

EMBEDDED RULE CHANGE: NETWORK EXPOSURE
AND CLINICAL PRACTICE GUIDELINE REVISIONS

by

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Abstract

The primary goal of this study is to explore the effects of rule networks on rule change.

Organizational rules are often interdependent with other rules that govern related subtasks, workflows, actors, and organizational subunits. Therefore, rules shape the context for the use of related rules, and they can impede or intensify the change of related rules. Even though prior research has suggested that organizational rules are interdependent and can affect each other, the relationship between rule interdependence and rule change has not been systematically studied so far. This study is the first attempt to explore this relationship directly and empirically.

I focus on rule interdependencies that have been articulated and formalized as citation ties between rules. Citation ties link interdependent rules together into directed rule networks. I adopt an ego network approach and examine how shifts of characteristics of individual rules' inbound citation networks affect their revisions.

I argue that when rules are cited by other rules, they become exposed to the experiences arising from citing rules' contexts. Because different rules serve different roles, those experiences can be incongruous to the experiences in their own contexts. This can produce tensions, which I refer to as *rule strain*, for the cited rules. Rule strain produces change impulses that intensify rule revisions. Shifts in rule networks can shape the exposure of individual rules to rule strain and thereby affect their revision rates. I identified four important dimensions of exposure and developed hypotheses of their effects on rule change: network exposure (presence of an inbound network), exposure intensity (network size), exposure nonredundancy (network density) and

exposure newness (occurrence of network change events, i.e., arrival of new ties, revisions of citing rules).

I test my hypotheses with data extracted from the archives of clinical practice guidelines (CPGs) of a Canadian regional healthcare organization, spanning the years from 1989 to 2010. I find strong evidence that rule networks affect rule change. Becoming cited by others significantly increases individual rules' rate of revision. Moreover, I also find significant effects of network density and occurrence of network change events, but no systematic effect of network size.

Preface

This dissertation is part of Prof. Martin Schulz's project, titled "Towards Better Knowledge Translation: Examining the Integration of Research Findings into Clinical Practice Guidelines". The project and the associated data collection reported in Chapter 5 were approved by the University of British Columbia's Behavioral Research Ethics Board (BREB) with the certificate number H09-01989. The project has led to several papers that coauthored by Prof. Schulz and me. These papers have been accepted and presented at various conferences and are close to submission to journals. None of the text of this dissertation is taken directly from previously written articles.

I coded the archives of CPG revision histories with citation information into Excel spreadsheet, which was later imported into and processed by SAS. Prof. Schulz and I co-developed the data-cleaning SAS program that cleaned and parsed out the raw data and the spell-splitting SAS program that created dynamic covariates. The FORTRAN program that I used to extract dynamic rule network information, which constitutes key independent variables of my study, was conceptually co-developed by Prof. Schulz and me, and written by Prof. Schulz. I independently conducted the data analysis that leads to the results.

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Chapter 1

Introduction – Why Study Rules, Rule Revisions, and Rule Networks?

1.1 Rules, Rule Networks, and Rule Change

Rules have long been playing a central role in human societies and civilization throughout the recorded history. The earliest known rule text in human history is probably the Ancient Egyptian laws that date as far back as 3000BC. The oldest extant legal text, the Code of Ur-Nammu, dates back to 2100 BC – 2050 BC and predated the famous Code of Hammurabi by three centuries.

Rules can be defined as “fixed response to defined situations” (March & Simon, 1958, p. 142).

Rules are action programs that elicit similar behaviors and produce similar outcomes for recurrent situations. They are often formalized and kept as written texts that govern individual conduct and organizational action (e.g., as bureaucratic rules, laws, regulations, policies, guidelines). This study explores written rules empirically, but I believe that the models of this study can also apply to other rule-like phenomena, such as habits, grammars, cultures, norms, routines, procedures, conventions, roles, beliefs, paradigms, rules of game, rules of thumb, etc.¹ (March & Olsen, 1989, p. 22; March, Schulz, & Zhou, 2000, p. 5).

Rules guide action in almost every aspect of human life, from individuals’ activities in daily life to behavior in and of social organizations (e.g., schools, hospitals, workplace, shops, associations,

¹ There are at least two streams of research on organizational rules. One is on formal written rules, and the other is on organizational routines. Rules and routines share some similarities, but also have differences. Please refer to section 1.3 for more details.

etc.), and to international relations, such as trade and wars, that can have huge implications for the international community (G. T. Allison, 1971). Undoubtedly, rules have penetrated into every single cell of our societies, which would have otherwise been disorderly mess. Rules therefore are the fundamental building blocks of social structure, forming recurrent patterns of behavior in organizations and society, and enforcing and maintaining social order. As March and his colleagues have pointed out: “contemporary hierarchies, markets, and international relations are governed by institutions built around formal and informal rules” (March, et al., 2000, pp. 7-8).

Rules function as kernels of social order and ensure predictability of action and stability of societies. However, they do not operate in isolation, but rather work together with other rules in rule systems that shape action and define its context. Organizations are built from interdependent bureaucratic rules, which can be combined to form complex organizational structures and facilitate differentiated organizational responses.

At the same time, rules are by no means static. Rules respond to shifts in their environments, e.g., their organizational context or economic conditions (e.g., March, et al., 2000). They undergo repeated revisions that incorporate lessons drawn from experiences (of the same organization or of other organizations), including experiences made with other connected rules. Rules and rule change have found considerable attention in prior organization studies, such as Weber’s analysis of bureaucracies, the Carnegie School, evolutionary economics, institutionalism, and organizational learning. In this study, I aim to contribute to the understanding of the processes of rule change. Unlike prior research, I bring the interdependencies between rules into focus and use a network approach to examine their effects on rule revisions.

Interdependencies between organizational rules are surprisingly underexplored, even though they are rather common and have significant potential to affect rule changes. Rules can, and often do, clash with other rules, and this can trigger rule changes (e.g., legal statute changes in response to legal challenges in the courts). Rules are often connected to other rules pertinent to the same situation or the same workflow, and changes in some rules can lead to cascades of changes of other rules. Rules can also invoke other rules, producing complex chains of organizational action, yet this can also lead to unexpected outcomes that can trigger or prevent other rule changes. As these examples show, rules are likely to be interdependent, and the interdependencies are likely to affect their change. How interdependencies between rules affect their change is the subject of this study.

1.1.1 Centrality of Rules in Human Societies

Rules play a central role in all human societies. They shape actions of actors in organizations, in public, and in their private lives. