Burcher 2006; Voss 1992). This suggests that macro level theories may not be sufficient to explain differences in OSM performance. Ployhart, Weekley, and Baughman (2006) noted that, while lower-level constructs are formative of the higher-level constructs, this logic does not work in reverse; the presence of a high-level construct does not uniquely identify the micro-level state. This implies that macro-level observations do not reveal much about the micro level, and thus may not be a useful basis for theory in predicting future results.

Theory development opportunities

Apply graphic modelling. The results of theory development are often displayed in a graphic model, using boxes and arrows to portray relationships. A good theory should be parsimonious enough that it can be concisely described using a graphic model, yet rich enough that it requires textual discussion to explain it (Whetton 2009). OSM graphic models often fail to serve as a foundation for construction of theoretical propositions that can withstand logical and empirical scrutiny.

Table 5 summarises guidelines for developing effective theoretical constructs, either focal or complementary, in order to increase the precision of terminology and comparability of OSM theories. In developing a graphic model, it is useful to record a textual explanation for each arrow, ensuring that only those that are associated with theoretical explanations are included. Once the focal and complementary constructs have been identified and described in a simple $X \rightarrow Y$ proposition, more complex propositions can be developed (see Table 3). Note that only the side of the proposition that contains the complementary construct is expanded (Whetton 2009), in order to ensure that the focal construct isn't downgraded or diluted. Before finalising a graphic model, it is useful to draw an oval around it and add relevant assumptions around the perimeter. Contextual assumptions delimit the conditions under which a theoretical model holds (Whetton 2009), while conceptual assumptions help differentiate between scholarly conversations (Huff 2009), for example, behavioural versus economic perspectives of an OSM issue.

Metaphorical transfer. Metaphorical transfer (Chen et al. 2013) is a systematic approach to developing theory by transferring understanding from a better-known source phenomenon to a lesser-known target phenomenon. A theory-constitutive metaphor (Boyd 1993; Morgan 1980) is different from a casually invoked metaphor, such as the rocks and river metaphor. For example, Chen et al. (2013) used divorce as a theory-constitutive metaphor for dissolution of a supply chain relationship, drawing upon the sociological literature on divorce theory. Conceptual equivalence is established through translation of knowledge from the domain of the source phenomenon (sociological principles of divorce) to the domain of the target phenomenon (supply chain relationship dissolution) at various levels of abstraction. At each level,

Table 5. Guidelines for development of theoretical constructs.

To the extent possible, use generally accepted scholarly constructs, and stick with their proper names: • Express as a noun or a 2–3 word noun phrase • Use your creativity in the way that you combine constructs, not in the names that you give them
Do not use multiple boxes to express or operationalise a single construct Try to maintain a consistent level of specificity among X and Y constructs Avoid mixing different kinds of constructs and levels of analysis: • Distinguish between single-level and multi-level constructs • Be cautious about using them together, within a single X → Y proposition
Given the expectation that strong theoretical propositions should be testable, avoid the use of exceptionally broad, very general constructs
Be sure that every box qualifies as a variable and that it is capable of being acted upon: • Variable: can take on values ranging from high to low • Capable of being acted upon: a cause or an effect • No broad topics, such as 'environmental conditions,' 'gender theory' or 'ecotourism' • Don't include steps in a process flow, such as 'decide to purchase,' 'initiate a purchase' or 'approve a purchase' • No logical or developmental sequences, such as 'early,' 'middle' or 'late' stages
In addition to the focal construct, also include complementary combinations with related antecedents and outcomes: • Focal construct: the subject of your current scholarly interest • Complementary construct: what combines with your focal construct to form a proposition • Either the focal or complementary construct can function as an X-antecedent or a Y-outcome

Source: From Whetton (2009).

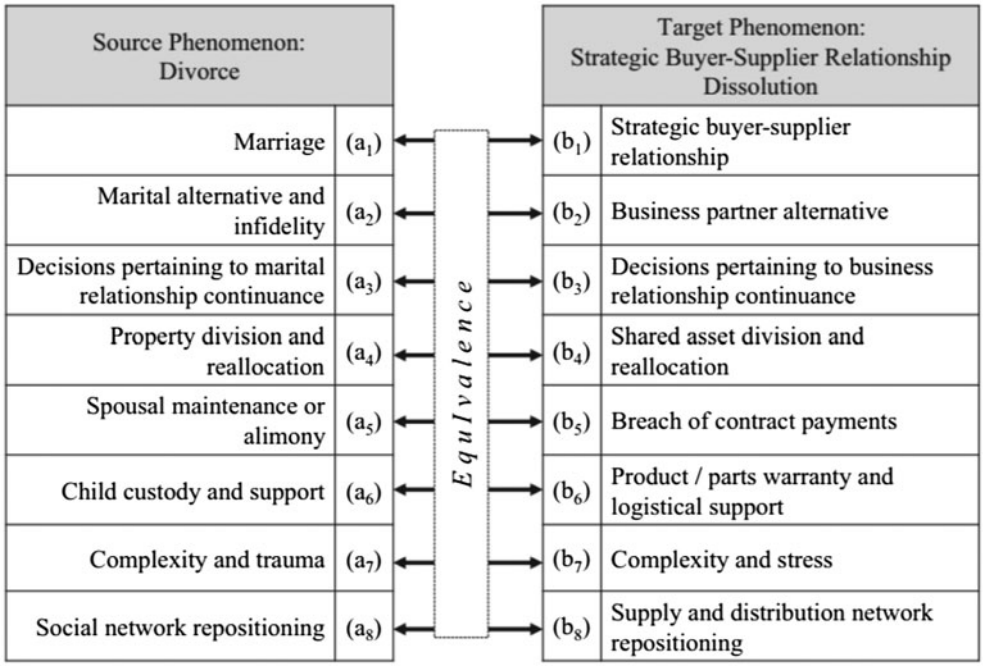


Figure 2. Example of equivalence at the level of ontology. Source: From Chen et al. 2013

lower level insights are refined through many-to-one transformations (Chen et al. 2013), retaining only key elements that link the source and target phenomena (Garud and Kotha 1994).

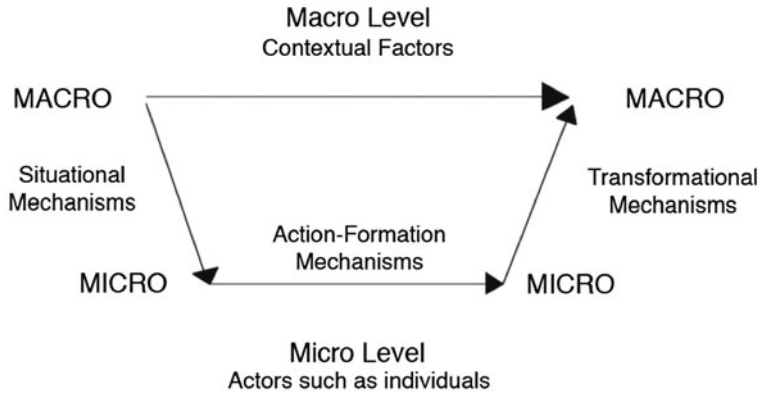


Figure 3. Relationship between macro and micro actions. Source: Adapted from Anderson et al.'s (2006) mechanism model.

Ontology, the lowest level of abstraction, is the logical correspondence between key elements of the source and target phenomena (Garud and Kotha 1994; Tsoukas 1991), illustrated in Figure 2, generating the *whats* of the theory (Whetton 1989). Analogy, the middle level of abstraction (Garud and Kotha 1994; Tsoukas 1991), develops correspondence between relationships among elements of the source and target phenomena (Chen et al. 2013). Relationships address the *hows* of the relationship among the ontological *whats* (Whetton 1989). Establishment of equivalence at the ontological and analogical levels leads to the emergence of more generalizable principles (the identity level of abstraction) (Garud and Kotha 1994; Tsoukas 1991). Chen et al. (2013) matched semantically equivalent divorce terminology with supply chain relationship dissolution terminology to establish propositions about the relationships.

Shifting perspectives. Theory development can sometimes be enhanced by shifting perspectives. Examining a research problem from both micro and macro perspectives can provide a richer understanding of the *why* behind a theoretical model, causing the emergence of new insights (Aguinis et al. 2011; Rousseau 2011). For example, although top management may spearhead an initiative such as Lean, it is ultimately implemented by individuals (Rothaermel and Hess 2007). Thus, macro effects give rise to situational mechanisms, which, in turn, influence micro level actors (individuals). While macro effects are related to performance, micro actions are taken by individual decision makers who are influenced both their preferences (e.g. for risk, uncertainty, time horizons) and macro effects. Micro forces contribute to action-formation mechanisms that, over time, result in decisions that can transform a firm (Anderson et al. 2006), illustrated in Figure 3. Thus, individual decisions, when aggregated, can impact macro performance (Hayes and Wheelwright 1984). By linking action-formation and transformational mechanisms, a theory will exhibit 'methodological holism' (Kieser 2015) that is lacking when micro and macro factors are considered independently (Moliterno and Mahony 2011); 'all … research … must move back and forth between macro and micro levels to show how the macro-level changes occurred' (Coleman 1986, 1323).

Data collection

The data collection strategy provides evidence of the trustworthiness and significance of the claims made by a research study (Huff 2009). It should help to make what has been discovered more plausible to readers, reassuring the target audience that the research is trustworthy.

For theory validation research, the data collection strategy should flow from the research problem and theoretical lens. It consists of sample selection, design of data collection instruments, designation of independent and dependent variables, and procedures for collecting data (Shadish, Cook, and Campbell 2011). On the other hand, for theory development research, the data collection strategy is often deep immersion in a single or a few firms. Data is collected through experiencing the context as a participant, interviews, focus groups, archival data and other sources that provide rich detail about a firm. While there may be a data collection plan and structured data collection instruments, data collection for theory development is more opportunistic, building on whatever sources of relevant data are available.

Issues

Sacrificing relevance for rigour

The effort to tightly control all aspects of data collection may cause research to lose its connection to the real world. The result, while rigorous and elegant, is imminently forgettable. This illustrates an unbalanced perspective, where data collection takes priority over the research problem, theoretical lens and data analysis.

Sacrificing rigour for relevance

On the other hand, relevance doesn't compensate for lack of rigour. 'When it comes to empirical research, being interesting cannot substitute for a lack of validity' (Bartunek, Rynes, and Ireland 2006). 'Claims unsupported by thorough academic research, no matter how intriguing they may sound, … are not relevant. Actually, I fear they could be dangerous' (Vermeulen 2005). This also illustrates an unbalanced perspective, where the research problem takes precedence over the theoretical lens and data collection and analysis strategies. Thus, balance among the four points of the research diamond is critical.

Table 6. Threats to validity.

Type	Definition	Selected threats
Internal validity	• Does their covariation result from a causal relationship? • Validity of inference about whether there is a causal relationship	• Selection • Maturation • Instrumentation • Attrition • Regression to the mean
External validity	• Generalisations from samples of persons, settings and times to constructs • Validity of inferences about where the cause-effect relationships hold over variation in persons, settings, treatment variables and measurement variables	• Interaction of causal relationship with selection of respondents • Interaction of causal relationship with other factors • Interaction of causal relationship with outcomes • Interaction of causal relationship with settings • Context-dependent mediation
Construct validity	• Validity of inferences about higher order constructs that represent sampling particulars • Generalisations from operations to constructs	• Inadequate understanding of constructs • Construct confounding • Mono-operation bias • Mono-method bias • Confounding constructs with levels of analysis • Reactivity of self-reports • Researcher expectancies
Statistical conclusion validity	• Appropriate use of statistics to infer whether the presumed independent variables and dependent variables covary • Validity of inference about correlation between treatment and outcome	• Low statistical power • Violation of assumptions • Fishing • Unreliability of measures • Restriction of range • Heterogeneity of respondents • Inaccurate effect size estimation

Source: Based on Shadish, Cook, and Campbell (2011).

Assumption of similarly motivated respondents

Theory validation research is often designed as though all respondents shared the same motives, ignoring individual differences in background and motivation. Capitalising on this, Westphal, Gulati, and Shortell (1997) were able to leverage their finding that early adopters of TQM were economically driven while later adopters were institutionally driven into a paradox, creating an interesting research study that explicitly examined the motives of all respondents.

Threats to validity

Table 6 summarises validity concerns related to empirical research (Shadish, Cook, and Campbell 2011), relevant to both theory validation and theory development research. Threats to validity provide an alternative explanation for why an observed effect occurred, thus, they are relevant to data collection strategy design.

Internal validity deals with the validity of the measurement sample and methods, while *external validity* is related to generalizability of the results beyond the sample (Shadish, Cook, and Campbell 2011). Experimental studies are high in internal validity because of their tight control over extraneous effects, but are weaker in external validity, because of their artificial setting and manipulations. On the other hand, grounded theory research is higher in external validity, but often suffers from internal validity concerns.

Construct validity is the accuracy with which a measure captures the essence of a construct (Shadish, Cook, and Campbell 2011), and most OSM researchers routinely assess the construct validity of survey measurement scales. However, construct validity is also a critical issue for archival data sources. Because measures are limited to what is available within an archival data-set, researchers must use proxies to measure constructs of interest, which may only weakly represent it. For example, absenteeism is sometimes used as a proxy for job satisfaction. While low levels of job satisfaction may, indeed, result in higher absenteeism, there are potentially many other contributors. Careful operationalisation of constructs through proxies is critical to ensuring construct validity of archival research studies.

Statistical conclusion validity is related to the assumptions upon which statistical methods rest (Shadish, Cook, and Campbell 2011). Inaccurate effect size estimation is particularly common in OSM research. Researchers may neglect the need to compensate for the increased likelihood of a Type I error as the number of hypotheses that are tested increases, leading to potential inaccurate effect size estimation in light of the complexity of many OSM models. Omitted variable bias arises in cross-sectional survey research when the error term is correlated with one of the independent variables, leading to endogeneity concerns.

Omitted variable bias (endogeneity)

Omitted variable bias usually arises because an important independent variable was omitted because empirical data was not available to measure it (Hamilton and Nickerson 2003). For example, assume that the model for y is:

$$y = \alpha + \beta_1 x + \beta_2 z + \varepsilon_1$$

However, if empirical data to measure z is not available, $\beta_2 z$ is dropped from the model and absorbed into ε. The new model is then:

$$y = \alpha + \beta_1 x + \varepsilon_2,$$

where $\varepsilon_2 = \beta_2 z + \varepsilon_1$.

Therefore, if x and z are correlated, then x will be correlated with the new error term ε_2, thus violating two of regression analysis' assumptions (Johnston and DiNardo 1972; Wooldridge 2015):

- The error term is independently distributed and not correlated with any of the independent variables.
- x is deterministic, therefore, uncorrelated with the error term.

This leads to endogeneity, which can cause the standard error of the coefficient to be biased, leading to an incorrect significance test results and, ultimately, to false conclusions.

Difficulty in obtaining survey data

Survey data collection has become increasingly difficult to obtain as the popularity of surveys has increased as an OSM data collection strategy. Managers who regularly receive survey requests may believe that they interfere with their work or feel burned out. The availability of potential survey respondents also seems to be related to the state of the economy;

in tough economic times, there seems to be a greater reluctance to participate in survey research. This may be related to unwillingness to disclose sensitive data, the need for organisations to operate with a leaner staff or a host of other reasons.

New sources of respondents

There has been increasing use of non-traditional means for obtaining survey respondents and experimental subjects, including Amazon's Mechanical Turk (mTurk), Qualtrics and other sources that solicit respondents electronically and compensate them for their responses. These methods are associated with fast data collection in the desired sample size, offering substantial benefits for researchers. However, there is an issue of alignment with the research problem. While mTurkers are perhaps appropriate for research on general consumer behaviour and attitudes, they seldom have OSM experience. Further, many mTurkers are professional survey respondents, whose commitment to carefully considering survey items may be suspect.

Single respondents

Cross-sectional survey research that relies on a single respondent per firm suffers from validity issues, since individual responses can be biased by personal feelings, opinions, behaviours and the informant's length of tenure, level of position and job satisfaction (Bagozzi, Yi, and Phillips 1991) that would average out over multiple respondents. The single respondent may be rationalised as a key informant (Kumar, Stern, and Anderson 1993), who is knowledgeable about issues at an organisational level and able to generalise about intraorganisational patterns of behaviour, however, the validity of this approach is questionable (Frohlich 2002; Melnyk et al. 2012). Because key informants are asked to perform complex judgments, such as making inferences about macro level phenomena and aggregating across people, tasks, functions and events, there is more than the normal amount of random error. Other factors contributing to variability in key informants' judgments are related to difficulties of observation in large or complex firms, breadth of information sources and volatility of changes. This is further complicated in a supply chain, where decisions are the result of actions made by a firm, its customers and suppliers (Rothaermel and Hess 2007).

Survey translation issues

The amount of non-U.S. OSM survey research has grown dramatically in recent years. Although most researchers understand the importance of using established scales, the vast majority of existing measurement scales were originally written in English. This gives rise to two important questions (Tsui 2006).

First, should measurement scales be translated? The indigenous psychology movement, which challenges U.S. domination in conceptual frameworks, calls for development of measures based in local cultural realities, considering the unique aspects of the target culture (Behling and Law 2000). However, this approach limits the comparability of findings and restricts generalizability.

Second, is it possible to accurately translate measures, due to *semantic equivalence* issues across languages, where the same word may exist in both, but with subtle differences in meaning? For example, the word 'dúvida' means both 'question' and 'doubt' in Portuguese. When Brazilians say that they have a doubt, Americans may interpret this as scepticism, while what is meant is simply that they have a question. In some cases, there may be no equivalent word in the target language; for example, there is no equivalent to the English 'skill-based pay' in many languages. A second issue is the lack of *conceptual equivalence* across cultures. Concepts may exist independent of the actual words used to represent them. Finally, there may be a lack of *normative equivalence* across cultures. Norms, such as willingness to discuss certain topics, the way in which ideas are expressed and how strangers (such as researchers) are treated, can have important implications for data collection (Behling and Law 2000), particularly in a face-to-face situation such as an interview or focus group, potentially compromising the results.

Opportunities

Control for endogeneity

Since endogeneity results from missing variables, the best way to control for it is in the research design, ensuring that empirical data for the potentially missing variable is collected or considering other important independent variables for which data is available. When this is not possible, the use of an instrumental variable provides a way to address endo-

geneity. Continuing with the example from above, a variable that is correlated with x, but not with ε (known as an instrumental variable w) would need to be found. Two-stage least squares could then be used to develop an understanding of which part of the independent variable x is correlated with the error term and which part is not. In the first stage, $x = \lambda + \beta_3 w + \varepsilon_3$ in order to estimate $\widehat{x}$, which is then used in the second stage regression: $y = \alpha + \beta_1 \widehat{x} + \widehat{\varepsilon}$. The new estimate of x should be uncorrelated with $\widehat{\varepsilon}$.

New sources of archival data

There has been an increasing number of OSM papers that use archival financial data, due to its convenience and perceived objectivity. Depending on the research problem and the ability to address construct validity issues, archival financial data may be very appropriate. For example, event study approaches have been used to understand the stock price impact of events such as supply chain glitches (Hendricks and Singhal 2003), environmental management programme implementation (Klassen and McLaughlin 1996; Lo, Yeung, and Cheng 2012), technological product innovation (Xin, Yeung, and Cheng 2008), ISO certification (Lo, Yeung, and Cheng 2009; McGuire and Dilts 2008), winning a quality award (Hendricks and Singhal 1996) and product recalls (Ni, Flynn, and Jacobs 2016; Thirumalai and Sinha 2011).

Other sources of archival data may be more relevant to OSM research problems. ERP systems store a substantial amount of data about demand, inventory, lead time, delivery time and other important OSM factors. Sensors collect manufacturing data from assembly lines, uploading it to a central database as frequently as once per minute (Li and Wang 2017). Over-the-road trucks transmit location information up to five times per second, using embedded computers and modems (Van der Spoel, Amrit, and van Hillegersberg 2017). RFID can be used to track cartons or products as they move within a warehouse. Sustainability performance is measured by metres that monitor utilities, effluents and energy use; for instance, a metre can measure how much energy a steam generator uses, the amount produced in a steam plant and the amount used on each line, allowing management to continuously extrapolate the amount of steam lost throughout a plant. Such data may provide better OSM construct validity than financial data.

Big data

Big data (BD) aggregates different databases to be applied simultaneously, in support of business decisions (Putka and Oswald 2017). It has developed from the advent of new technologies, such as the IoT, social media, RFID, and the Internet. While firms continue to invest in BD analytical tools (Short and Todd 2017), many still struggle with extracting important insights from their BD repositories. BD is an exciting potential data source for OSM research because it is routinely collected as part of normal operations, and much of it does not suffer from the sensitivity of financial data. BD is characterised by the following traits (McAbee, Landis, and Burke 2017):

- *Volume:* There is a very large number of cases and variables per case. The size of BD datasets often exceeds the capability of conventional analysis software, like SPSS and SAS.
- *Velocity:* BD is generated, processed and made available for use at a high rate of speed. For example, Walmart processes more than 2.5 petabytes of transactional data per hour.
- *Variety:* BD is stored in structured, semi-structured (e.g. email) and unstructured (interviews, pdf files, Word documents, audio files, images, videos) formats.
- *Veracity:* The veracity of BD may be questionable, with construct validity implications. Like a simulation model, what is programmed into an IoT device is what you get.

One of the biggest challenges of working with BD is the substantial amount of extraneous data. Because BD is collected to meet a firm's needs, rather than a researcher's needs, inductive approaches are often more useful than deductive approaches in revealing the story that BD is telling and using it to develop theory. Quantitative analysis is used to explore the data, allowing themes to emerge and guide theory development.

Thick data

Thick data (TD) gives researchers a better understanding of the information underlying BD and can be an integral data source for theory development. While BD has hundreds of thousands of observations from different parts of a firm, TD contains fewer observations, but greater variety of information for each. For example, a motor carrier's data about a shipment from Los Angeles to New York includes the expected and actual departure time, expected and actual arrival time, truck size, departure and arrival location information, truck type (specialised or general purpose), and exception codes for issues encountered along the way. BD would contain all observations for all loads on all of a motor carrier's

trucks over time, so there could be a million observations with 20 or so columns accumulated in a few months. TD would have many more columns and include non-digital, as well as digital, information; for example, it could include truck drivers' accident reports. This type of data can also be important to OSM researchers, for example through analysis of online customer reviews, using a web crawler (Chong et al. 2017), or YouTube product reviews posted by first adopters. In manufacturing, microphones on assembly lines capture data in the form of words spoken by front line workers, which can be transcribed and combined with production data to better understand quality-related issues.

Dark data

Dark data (DD) is data that exist within an organisation, yet it is not examined or analysed and thus managers do not use it to gain any insights into the firm's operations. Researchers will also need to expand their data gathering and analytical skill set to help them discover and tease apart the data that is available. Researchers might believe that firms don't have much data for analysis or that such data doesn't exist. This might be because managers themselves might not know what data they have available or what data is collected within other units. Such data typically doesn't exist in perfectly formatted BD datasets ready for analysis and interpretation. However, such data might be 'hidden' within the firm's existing data systems. Thus, researchers need to work with managers to understand all the data that is available so they can discover such DD. DD might be difficult to extract and format in preparation for data analysis. However, DD can contain a lot of information that can provide rich insights for academics as well as managers.

Align Translation Approach with Assumptions

Farh, Canella, and Lee (2006) describe four approaches to survey translation issues, summarised in Table 7, based on assumptions about whether a construct is universal or specific to a culture and the availability of a high quality source language scale. It provides a guideline to alternatives for measuring a construct in a target culture and the strengths and weaknesses associated with each.

Data analysis

The data analysis strategy is the way in which quantitative and qualitative empirical data is analysed, in order to allow drawing valid conclusions. It consists of statistical procedures for theory validation and structured methods for analysing qualitative data and conducting inductive analysis for theory development. Table 8 provides an overview of types of analysis methods, summarising the strengths and weaknesses associated with each. There is no analytical silver bullet to ward off all potential criticisms. Rather, it is important to select an analytical approach that is consistent with the research problem, theoretical lens and data collection approach, building on its strengths, while acknowledging its weaknesses.

> Do not 'fall in love' with the methods you currently use. Understand their inevitable weaknesses, and juxtapose your results with compensating observations from other projects that you or others carry out (Huff 2009, p. 187).

Issues

Weak inference

The typical theory validation approach involves testing propositions against empirical data (Mantere and Ketokivi 2013); if there is a significant result, the study is considered a success. The problem of weak inference exists when a researcher has a vested interest in obtaining the hypothesised results. It is sometimes manifest in a penchant for data transformation, 'torturing' the data by applying various transformations until it yields the desired results. Weak inference can cause researchers to lose sight of what the data is actually telling them. Unexpected results may have been due to a data entry or analytical error, or perhaps an outlier. More interestingly, the expected results may not have materialised because there were other forces at work. For example, Ritchie and Melnyk (2012) initially approached analysing data about Customs-Trade Partnership Against Terrorism (C-TPAT) certification based on Westphal, Gulati, and Shortell (1997), becoming frustrated when the data didn't support the hypothesis that early C-TPAT adopters would be economically driven, while later adopters would be institutionally driven. They applied ever more sophisticated transformations, but continued to obtain the same results. Only when they realised the need for allowing the data to tell its own story did they understand that the bulk of C-TPAT's benefits were captured by the public, rather than participants in the principal dyad.

Table 7. Approaches to measurement scales in non-U.S. cultures.

Approach	Assumptions: Construct	Assumptions: Existence of high quality source language scale?	Development time and cost	Strengths	Limitations
Translation: Direct translation of existing measurement scale	Universal	Yes	Low	• Preserves possibility of high level of equivalence • Allows for direct cross-cultural comparison of findings	• Difficulty in achieving semantic equivalence between source and target versions • Difficulty of finding culturally unbiased source scales
Adaptation: Translation of existing measurement scale, with some modifications to create a more meaningful measure in target culture.	Culture-specific	Yes	Low to Moderate	• Ease of scholarly exchanges of research finding	• Difficulty of doing cross-cultural research • Drastic adaptations may create a new scale that requires extensive validation in target culture
De-Contextualisation: Assemble a universal measurement scale from scratch in the local context.	Universal	No	High	• Opportunity to develop a universal measure for the construct • Ease of scholarly exchange of research findings	• Items tend to be phrased at a more abstract level, which may limit informational and practical value
Contextualisation: Assemble a context-specific measurement scale from scratch in the local context	Culture-specific	No	High	• Opportunity to develop scale that is highly relevant to target context • Opportunity to contribute context-specific knowledge to research on target culture	• Limited generalizability • Hard to communicate findings to the broader literature

Source: Based on Farh, Canella, and Lee (2006).

Predictable data analysis

Many survey researchers apply the same popular analytical approaches, however, the need for rigour doesn't dictate the same approach for every research problem. This may result from a perception that, if a research problem isn't amenable to SEM, the resulting paper will have reduced chances of being published in a high quality journal. According to the Law of the Instrument, 'Give a small boy a hammer, and he will find that everything he encounters needs pounding' (Kaplan 1964, p. 28), restated by Maslow (1966, p. 15) as 'I suppose it is tempting, if the only tool you have is a hammer, to treat everything as if it were a nail.'

SEM has become a methodological hammer. This isn't surprising, since researchers have similar training, and it is natural that reviewers are comfortable with manuscripts that use a familiar analytical method. However, it can lead to

Table 8. Strengths and weaknesses of analytic methods.

