

Internal versus External Knowledge Sourcing of Organizational Rules: An Exploratory Study of CPGs in a Healthcare Organization

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Abstract

In this study, we examine how organizational rules source knowledge. By knowledge sourcing of a rule, we mean the formation of reference ties from the rule to knowledge sources located outside of the focal rule. Rules can source knowledge from sources within the organization (e.g., other rules) and outside (e.g., research publications, policies, standards, etc.). Our theoretical model proposes that knowledge sourcing of rules is driven by inherent incompleteness of rules as a result of bounded rationality of rule makers and rule making process. Incomplete rules can lead to experiences of insufficient rule knowledge, termed 'knowledge gaps', which are shaped by rule dynamics at the levels of individual rules, the rule system, and rule networks. Our theoretical model leads to several hypotheses that we test with longitudinal archival data of clinical practice guideline (CPG) changes in a Canadian healthcare organization. The findings support our theoretical model of incomplete organizational rules which encounter knowledge gaps and close them through internal and external knowledge sourcing. The theoretical and practical implications of the findings are discussed.

Introduction

Organizations increasingly operate in knowledge-intensive contexts and need to make decisions about complex matters supported by rules which can supply relevant knowledge to decision makers and decision-making processes. For example, in healthcare – the empirical context of this study, rules in the form of ‘Clinical Practice Guidelines’ (CPGs) play a critical role for “knowledge translation” and “evidence-based medicine” (e.g., Gaddis *et al.*, 2007; Irvin *et al.*, 2007; Straus *et al.*, 2013). CPGs are written rules, but they are less coercive and more enabling (Adler and Borys, 1996) than other rules (such as laws). CPGs are essentially formalised organizational routines which provide guidance for healthcare practitioners to make informed decisions based on healthcare research and available resources¹.

How can organizational rules supply relevant knowledge to knowledge workers? One way is knowledge sourcing. Similar to patents and research publications, rules can reference knowledge sources. By knowledge sourcing of rules, we mean that a rule refers to knowledge sources located outside the rule. For example, a CPG might refer to another CPG or a relevant healthcare publication. Knowledge sourcing of rules creates ties from a rule to the referenced knowledge sources located in the focal organization (internal sources) or outside (external sources). These ties are formed when organizational rule makers revise rules and add references to knowledge sources – often by including instructions in the rule which explain the reason for the reference. They can direct the attention of rule users to sources of potentially relevant knowledge (e.g., a handbook article about a medical procedure) that can complement the instructions of the rule. We refer to these ties as knowledge sourcing ties. They form knowledge

¹ The concepts “rule” and “routine” refer to similar phenomena, but their overlap can be approached from diverse theoretical perspectives. This paper essentially focuses on special kinds of routines: rules in the form of CPGs.

sourcing networks that connect individual rules to knowledge sources within and outside the organization.

Knowledge sourcing is especially important in contexts where specialized knowledge sources exist or arise. Specialized sources can provide relevant knowledge that is deeper, more effective (e.g., a patient will go to a doctor for the doctor's knowledge and expertise), often more current (updated), and more legitimate. When specialized knowledge sources exist, knowledge sourcing is attractive because it can provide superior knowledge at relatively low cost. For organizations operating in contexts rich in specialized knowledge sources, knowledge sourcing of rules becomes attractive because it connects rules to specialized and potentially superior knowledge.

Knowledge sourcing of organizational rules draws on specialized knowledge sources within and outside the focal organization. Within organizations, rules are surrounded by intra-organizational knowledge sources, including a complex rule system and collections of organizational documents, organizational policies, protocols, and directives, which offer diverse knowledge related to other subtasks or subunits of the organization. We refer to sourcing from intra-organizational sources as "internal sourcing". For example, a CPG on mastectomy (i.e., surgical removal of one or both breasts, partially or completely, to treat breast cancer) cites another CPG related to breast reconstruction to source knowledge about how to replace the lost breast tissue either at the same time as mastectomy or at a later time. Outside the focal organization, there is a rich set of diverse knowledge sources (e.g., there is a "division of knowledge" in society which structures social and economic action; von Hayek, 1937: 49) from which organizational rules (and their users) can source knowledge, such as related regulations, policies, professional guidelines, and relevant publications (e.g., knowledge about evidence,

goals, decision premises, methods, conditions, etc.). We refer to sourcing from extra-organizational environments as “external sourcing”. For example, the CPG on mastectomy mentioned above cites an external guideline for the management of breast cancer related lymphedema (a condition in which extra lymph fluid builds up in tissues and causes swelling), which is based on a systematic review of the recent literature, approved and published by the Steering Committee for CPGs convened by Health Canada. This document cited by the focal CPG provides information and recommendations for patients and physicians when they make decisions on the management of lymphedema which is a potential consequence of mastectomy.

Knowledge sourcing of rules is critical in knowledge-intensive contexts. But what makes it happen? Are there factors that facilitate or hinder the formation of knowledge sourcing ties? Are there differences in internal versus external knowledge sourcing? Do the two forms of knowledge sourcing support each other or substitute for each other?

There is virtually no prior research on knowledge sourcing of rules. But there are related literatures. (i) Prior research has explored the antecedents and effectiveness of organizational strategies for knowledge sourcing – e.g., investing in foreign countries (Alcacer and Chung, 2007; Almeida, 1996; Iwasa and Odagiri, 2004), forming alliance, acquiring (Carayannopoulos and Auster, 2010), building formal and informal knowledge networks (Trippel *et al.*, 2009). That line of work has focused on knowledge sourcing between organizations, and studied it in various contexts, including multinationals (Almeida, 1996) and SME’s (Brunswick and Vanhaverbeke, 2015), as well as various industries, such as semiconductor (Almeida, 1996), biotechnology (Carayannopoulos and Auster, 2010), pharmaceuticals (Grigoriou and Rothaermel, 2017) and manufacturing (Vega-Jurado *et al.*, 2009). (ii) The absorptive capacity literature focuses on the organizational capabilities to identify and make use of external knowledge (Cohen and

Levinthal, 1990; Lane and Lubatkin, 1998). (iii) Research on transactive memory – that is, team members’ knowing who knows what (Ren and Argote, 2011; Wegner *et al.*, 1991) – has explored how it increases team performance when knowledge is dispersed (Liang *et al.*, 1995; O’Leary and Mortensen, 2010). (iv) How individuals source knowledge within and beyond organization in their work and how their knowledge sourcing strategies affect their performance have been studied (Gray and Meister, 2004; Gray and Meister, 2006; Wang *et al.*, 2014). (v) Research on the evolution of formal rules in organizations has explored how inbound rule networks shape the speed and direction of rule revisions that encode knowledge (Zhu and Schulz, 2019). (vi) “Knowledge translation” using CPGs has been emphasized in evidence-based healthcare to address the gaps between knowledge developed in research and the implementation of this knowledge in clinical practice to improve healthcare quality, however, presents significant challenges (Graham *et al.*, 2006; Grimshaw *et al.*, 2012).

Although prior work reconfirms the importance of knowledge sourcing and related phenomena, it has little to say about the drivers of knowledge sourcing of formal, written rules. We build a theoretical model on Carnegie School foundations and their elaboration in the myopic learning literature (Levinthal and March, 1993; March *et al.*, 2000; Schulz, 2002; March, 2010). We assume that rules are inherently incomplete due to rule makers’ bounded rationality and myopic adaptation processes.² Rules are incomplete in the sense that they have a limited capability to handle new or unusual conditions. Oftentimes, especially in dynamic and knowledge-intensive contexts, new circumstances can arise, unexpected outcomes can occur,

² We assume that rule makers (and their bounded rationality) and rule making processes (and their myopia) are analytically independent, although they might be empirically correlated. The myopia of rule making processes can be seen as arising from limitations inherent in adaptation, independently of bounded rationality of participants. We build in particular on the work of James March (especially his later work) who has emphasized the limitations inherent in adaptation processes (e.g., replication of success or the hot stove effect; see March, 2010 and Denrell and March, 2001).

exceptions can become necessary, and the rule application has to be customized to the specific conditions present in a given situation. The incompleteness of rules can lead to knowledge gaps³ – experiences of insufficient knowledge in rule applications. We argue that incomplete rules can encounter knowledge gaps and that the occurrence of the gaps is shaped by three important rule dynamics operating in a rule system (March *et al.*, 2000) – the evolution of individual rules, of the rule system, and of knowledge sourcing networks of rules. Our theoretical model leads to several hypotheses that we test with longitudinal data about CPG changes in a healthcare organization in Canada.

Our study intends to contribute to prior work in three ways. First, we aim to contribute to the literature on knowledge sourcing by extending the concept to organizational rules. Second, we extend rule-based learning theories by examining how organizations learn by sourcing knowledge, in addition to encoding lessons extracted from experience into rules. Third, we aim to contribute to research on knowledge translation in healthcare and knowledge transfer in general by examining how knowledge is sourced, transferred, or incorporated into organizational rules – instead of organizational members – to support knowledge-intensive work.

Knowledge Gaps and Knowledge Sourcing of Rules

Rules can function as repositories of knowledge – they retain lessons found in past experience. It is a central notion in theories of rule-based learning (March *et al.*, 2000; Schulz, 2002). In that view, organizations learn by encoding lessons/knowledge (inferred from own or other's experiences) into rules (Levitt and March 1988; March *et al.*, 2000). Rules are the product of rule-based learning processes, and they reflect the features – and the limitations – of those processes.

³ Rule incompleteness is a theoretical concept. It can produce knowledge gaps. Knowledge gaps can also arise from other factors, such as the limitations of rule users and their (mis)interpretation of the rule.

Rule-based learning is shaped by the bounded rationality of rule makers (Simon, 1957; March and Simon, 1958) and the myopia of rule-making processes (March *et al.*, 2000), such as replication of success (March, 2010) and garbage can decision processes (Cohen *et al.*, 1972). As a result, organizational rules are incomplete, and that can lead to questions about the meaning and use of the rules. When rules are applied in a situation, the mere knowledge encoded in the focal rules can be too limited and insufficient for the specific conditions present and thereby hinder the accomplishment of the task at hand. We refer to the insufficiency of knowledge that organizations (e.g., rule users, decision makers) encounter when a rule is applied in a particular situation as knowledge gaps of the rule.

Knowledge sourcing of rules could be seen as an adaptive response to knowledge gaps. When the gaps are sufficiently large (e.g., raise spectacular questions or entail significant costs), rule makers are likely to add knowledge sourcing ties that connect the rule to available sources of knowledge relevant for those situations, thereby closing the gaps.

Knowledge sourcing essentially complements the encoding of knowledge in rules. To some degree, this is the result of different foci of sourcing versus encoding. While encoding focuses on evidently relevant knowledge, sourcing focuses on potentially relevant knowledge. In contexts where potentially relevant knowledge is abundant (i.e., in knowledge-intensive contexts), encoding all potentially relevant knowledge is difficult (often impossible) as rules would become too complex and unwieldy. Sourcing, however, can connect rule users to a large pool of potentially relevant knowledge, thus provides them with the flexibility to determine whether and how to use it in a focal situation they are facing.

Rule Dynamics and Formation of Knowledge Sourcing Ties

We see the formation of knowledge sourcing ties happening in a dynamic rule system – a dynamic, knowledge intensive context. Rule systems evolve over time (March *et al.*, 2000). New rules are created, existing rules are revised and sometimes suspended. This can affect the occurrence of knowledge gaps of rules. For example, it can cause new problems that current knowledge encoded in rules cannot solve. It can also affect the interrelationships among rules. Rules can become more or less interdependent, more or less compatible, and knowledge gaps can be increased or decreased.

We examine how knowledge sourcing is shaped by rule dynamics at three levels: individual rules, the rule system, and knowledge sourcing networks of rules. At the level of individual rules, rule dynamics arise from obsolescence processes; at rule system level, rule dynamics arise from the expansion and renewal of the system; and at the level of rule knowledge sourcing networks, they arise from a history of prior knowledge sourcing. In the next three subsections, we develop hypotheses about how rule dynamics at these three levels affect knowledge sourcing.

Aging of Rule Versions

Rules are created and maintained by organizational members with bounded rationality (Cyert and March, 1963; March and Simon, 1958; Schulz, 1998; March *et al.*, 2000), therefore, knowledge encoded in rules is subject to obsolescence – a process in which knowledge encoded in rules becomes less consistent with their surrounding environment over time (Schulz, 1998). Because of bounded rationality, rule makers tend to focus more on the present conditions and make only poor predictions about future contingencies. Myopic rule makers and rule making processes encode lessons derived from conditions experienced at the time when rules are created and

revised. As a rule version ages, its surrounding environment inevitably changes. For instance, new technologies can emerge and new research can bring about new procedures; at the same time, old wisdoms and knowledge may lose their relevance or become more relevant (Nerkar, 2003). New knowledge sources can arise and existing ones can change. The shifts in a rule's surrounding environment will "erode" its consistency with the conditions in the surrounding environment.

The growing level of inconsistency between aging rule versions and their surroundings can enhance knowledge gaps. The existing knowledge in rules may not be sufficient to respond to new demands arising from the current environment – both internal and external to the organization – which could not be foreseen by myopic rule makers. As rule versions age, more complementary knowledge from sources both internal and external to the organization will become available and stimulate knowledge sourcing tie formation. Therefore, we hypothesize:

H1: Both internal and external knowledge sourcing increase with rule version age.

Expansion and Renewal of the Rule System

Organizational rule systems tend to expand over time and develop an increasingly finer division of labor. Consequently, the degree of specialization and differentiation of rules increases in the rule system. Individual rules become more interdependent and their functioning relies more on other rules. The interdependencies among rules have two implications. First, rule interdependencies imply that knowledge encoded in individual rules is more likely to be insufficient when being applied independently, and thus rule users are more likely to encounter knowledge gaps. Organizations (rule makers and rule making processes) are likely to respond to this situation by knowledge sourcing, especially from other rules for internal coordination on

complex organizational tasks. This should intensify as the rule system expands. Thus, the formation of internal knowledge sourcing ties should increase with the size of the rule system.

Second, when interdependent rules become misaligned, rule clashes and strains can arise. Since individual rules in organizations often originate from separate jurisdictions (March *et al.*, 2000) with specific problems, rule makers, rule users, and application constraints (e.g., technologies, organizational resources, etc.), they might get misaligned with other rules from different jurisdictions. Therefore, different rules can contradict each other. Such conflicts and strain among rules can cause uncertainties and increase organizational experiences of insufficient knowledge and likelihood of knowledge gaps. The conflicts between rules and resulting strains in rule systems can trigger non-local search for knowledge and solutions outside of organizational boundaries (e.g., in research publications, guidelines issued by professional associations). Thus, the formation of external knowledge sourcing ties should increase with the size of the rule system. Together, these arguments lead to the following hypothesis:

H2: Both internal and external knowledge sourcing increase with rule system size.

Organizational rule systems can sometimes undergo system renewal with a wave of rule births and changes. System renewal can be accompanied by system expansion, but not necessarily. A rule system can undergo drastic changes (e.g., revising or replacing rules) without a significant increase in size. System renewal often disturbs the operation of the current system by changing the interdependencies among them. Likewise, the renewal of a rule system can cause some rules to become more or less relevant and effective, and alter the ways of how different rules interact with one another. As a result, such system churn can profoundly disrupt the existing routines and thus cause uncertainties, confusion and unexpected problems. This can enhance knowledge gaps, thereby increasing the likelihood of forming knowledge sourcing ties

internally to realign different rules, as well as externally to search solutions to novel problems caused by system renewal. Therefore, we hypothesize the following:

H3: Both internal and external knowledge sourcing increase during time periods of rule system renewal.

Expansion of Knowledge Sourcing Networks

Over time, rules add knowledge sourcing ties and their knowledge sourcing networks expand, from which rules can source potentially relevant knowledge in multi-faceted situations (e.g., in the presence of patients with co-morbidities). As the knowledge sourcing network of a rule expands, its knowledge gaps are reduced/closed, and this can affect the formation of additional knowledge sourcing ties. One possibility is adaptation of knowledge sourcing networks to prevailing conditions in the environment. As the sourcing network of a rule expands, the fit between the sourcing network with prevailing conditions might improve and thereby reduce the need to add more knowledge sourcing ties. For this adaptation mechanism to work, we would need to assume that the environment is sufficiently stable so that existing knowledge sourcing ties of a rule can reduce or avoid future knowledge gaps of the rule. However, this assumption is not very plausible given innovative contexts, such as healthcare, in which knowledge and its relevance are constantly evolving.

A more plausible mechanism comes into focus if we consider that knowledge sourcing ties connect a rule not only to knowledge sources but also indirectly to other sources referenced by those sources. In other words, rules can source knowledge from distant sources through indirect ties. Knowledge sourcing ties of rules can direct the attention of rule users to sources which themselves contain references to other knowledge sources (and so on). In that respect, each knowledge sourcing tie is potentially connected to a broad swath of relevant knowledge. Such indirect knowledge sourcing can eliminate the need to create a direct tie to each of the indirectly

accessible sources through existing ties, because that would be redundant and make the rule unnecessarily complex. Thus, each additional tie can connect a rule to knowledge sources in a multifold fashion. As the knowledge sourcing network of a rule expands, more knowledge can be sourced indirectly, reducing the likelihood of new knowledge sourcing tie formation. These arguments lead us to the following hypothesis:

H4: External (internal) knowledge sourcing decreases with the number of existing external (internal) knowledge sourcing ties.

Indirect sourcing can work across environments. Knowledge sources in one environment (e.g., other rules in the internal environment) can include references to knowledge residing in the other environment (e.g., healthcare publications in the external environment). Therefore, we would expect that existing ties connecting rules to knowledge sources in one environment impede the formation of additional ties to sources in the other environment. However, it is likely that the cross-environment mechanism is asymmetric and works only in one direction. Internal knowledge sourcing ties can connect rules to other rules which in turn reference external knowledge sources. This means that internal ties can indirectly source knowledge from the external knowledge sources cited by other rules, thereby obviating the need to form direct external sourcing ties in the focal rules. In contrast, external sources usually do not contain internal (e.g., organization-specific) knowledge needed to close the gaps for internal coordination. Hence, external ties cannot connect rules to internal knowledge sources through indirect sourcing. We therefore hypothesize that:

H5: The effect of the number of internal ties on external knowledge sourcing is negative and stronger than the effect of the number of external ties on internal knowledge sourcing.

Methods

Data

Our empirical context is healthcare and we examine knowledge sourcing of healthcare rules. We collected the archives of clinical practice guidelines (CPGs) that were in use between 1989 and 2010 in a Canadian healthcare organization. CPGs are “systematically developed statements to assist practitioner and patient decisions about appropriate healthcare for specific clinical circumstances” (Institute of Medicine, 1992: 27). They incorporate implications and lessons drawn from the state-of-the-art healthcare research knowledge and aim to support decision making of healthcare professionals and patients and to standardize clinical practice across geographical locations (Grimshaw and Russell, 1994; Woolf *et al.*, 1999). In this sense, they “translate” healthcare research knowledge into clinical practice, and therefore are at the core of the “evidence-based medicine” approach.

We constructed our dataset by extracting relevant information from the collection of CPG archives. For each version of a guideline, we recorded its effective date, length, the numbers of other guidelines and healthcare research publications that it cites. An example of a CPG is shown in Figure 1. It shows an excerpt of a version of CPG F-045, which took effect in November 2009 (the revision history of the guideline is shown in the section of “Date of creation/review/revision”). The highlights in that figure were added by the healthcare administrators in that organization to indicate important changes compared to the previous version. This excerpt shows that this version of CPG F-045 has five external knowledge sourcing ties (shown in the section of “References”) and one newly formed internal knowledge sourcing

tie to CPG⁴ P-250 (which can be reached through a hyperlink). We also tracked the information at the rule system level for each year, such as the numbers of effective CPGs, new CPGs, and revised CPGs. The resulting dataset contains 802 CPGs and 1567 CPG versions during the time period of 1989 to 2010.

Please insert Figure 1 about here.

Variables

Dependent variables. Our analysis focuses on the formation of knowledge sourcing ties of CPGs. We model the rates of forming knowledge sourcing ties. When CPGs are revised, new references can be added, some of them are to other CPGs or documents in the organizations and the others are to external sources, mostly publications of healthcare research. Accordingly, we have two dependent variables: 1) the formation of internal knowledge sourcing ties, which is coded as 1 if new references to other CPGs or intra-organizational documents are added and 0 otherwise; and 2) the formation of external knowledge sourcing ties, which is coded as 1 if new references to research publications are added and 0 otherwise⁵.

Independent variables. All the covariates in our empirical analyses are time-varying. To test H1, we constructed a measure of version age as the number of years since the effective date of a guideline version. To test H2, we measured rule system size with the total number of CPGs that exist in the CPG collection in a given year. To test H3, we constructed a measure of system renewal by summing the number of new CPGs and the number of CPG revisions in a given year (note that rule system size and renewal are system-level variables which were updated each

⁴ Note that in the healthcare organization, CPGs were in some time periods referred to as “CPDs” (Clinical Practice Documents).

⁵ Our dependent variables focus on knowledge sourcing of rules. Rule changes that do not lead to the formation of new ties are outside the scope of our study, but are included as control variables in our statistical models.

year). For H4 and H5, we captured the sizes of knowledge sourcing networks by counting the existing knowledge sourcing ties of each guideline version. Specifically, we measured the size of internal knowledge sourcing networks by the number of intra-organizational sources (CPGs or other intra-organizational documents) a guideline version cites and the size of external knowledge sourcing networks by the number of cited healthcare research publications. To reduce the potential biases caused by outliers, we transformed version age, number of cited internal and external sources by taking their square roots before including them in our statistical models.

Control variables. We included several control variables in our analyses to reduce estimation biases. First, we included two variables to control for the effects of CPGs' inbound networks. Ties are directed. Inbound ties of CPGs represent the citations they receive from other guidelines in the organization and they form inbound networks; whereas outbound ties of CPGs represent the citations to others (e.g., CPGs or research publications) they make, thereby forming outbound networks. The two networks can influence each other. In this study, we focus on CPGs' outbound networks, and control for the effects of inbound networks. In particular, we included a dummy variable that indicates whether a CPG version has an inbound network, as well as the inbound network density, measured with the ratio of the number of ties among the guidelines that cite the focal CPG version to the maximum number of potential ties that could be formed among them. Second, we included the number of prior revisions of a CPG to control for the effect of its revision history. It is conceivable that CPGs having gone through many revisions have had more opportunities to form knowledge sourcing ties, and this can confound with the effect of the number of knowledge sourcing ties. Third, we controlled for the length of CPG versions measured with the number of words. The length of guidelines may indicate their complexity or knowledge intensity, and hence can affect the likelihood of further knowledge

sourcing. Similar to the independent variables, we also took the square roots of the number of prior revisions and the number of words. Finally, we controlled for historical time periods to exclude the possible effects of institutional and historical shifts on our dependent variables. We divided our observation window into three segments. The first is from January 1, 1989 to July 31, 2002, during which all the CPGs in the collection were recorded on paper. We used the dummy variable that indicating whether a CPG version was created during this time period as the reference category in our model, therefore it is excluded from the statistical models. The second period is from August 1, 2002 to December 31, 2005; this was when the healthcare organization transitioned its CPG collection to digital format. The third period is from January 1, 2006 to December 31, 2010, which is the end of our observation window. During this last time period, the healthcare organization began to gradually integrate their guidelines with those of other healthcare organizations in the wider region into a more encompassing system at the region level, which aims to provide healthcare service of consistent quality across different areas in the region. Table 1 contains the descriptive statistics of all variables included in our statistical models and the correlation matrix.

Please insert Table 1 about here.

Models

We tested our hypotheses using the fixed-effect logit models (Beck *et al.*, 2008). Fixed-effect models can avoid biases caused by unobserved population heterogeneity. Given that our dataset contains only limited information about CPGs, it would be difficult to obtain unbiased estimates if we were to test the between-guideline effects. Therefore, fixed-effect models are appropriate to test our hypotheses by focusing on the within-guideline effects that compare the rate of tie formation before and after a change of characteristics (i.e., the independent variables) occurs.

The statistical approach is similar to a within-subject experiment design and can facilitate the analysis of causal effects (Allison, 2005; Beck *et al.*, 2008).

Fixed-effect logit models are essentially one type of discrete-time event history models that model the rate of a target event, which is tie formation in this study. To prepare our dataset for the statistical analysis, we split each guideline version into sub-episodes of 1/5 year.⁶ All the covariates, including independent variables and control variables, are updated at the beginning of each sub-episode and we model the likelihood of tie formation at the end of the sub-episode. The fixed-effect models automatically exclude non-changers (with regard to the target events), namely, the CPGs that have not cite any internal or external references, because they do not contribute to estimating the rate of knowledge tie formation (Beck *et al.*, 2008). As a result, 213 guidelines and 11,830 sub-episodes are included in the analyses that model the rate of forming external knowledge sourcing ties; and 186 guidelines and 9,771 sub-episodes are included in the analyses that model the rate of forming internal knowledge sourcing ties.

Results

The parameter estimates of the fixed-effect models are shown in Table 2. Models 1 to 3 show the effects of covariates on the rate of forming external knowledge sourcing ties, whereas Models 4 to 6 show the estimates for the rate of forming internal knowledge sourcing ties. All models include the control variables. We added the independent variables in an accumulative way. In Models 1 and 4, we included rule version age to test H1. In Models 2 and 5, we added two rule system characteristics to test H2 and H3. Finally, in Models 3 and 6, we added the knowledge sourcing network sizes to test H4 and H5.

⁶ We explored splitting the data with sub-episodes of different lengths and did not find any evidence that the estimates depend on the length of sub-episodes.

Please insert Table 2 about here.

The effect of version age is positive and highly significant ($p < .01$) for both internal and external knowledge sourcing. It suggests that as a guideline version ages, it is more likely to cite internal and external knowledge sources. The finding is consistent with H1. Obsolescence intensifies knowledge sourcing of rules, from both within and outside the organization.

Rule system size (the number of CPGs in a given year) has significantly positive effects throughout all the models ($p < .05$). It means that as the number of guidelines increases in the CPG collection, a CPG is more likely to cite intra-organizational sources (other CPGs or organizational documents) as well as external sources (healthcare research publications). This is consistent with the prediction of H2 that rule system expansion promotes knowledge sourcing.

The effects of rule system renewal (the number of CPG births and revisions in a given year) are significant and positive ($p < .01$) in Models 2 and 3, but are not significant in Models 5 and 6. These findings suggest that rule system renewal increases only external knowledge sourcing, but not internal knowledge sourcing. H3 is therefore partially supported. We discuss possible explanations in the discussion section.

Finally, in Models 3 and 6 we test how the expansion of knowledge sourcing networks of rules affects their knowledge sourcing (H4 and H5). H4 predicts negative within-environment effects, and indeed, that is what we find. The number of existing external ties decreases the likelihood of forming additional external ties (coef. = -1.508, $p < .01$), and the number of existing internal ties decreases the likelihood of forming additional internal ties (coef. = -0.631, $p < .01$). H4 is therefore supported. In H5, we hypothesize a cross-environment effect of existing knowledge sourcing ties. We find that the number of existing internal ties does inhibit the

formation of subsequent external ties (coef. = -1.004, $p < .01$). At the same time, the number of existing external ties does not have significant effect on the subsequent internal tie formation (coef. = -0.205, ns). These findings support H5. They indicate that cross-environment effects of indirect sourcing do exist, but they are asymmetric.