Method	Goals	Examples	Ideals	Critique
Theory validation	• *Inference*: sample to population • *Prediction*: past to future • *Description*: patterns in data sets • *Hypothesis testing*: increasing confidence in a theoretical explanation • *Generalisation*: expanding the range of a theoretical explanation	• Regression • Principal component and factor analysis • ANOVA, MANOVA • Structural equation modelling • Game theory • Time series analysis • Optimal control theory • Simulation • Trend analysis • Big data	• Objectivity • Neutrality • Replicable procedures • Discovery of causal laws • Abstraction • Precision • Rigour • Verifiability	• Oversimplification • Unacknowledged subjectivity of definitions and procedures
Theory development	• *Explication*: how or why • *Detail*: adding depth to theoretical explanation • *Empathy*: connecting abstract ideas to human experience • *Exploration*: seeking unacknowledged antecedents, unanticipated consequences	• Observation • Historical research • Content analysis • Focus groups • Unstructured and semi-structured interviews • Case studies • Ethnographies • Grounded studies • Document analysis • Thick data • Big data	• Rich description • Meaning • Qualified arguments • Context-specific description • Reflection • Connection	• Subjectivity • Sloppy observations masquerading as interpretation • Intrusion of the researchers in all representations
Mixed	• Make quantitative results more understandable • Understand broader applicability of small sample qualitative results • Robust description and interpretation	• Analyse documents and behaviour • Simulation • Survey research	• Balance • Compensating strengths • Cancelling weaknesses • Inclusive outcomes	• Shallow application of intrinsically incompatible methods

Source: Adapted from Huff (2009).

methods convergence; it is like ordering the same entrée every time you visit a particular restaurant. Although tasty at first, after some point it becomes boring. OSM theory validation research is full of hammers in search of nails and researchers in search of problems that will allow them to demonstrate their prowess with a particular analytical method. Rather than starting with an analytical hammer looking for a nail, researchers should start with an interesting and important research question, use a theoretical lens to develop appropriate hypotheses, then investigate them using the most appropriate methods.

Analysis of unstructured data

While structured BD, such as machine downtime or retail transaction data, can be easily analysed once volume issues have been resolved, unstructured textual data, such as customer sentiment reflected in tweets or engineering reports on

maintenance problem resolution can be much more difficult to analyse through conventional methods. Machine learning, inductive analysis tools and active researcher interaction with the data may be required.

Opportunities

Alignment with research problem

The data analysis strategy should be aligned with the research problem, rather than driving it. For example, survival analysis is appropriate for point-in-time-based research problems, identifying factors influencing time-to-event decisions (Lee and Whitmore 2010) and quantifying the time until a dichotomous event, based on a hazard function (Kaplan and Meier 1958). Time series analysis is aligned with identifying elements that occur over time. For example, Melnyk et al. (2014) used modified outlier detection to assess the impact of a supply chain disruption on various system traits. There are many other analytical methods that hold potential for empirical OM researchers and are aligned with different types of research problems, including structured case analysis (Barratt, Choi, and Li 2011; Eisenhardt 1989; Glaser and Strauss 1967; McCutcheon and Meredith 1993; Voss, Tsikriktsis, and Frohlich 2002), behavioural experiments (Bendoly, Donohue, and Schultz 2006; Perdue and Summers 1986), action research (Altrichter 1993; O'Donoghue 2003), engaged research (Touboulic and Walker 2016), linguistic analysis (Bach and Robert 1982), meta-analysis (Borenstein et al. 2009; Borenstein and Higgins 2013; Mackelprang and Nair 2010; White 1996), event studies (Brown and Warner 1985; MacKinlay 1997), lab research and longitudinal methods (Diggle et al. 2013; Menard 2007). Researchers should strive to develop a broad awareness of a variety of analytical procedures and a rich methodological toolkit.

Data visualisation

Various forms of visual display are useful in visualising BD, in order to allow its story to emerge (Börner 2010), offering exciting opportunities to OSM researchers. For example, geospatial visualisation examines data trends based on geography. Researchers can use street maps or larger infrastructural elements to analyse the implications of various supply chain decisions, overlaid with additional information such as traffic and delays, to help explain and prevent supply delivery delays. Permanent and programmable video dashboards display data for inductive analysis. Video dashboards can display current performance of dynamic BD against targets and other information about how a plant is performing and where attention is needed.

Alignment of visualisation with research question

When addressing research questions related to *what,* data is best presented in charts, tables, or figures, such as a word cloud, where software analyses the words in a textual document and displays them, giving more prominence (size) to words that appear more frequently. Tables summarise large datasets relatively compactly by grouping different categories. Figures show different topics and their importance, using graphical sizes or colour representations to differentiate the data. Questions of *where* address research problems related to where products or customers flow. Geospatial maps are useful for these types of data. Global maps visually display a firm's global supply chain or how widely its raw materials are sourced, in order to identify potential trouble areas. Country maps can show demand for a firm's products in different states, in order to enhance product delivery. Local maps are useful in routing last-mile delivery trucks, in order to reduce delays. Research problems related to *when* describe how events unfold over time. The data can be continuous, where data points are continuously gathered (such as from an electronic metre), or it can be discrete, where values are only collected at certain intervals, such as annual financial performance. Temporal graphs visualise this type of data based on time series analysis. Research problems related to *whom* are based on relationships between entities. Network analysis shows the relationship between different product categories and suppliers to determine overall firm dependence on specific suppliers or parts commonality across the finished goods, in order to understand the importance of specific parts or suppliers. Network analysis is also useful in linking managers to specific areas of expertise, so they can be fully leveraged when specific knowledge areas are needed.