Discussion

On a general level, our study shows that knowledge sourcing of rules happens. The rules in our study add knowledge sourcing ties; that is, rule makers add outbound citation ties which connect the rules to internal and external knowledge sources. The CPGs source knowledge from both internal sources, including other CPGs and documents, and external healthcare publications, and the sourcing intensifies over historical time (our time period effects in Table 2 indicate that sourcing tie formation rates increase). This might reflect the increasing knowledge intensity of the healthcare sector and the growing knowledge needs of decision makers of the healthcare organization. Our models support the perspective of rules as decision support devices. By knowledge sourcing, rules can feed decision processes with potentially relevant knowledge. The knowledge sourcing ties of rules direct the attention of decision makers to knowledge that is located in sources outside the focal rule and that offer specialized knowledge which might be relevant in specific situations or for a deeper understanding of the broader context.

Our analysis zooms into the organizational drivers of knowledge sourcing of rules. We build on rule-based learning theories and propose that knowledge sourcing of rules is driven by knowledge gaps arising from three rule dynamics – the evolution of individual rules, of the rule system, and of knowledge sourcing networks. We find that the expansion and renewal of the rule system as well as the aging of rule versions intensify knowledge sourcing of rules, while the expansion of knowledge sourcing networks produces self-limitation and substitution effects

which impede further knowledge sourcing of rules. The empirical findings provide overall support for our theoretical model, while the detail of our findings offers a slightly more nuanced view.

We hypothesized that rule obsolescence should intensify knowledge sourcing over time (H1). The significant and positive coefficients of version age confirm this hypothesis. They suggest that as rule versions age, they become more likely to source knowledge, and that old rule versions have stronger need to seek additional knowledge than young rule versions. It is a result with notable implications (e.g., for knowledge/advice seeking/giving of rules) which we discuss further below.

We expected that expansion and renewal of the rule system should have positive effects on both internal and external knowledge sourcing. We find that expansion (H2) of the rule system has significant positive effects for both types of knowledge sourcing, while the renewal (H3) intensifies only external knowledge sourcing, and has no significant effect on internal knowledge sourcing. It is possible that this difference arises because rule system renewal creates knowledge gaps (e.g., tensions and problems) that exceed the capacities of existing intra-organizational knowledge sources. Therefore, sourcing knowledge from outside the organization by forming external ties is necessary to close gaps.

We expected that the expansion of the knowledge sourcing networks would affect knowledge sourcing. Our argument was based on a mechanism of indirect knowledge sourcing. Existing knowledge sourcing ties can connect a focal rule to sources which might cite other relevant sources and thereby obviate direct sourcing. We thus hypothesized negative effects within environments (H4). We find that the expansion of the internal knowledge sourcing network of a rule depresses further knowledge sourcing from intra-organizational sources, and

the expansion of the external knowledge sourcing network of a rule depresses further knowledge sourcing from external sources. The findings are consistent with our indirect sourcing hypothesis.

We also hypothesized that the indirect sourcing mechanism could work across environments, but that the effects should be asymmetric (H5). We find that the expansion of the internal knowledge sourcing networks suppresses external knowledge sourcing, but there is no significant suppression in the opposite direction. The asymmetric effects are consistent with H5 and suggest that while sourcing knowledge internally may substitute for external knowledge sourcing (through the indirect sourcing mechanism), sourcing knowledge from the extra-organizational environment cannot substitute for the internal sourcing. This means that knowledge sources may play different roles. While intra-organizational sources compile organization-specific knowledge, extra-organizational sources offer deep knowledge developed in a discipline or a knowledge domain that is not specific to the focal organization. Internal sourcing ties can provide access to external knowledge via indirect sourcing, i.e., when a focal rule sources external knowledge indirectly by referencing other rules which reference the external sources. But the reverse does not hold; sourcing internal knowledge by referencing external sources is not likely to work as external sources usually do not contain organization-specific content.

Overall, the results support our theoretical model of incomplete organizational rules that encounter knowledge gaps and close them through internal and external knowledge sourcing. Knowledge sourcing of rules is powerful; it can infuse relevant knowledge – including contingently relevant knowledge located inside and outside the organization – into a wide range of decision-making processes, thereby allowing organizations to more flexibly and reliably

respond to diverse challenges they face. The knowledge sourcing of rules serves instrumental purposes for organizations.

Alternative Interpretations of the Results

We have considered alternative interpretations of our findings. Institutional theory does not directly address knowledge sourcing, but its lines of argument about legitimacy (e.g., Meyer and Rowan, 1977; DiMaggio and Powell, 1983; Tolbert and Zucker, 1983; Ashforth and Gibbs 1990; Beddewela and Fairbrass, 2016) would suggest that knowledge sourcing ties of rules might bestow legitimacy on rules and their provisions. In that perspective, sourcing tie formation could reflect some degree of legitimacy seeking of rule makers aiming to create legitimate looking rules. That might happen – legitimacy could be a motive for the closing of knowledge gaps of rules (it would be joining other motives such as retaining references to knowledge that is potentially relevant for replicating success), but it is less clear how it affects the opening of knowledge gaps (and the formation of sourcing ties). Moreover, institutional theory would predict that new rule versions have higher needs for legitimacy and thus would form more knowledge sourcing ties than old versions, but that is opposite to our findings of positive version age effects. It is also not clear how internal knowledge sourcing would contribute to the legitimacy of a rule. Lastly, the significant effects of rule dynamics in our models indicate that knowledge sourcing is shaped by intra-organizational drivers, and can not easily be reduced to a case of institutional isomorphism. It thus seems that institutional processes do not provide a plausible alternative explanation of our findings.

Another interpretation could potentially be built from transaction cost theory (e.g., Williamson, 1981; Murray, 2001; Sturgeon, 2002). One could consider knowledge sourcing of rules as a form of contracting – a subscription of a rule to a knowledge source – and then try to

analyze the trade-offs between sourcing of knowledge and encoding of knowledge into rules. However, expanding transaction cost theory into this direction is likely to face some challenges. First of all, it moves the transaction cost model to the level of rules to analyze efficient boundaries around rules. Although that might appear intriguing, it is not clear how other parts of the model – such as hierarchy or opportunism – would fit on that level. Moreover, if we take knowledge sourcing as a transaction in the sense of a movement of a resource across a boundary, we would need to examine the difference between transaction costs of knowledge sourcing versus knowledge encoding in rules. A priori, it is not clear that encoding of knowledge into rules entails lower transaction costs than sourcing it. The reverse might actually be more likely; specialized knowledge sources often have superior capabilities to maintain the quality of the knowledge they provide⁷. The transaction costs of maintaining the quality of knowledge might thus be lower if the knowledge is sourced rather than encoded in rules. However, it is likely that the story gets more complicated if we consider political factors. In fields where knowledge has a political dimension (almost always), the owners of specialized sources can have an agenda that they pursue, including influencing or controlling their users by filtering or manipulating the knowledge they provide. The impact of knowledge sourcing from political sources can be massive, and avoiding and managing associated risks can entail large transaction costs. These complications indicate that the transaction costs of knowledge sourcing and encoding can vary in complex ways. Neither sourcing nor encoding of knowledge in rules offers a clear advantage in avoiding transaction costs. It seems that transaction cost theory does not offer a plausible alternative interpretation of knowledge sourcing of rules.

⁷ Sourced knowledge can come from specialized sources which correct or update the knowledge (other rules can be updated, published research findings can become disputed). Moreover, specialized knowledge sources are used by other knowledge users (other rules or other organizations) who might produce signals about the quality of the knowledge, while encoded knowledge of a rule might fall obsolete without anyone noticing for a long while.

Theoretical and Practical Implications

Knowledge sourcing of organizational rules can play an important role in knowledge-intensive contexts, and is likely to become more important in the future as knowledge intensity of contexts increases. It is a multifaceted concept which allows for unusual connections to several prior lines of thinking.

Knowledge Sourcing and Organizational Learning

Knowledge sourcing of rules can be seen as a form of organizational learning. It directs the attention of decision makers to potentially relevant knowledge and thereby can help them to make better decisions. What makes it special, as a form of learning, is that it proceeds through the formation of reference ties to knowledge sources located inside and outside the focal organization. It can make the rules and the organization smarter and more adaptive, especially in knowledge-intensive contexts.

Our study contributes in particular to theories of rule-based learning. The core claim of rule-based learning models (March *et al.*, 2000; Schulz, 2002) is that organizations learn by encoding knowledge into rules. Our study extends that claim by suggesting that organizations can also learn through knowledge sourcing of rules, that is, by including in rules references to knowledge sources within and beyond organizational boundaries. Learning-by-sourcing retains in rules references to knowledge sources that the organization has recognized as sources of potentially relevant knowledge. Rules thereby can help rule users to find knowledge relevant to contingencies they might encounter during specific applications of the rule. Learning-by-sourcing thus could be seen as a special case of learning-by-encoding, that is, as encoding of references to knowledge sources located outside the focal rule.

At the same time, learning-by-sourcing is a response to the limitations of learning-by-encoding. Learning-by-encoding creates incomplete rules that can run into knowledge gaps. Knowledge sourcing of rules can help to close those gaps. It can help to overcome inherent limitations of learning-by-encoding because it references potentially relevant knowledge which is not directly included in the rule text. It gives rules the capacity to handle a wide range of knowledge gaps and thereby can support decision makers with knowledge relevant for particular contingencies.

Although knowledge sourcing can help to overcome the limitations of learning-by-encoding, it is not perfect. Knowledge sourcing itself is driven by myopic organizational learning processes which produce the dynamics of rules at the levels of individual rules, the rule system, and rule knowledge sourcing networks (March *et al.*, 2000). Knowledge sourcing of rules thus can produce undesirable outcomes, e.g., when internal knowledge sourcing impedes the use of superior knowledge available in external sources.

For practitioners, it is important to be aware of the limitations of knowledge sourcing of rules. Knowledge sourcing of rules is powerful, but can fail when sources get corrupted or biased. Knowledge sourcing entails a dependence on designated knowledge sources and can have undesirable consequences, in particular, it can prevent the access to alternative sources of superior knowledge. Reliance on an existing knowledge sourcing network can impede further knowledge sourcing (as our findings for H4 and H5 indicate) and thereby lock a rule into obsolete or inferior knowledge. As a rule's sourcing network expands, the rule might rely on the direct and indirect knowledge sourcing capacities of its network and thereby overlook relevant knowledge that could be provided by alternative sources. Avoiding such lock-in effects might be difficult in practice. It would require careful monitoring and reviewing of knowledge sourcing

ties and knowledge sources (existing and new) and adjusting sourcing ties when the knowledge needs of the organization change or superior sources become available. This would take substantial organizational resources, and could encounter resistance of other subunits or specific members who have an interest in relying on particular knowledge sources.

Sourcing of Actionable Knowledge into Rules

What makes knowledge sourcing of rules so powerful is that it integrates organizational rules with the sourced knowledge. Because the ties are incorporated into the instructions of the rule, they can transform (or translate or recontextualize) sourced knowledge into actionable knowledge of the rule and of rule followers. Knowledge sourcing of rules thereby can facilitate the implementation (e.g., “knowledge translation” in healthcare) of dedicated initiatives and programs. This is often desirable⁸, but can also lead to undesirable developments. Knowledge sourced by rules can be weaponized and used for the implementation of questionable action, sometimes with spectacular outcomes⁹.

Nevertheless (and fortunately), referencing of knowledge introduces the possibility of interpretation into rule following (and thereby can stimulate mindfulness and critical thinking which might alleviate over-zealous weaponization of sourced knowledge). The possibility arises because the knowledge referenced by a rule resides in another context, and this might affect the

⁸ Notable cases of positive outcomes of knowledge sourcing of rules include the use of germ theory in sanitation programs to limit spreading of infectious diseases (Stimson, 1938; Thomes, 1990; Rosen, 2015; Tulchinsky and Varavikova, 2014). Pasteur’s breakthrough innovations led to bacteriologically based public health systems and quickly spread around the globe (Velmet, 2020).

⁹ Spectacular negative outcomes can occur when political systems translate questionable theories into coercive rule systems. For example, some historical accounts of Lysenkoism suggest that over-reliance on Lamarck’s theories – sourced from the field of biology – might have supported Soviet implementation programs (fuelled by “the pressing needs of Soviet agriculture which made the society receptive to radical proposals”, Lewontin and Levins, 1976: 33) that tried to ‘educate plants’ which then led to famine (e.g., Borinskaya *et al.*, 2019). Another example are accounts of Cambodia in the late nineteen seventies which suggest that over-reliance on the theories of Marx led to the Red Khmer terror (e.g., Kiernan, 2002; Hinton, 2005).

meaning of the knowledge. The underlying reason is remoteness of sources. Sourced knowledge comes from sources that are remote from the perspective of the focal rule, sources that are not under the immediate control of the rule or its rule makers. Because of the remoteness of sources, knowledge sourced from them carries some degree of independence which can make the knowledge appear imperfectly aligned with the focal rule. Sourced knowledge thus brings along with it an acknowledgement of distance that needs to be bridged. Rule users might recognize that sourced knowledge can reflect different priorities, interests and biases, and thus is subject to interpretation (or recontextualization). For example, research papers cited by a rule might have biases due to measurement problems or publication pressures of researchers; rules of other departments cited by a focal rule might reflect the interests of those departments. Recognizing the problems of sourced knowledge is important for organizations, but not easy as the intellectual and attention resources of organizations are limited and monitoring and upkeeping knowledge sourcing ties is somewhat resource intensive (e.g., “systematic reviews” of a single CPG can easily cost a quarter million dollar). Still, critical-minded users of rules that source knowledge can recognize that the referenced knowledge is shaped by outside forces and interpret it accordingly. For example, a healthcare practitioner might recognize that a given CPG relies on biased knowledge encoded in other rules of the organization while potentially superior knowledge might be available outside the organization, and thus might interpret the knowledge provided by the other rules as obsolete and less helpful.