Data mining

One of the downsides of BD is the difficulty of examining the various relationships that can exist in the data, which can be overwhelming, given the large number of available variables. It may introduce new potential independent variables whose relationships are not be known from prior research or theory. Data mining is an analytic, inductive

approach to help researchers discern the story that BD is telling (Fayyad, Piatetsky-Shapiro, and Smyth 1996). It can inform researchers of initial relationships and help to point the direction for future research (McAbee, Landis, and Burke 2017) through its automatic process for identification of patterns or relationships in the data. These relationships can then be used in more advanced analysis techniques, such as predictive analytics.

Data virtualisation

Using machine learning (e.g. IBM's Watson), computers learn new ways of looking at data and analysing it, without specific programming, allowing them to identify potential issues and develop predictive analytics to address problems before they become major. For instance, potential equipment breakdowns can be predicted, allowing preventative maintenance to be performed during downtime and reducing the probability of a machine breakdown, as well as reducing maintenance costs. This provides an exciting inductive approach to theory development.

Text mining

Programming languages like Javascript and Python analyse text from sources such as review websites or Twitter, using natural language processing algorithms to assess sentiment. Analysis software, such as SAS Text Miner or JMP, can then be used to examine the resulting unstructured data to identify important constructs and relationships between them, serving as a foundation for inductive theory development. Sentences are examined, assuming that words that appear in the same sentences are much more likely to be related or associated, then nouns or groups of words that form nouns to identify things that might be important are identified, as well as actions or verbs, providing researchers with an effective inductive approach to analysing textual data.

Predictive analytics

While descriptive analytics enable a researcher to examine historical data, predictive analytics uses machine learning and predictive modelling techniques to gain insights into BD. Combining both, the ultimate frontier is prescriptive analysis, where past BD is analysed and models are predicted using simulation, resulting in data-based prescriptions. Although most OSM research uses descriptive analytics, the nature of BD changes the way that data can be examined.

Conclusions

Research is dynamic, growing and changing in response to new challenges, new research questions, new developments, new analytical and data collection methodologies and new demands from both its readers and those who hope to use it. Consequently, every so often, scholars should stop to take stock of what has happened, what is taking place, and what is likely to occur, assessing the field and its approaches, with a goal of *learning*, *unlearning*, and *relearning*. Through learning, researchers develop an understanding of what has worked in the past and why, learn about new opportunities and methodologies, and discover issues that are becoming critical to readers. By unlearning, through studying past research and current needs, researchers identify and discard approaches, tools, theories, and frameworks that are no longer effective. In relearning, researchers get back to the basics of research, considering critical but often overlooked fundamentals for dealing with the challenges of today's environment.

Thus, researchers should be concerned about both the past and future. As they study the past, researchers preserve and communicate effective approaches and expose those that have been less effective, so that they can be discarded. As researchers focus on the future, they identify emerging opportunities, related to issues, development of new theoretical frameworks, new sources of data or the advent of new methodologies, so that they can direct attention to them and recognise the challenges associated with exploiting these future opportunities.

In celebrating a significant milestone for a major OSM journal, the *International Journal of Production Research,* we have had the occasion to stop and re-assess OSM empirical research. We used Dickens' contrast between the best of times and the worst of times to frame our re-assessment. We focused on the best of times, a future in which empirical OSM research is entering into a veritable epoch of incredulity due to exciting opportunities available in BD and other new data sources, analytical techniques like text mining, interesting and important research problems, and innovative tools for developing theory. We also explored the worst of times, focusing on the challenges and problems that are currently plaguing empirical OSM research. Our goal was to show how the worst of times can be learned from, so that OSM researchers will be poised to take advantage of the best of times. We introduced the research diamond as a vehicle

for emphasising the importance of a balanced research perspective that treats the research problem, theory, data collection and data analysis as equally important.

We do not believe that OSM survey research is dead, but rather that it is time for a serious examination of the state-of-the-art. Just as a product's life cycle can be extended by improving a product or adding new features, the life cycle of OSM survey research can be extended by incorporating new developments to improve its quality. In contrast, other empirical research methods are still in their infancy (for example, engaged research methods, such as action research, and ethnographic research) or in the growth part of their life cycle (case research, experiments, event studies). It is critical to stay in touch with the latest theoretical and methodological developments, which often takes place in other fields, in order to sustain the quality of OSM empirical research.

By learning and addressing the issues in this period of the best of times and the worst of times, we can take advantage of the opportunities facing OSM to create and disseminate research that is balanced, insightful, rigorous, relevant, impactful and interesting. That is a challenge worthy of our field and one we believe it is ready to meet.

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