Knowledge Sourcing and Knowledge Relevance

One could see our study as a contribution to prior work that has considered knowledge relevance as an important driver of knowledge-related processes in organizations (e.g., Asmussen *et al.*, 2013; Augier *et al.*, 2001; Haas and Cummings, 2015; Haas and Ham, 2015; McGuinness *et al.*,

2013; Miao *et al.*, 2011; Monteiro *et al.*, 2008; Nag and Gioia, 2012; Schulz, 2001; Schulz, 2003; Schulz and Zhu 2021; Yang *et al.*, 2008). In our model, knowledge relevance plays an important role; rules source knowledge that is potentially relevant. It is the potential relevance of knowledge which essentially motivates knowledge sourcing. Specialized knowledge sources inside and outside the organization can hold knowledge that is potentially relevant to decision processes related to the diverse situations to which rules are applied. Forming knowledge sourcing ties to those sources makes sense because it can support a broad range of decision processes, and make an organization more flexible and adaptive and better matched to knowledge-intensive contexts.

A knowledge relevance perspective can help to understand multiple facets of knowledge sourcing. While evidently relevant knowledge is encoded in rules, potentially relevant knowledge is sourced. The relevance of knowledge held by specialized sources to rule knowledge gaps explains the formation of knowledge sourcing ties to those sources. The organization-specificity of knowledge explains from where it is sourced – organization-specific knowledge is sourced internally, while organization-unspecific knowledge is sourced externally.

As suppliers of relevant knowledge to decision makers, rules essentially play a dual role. Rules support decision makers by providing (i) immediately relevant knowledge in the instructions of the rule and (ii) potentially relevant knowledge through sourcing ties. Rules thereby can support both exploitation and exploration learning (March, 1991). Knowledge encoded in the instructions of the rule can support the routine use of established lessons and exploitation-type learning about them, while knowledge sourced through the rule's knowledge sourcing ties can help rule users to consider and explore alternative premises, implications, explanations, extensions, etc. However, this alignment of knowledge types and learning types is

not very tight; how the knowledge types facilitate learning can vary in practice, e.g., knowledge sourcing of a rule can stimulate local search and exploitation learning to accommodate the sourced knowledge within the frame of the encoded knowledge of the rule.

Knowledge sourcing of rules is comparable to advice seeking in social networks (e.g., Bunger *et al.*, 2018; Kantek *et al.*, 2022), whereas rules serving as knowledge sources is comparable to advice giving. Advice seeking and advice giving are complementary activities that are often driven by different forces. In rule networks, our findings suggest that seeking of advice or knowledge (that is, rules forming knowledge sourcing ties to others) is driven by seekers' (that is, rules and their users) encounters with knowledge gaps (e.g., knowledge gaps and knowledge sourcing intensify as rule versions get older and more obsolete). In contrast, giving advice (that is, rules being cited by others) seems to be shaped by other mechanisms related to the relevance of the knowledge that a source can offer (e.g., new rule versions can offer new knowledge – give advice – relevant to others, e.g., Schulz and Zhu, 2021). In that perspective, advice seeking and giving of rules can shape the evolution of rule networks. Rule networks expand as knowledge sourcing ties are formed from rules (knowledge seekers) to other rules (knowledge sources) in the system. Rules in rule networks can take on dual roles as knowledge seekers and givers. It entails a noteworthy role shift at the level of individual rules. As a rule version ages, the relevance of its knowledge for other rules decreases, and therefore is decreasingly likely to be cited (Schulz and Zhu, 2021); meanwhile, its application encounters more knowledge gaps which intensify the need for knowledge sourcing. This means, as rule versions age (i.e., rules stay unchanged in place), the role they play for other rules shifts from advice giver (being cited) to advice seeker (citing others). We hope future research will explore further the intriguing relationships between rule dynamics and rule network evolution.

Rules as Suppliers of Relevant Knowledge to Knowledge Workers

Our study supports the view that rules can source knowledge and thereby can supply relevant knowledge to knowledge workers. Rules can support knowledge-intensive work, which is often complex and uncertain, by sourcing knowledge from specialized sources located outside the focal rule. Intra-organizational sources can supply knowledge related to (and in part derived from) intra-organizational experiences in other parts of the organization. Extra-organizational sources can supply deep knowledge from diverse domains that are developed elsewhere (often by trained professionals).

In knowledge-intensive contexts, knowledge workers need rules that support their decision making; they need ‘enabling’ rules (Adler and Borys, 1996). Traditionally, rules have been used in rigid bureaucratic organizations to control and deskill workers. However, in knowledge-intensive contexts rules need to – and in fact can – leverage knowledge workers’ expertise and skills and enhance their capabilities. Rules that source knowledge can enable knowledge workers by connecting them to potentially relevant, deep knowledge located in specialized sources within and outside the focal organization and thereby can help them to make informed decisions.

Knowledge Translation in Healthcare

It is often a challenging task for healthcare organizations to maintain a set of updated CPGs (Shekelle *et al.*, 2001) that translate healthcare research knowledge into clinical practice, which is very concerning. Our study can potentially help healthcare organizations to facilitate “knowledge translation” by intensifying knowledge sourcing of their guidelines. Our results suggest that managers in healthcare organizations might want to develop an understanding of the guideline system dynamics and closely monitor it. This can help them to identify knowledge gaps that arise from the guideline system dynamics. For example, they should be aware that

creation and revision of guidelines in the system as well as the aging of guidelines can produce knowledge gaps, and then take proactive steps to close them, such as searching for adequate sources that can provide relevant knowledge and integrating references to sourced knowledge into the instructions of the rules. At the same time, managers should also be cautious about the suppression effects of prior internal and external knowledge sourcing, especially the strong substitution effect of internal on external knowledge sourcing. When the existing knowledge sourcing ties shield guidelines from the exposure to other sources, inferior or biased sources of knowledge can become relied on while better sources might be available elsewhere. Managers should pay more attention to guidelines embedded in large knowledge sourcing networks and make efforts to update their references to make sure that the sourced knowledge is relevant and appropriate.

Limitations and Future Research

Our study has several limitations. First, the study is conducted in one single healthcare organization in Canada, and the generalizability of the findings is uncertain. We hope future research can collect similar rule archive data in other contexts and test generalizability of our theory.

Second, our theory is built on the assumption that incomplete rules can encounter knowledge gaps and that rule dynamics (at the levels of rules, rule system, and rule networks) can affect the occurrence of knowledge gaps (and thereby drive knowledge sourcing). Due to the limitation of our data, we cannot directly measure knowledge gaps. Knowledge gaps are a theoretical construct in our paper. Although our empirical findings are overall consistent with our theory, we still encourage future research to collect data that can directly measure knowledge

gaps and test their relationship with the likelihood of knowledge sourcing, and examine whether knowledge sourcing can indeed reduce knowledge gaps.

In this study, we track the formation of rules' outbound citation ties over time as the indicator of knowledge sourcing. However, the citation ties only connect rules to written knowledge sources. Knowledge gaps of rules may be closed by knowledge derived from unwritten sources. The sourcing of knowledge from unwritten knowledge sources is difficult to observe and study. For instance, rule users may obtain complementary knowledge from other healthcare workers by collaborating or communicating with them, or by observing what others do. We do not know how this type of knowledge sourcing interacts with knowledge sourcing by forming citation ties in rules. Does it substitute knowledge sourcing of rules? How do features of knowledge gaps of rules affect types of knowledge sourcing? We hope future research can advance our understanding in this direction.

Conclusion

Knowledge sourcing becomes increasingly important for organizations as their contexts become more knowledge intensive. Knowledge sourcing can help organizations to obtain complementary knowledge from outside sources, e.g., by forming relationships and alliances to learn about specialized technology or the conditions in foreign markets. Our study shows that knowledge sourcing also happens at the level of organizational rules. In knowledge intensive contexts (healthcare in our study), rules reference intra- and extra-organizational sources of knowledge. Rules thereby can support organizational decision makers with knowledge that is potentially relevant for their decision making, e.g., in healthcare it can help to avoid negative interactions between treatments. Knowledge sourcing of rules entails enormous opportunities and benefits ("evidence-based healthcare" is one of them), but also significant challenges (e.g., over-reliance

on some sources). It is powerful, but imperfect, and thus entails risks. Doing it right is not easy, but organizations in complex, high-risk contexts will have to manage the knowledge sourcing of their rules. Our study gives some insights into the organizational drivers and limitations of knowledge sourcing of rules, and thereby might help practitioners to manage it.

The larger picture arising from this study is that incomplete organizational rules encounter knowledge gaps and close them through internal and external knowledge sourcing. It is a March and Simon inspired vision of rules, reflecting bounded rationality of decision makers and myopia of adaptation processes. It is a perspective which highlights the multifaceted nature of rules and knowledge sourcing of rules. We hope it will inspire others to continue on this path.

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TABLES

TABLE 1
Correlation Matrix

	Mean	Std. Dev.	Min	Max	1	2	3	4	5	6	7	8	9	10	11	12
1 Formation of external ties	0.020	0.141	0	1												
2 Formation of internal ties	0.018	0.132	0	1	0.524											
3 Having an inbound network	0.417	0.493	0	1	0.012	0.047										
4 Inbound rule network density	0.045	0.146	0	1	-0.004	-0.003	0.360									
5 Number of prior revisions ^a	1.214	0.701	0	3.606	-0.024	0.012	0.292	0.204								
6 Number of words ^a	28.119	12.491	6.245	87.321	-0.004	0.040	0.301	-0.004	0.345							
7 Time period 2	0.288	0.453	0	1	0.032	0.032	0.011	-0.029	-0.039	-0.045						
8 Time period 3	0.440	0.496	0	1	0.035	0.038	0.116	0.112	0.350	0.163	-0.564					
9 Version age ^a	1.460	0.739	0	3.821	0.112	0.046	-0.084	-0.050	-0.242	-0.176	0.073	0.063				
10 Number of CPGs	624.400	91.396	62	706	0.062	0.069	0.174	0.117	0.419	0.159	0.079	0.660	0.167			
11 Number of new CPGs + revisions	106.086	51.595	4	207	0.040	0.034	-0.005	-0.037	-0.080	-0.040	0.468	-0.333	-0.072	0.044		
12 Number of cited publications ^a	1.759	0.935	0	5.568	-0.002	0.016	0.255	0.010	0.333	0.521	-0.040	0.135	-0.084	0.132	-0.047	
13 Number of cited internal documents ^a	0.919	1.048	0	5.477	-0.025	0.046	0.289	0.084	0.332	0.398	-0.099	0.271	-0.188	0.234	-0.099	0.224

n = 13,289

a. Square root

TABLE 2
Fixed-Effect Logit Models of the Rates of Knowledge-Sourcing Ties Formation

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
	Rate of Forming <u>External</u> Knowledge Sourcing Ties			Rate of Forming <u>Internal</u> Knowledge Sourcing Ties		
Having an inbound network	1.673** (0.545)	1.595** (0.568)	1.224* (0.566)	1.258** (0.373)	1.158** (0.397)	1.308** (0.412)
Inbound rule network density	-3.973** (1.508)	-4.100* (1.626)	-4.391** (1.676)	0.946 (0.876)	1.418 (0.898)	1.493+ (0.904)
Number of prior revisions ^a	-3.504** (0.380)	-3.870** (0.461)	-3.691** (0.478)	-2.254** (0.232)	-2.783** (0.272)	-2.512** (0.290)
Number of words ^a	-0.002 (0.021)	0.003 (0.022)	0.129** (0.033)	0.017 (0.015)	0.018 (0.015)	0.046* (0.019)
Time period 2 ^b	2.725** (0.410)	2.147** (0.438)	2.223** (0.443)	2.908** (0.424)	1.533** (0.458)	1.534** (0.455)
Time period 3 ^c	4.263** (0.493)	3.546** (0.554)	3.694** (0.566)	4.062** (0.468)	2.111** (0.557)	2.062** (0.555)
Rule Obsolescence						
Version age ^a	1.849** (0.198)	1.791** (0.221)	1.924** (0.233)	0.949** (0.137)	0.941** (0.148)	0.846** (0.153)
Rule-System Evolution						
Number of CPGs in the system		0.008* (0.003)	0.009** (0.003)		0.019** (0.004)	0.021** (0.004)
No of CPG birth + revision events		0.004** (0.002)	0.004* (0.002)		0.002 (0.002)	0.001 (0.002)
Knowledge Sourcing Network Expansion						
Number of cited publications ^a			-1.508** (0.301)			-0.205 (0.183)
Number of cited internal documents ^a			-1.004** (0.297)			-0.631** (0.189)
Log-likelihood	-765.194	-752.134	-734.512	-841.568	-814.379	-807.423
χ^2	525.669	551.791	587.034	310.775	365.152	379.065
df	7	9	11	7	9	11
$\Delta\chi^2$		26.12**	35.24**		54.38**	13.91**
Δdf		2	2		2	2
Observations	11,830	11,830	11,830	9,771	9,771	9,771
Number of guidelines	213	213	213	186	186	186

Standard errors in parentheses

** p<0.01, * p<0.05, + p<0.1

a. Square root

b. Period 2: Aug 1, 2002 – Dec 31, 2005 (Note, the reference category is Period 1: Before Jul 31, 2002)

c. Period 3: After Jan 1, 2006 (Note, the reference category is Period 1: Before Jul 31, 2002)

FIGURES

FIGURE 1 Excerpt from CPG F-045 on Femoral Arterial Sheath/Line: Removal and Groin Clamp

Post-Femoral Clamp Removal

13. Assess whether a bruit is absent. Obtain vital signs, assess puncture site and pedal pulses Q15min x 4, Q30min x 2, then Q1H x 4 hours.
14. Apply >5 lb sandbag x 1 hour. The sandbag does not apply extra pressure to the puncture site. It is used to remind patients not to move or bend their affected leg.
15. Remind patient to place hand over affected groin and hold when voiding, sneezing, or coughing. The patient should inform the nurse if s/he feels any blood, wetness or stickiness.
16. Wash compression arch and base with Cavi-Wipes and rinse. Dispose the compression disc as per hospital policy (Blood and Body Fluid precautions: place saturated or visibly contaminated items with blood or body fluid in a container with the biohazard symbol).
17. Refer to CPD P-250 Care and Management of Pre-/Post- PCI and cardiac catheterization for activity level and possible complications.

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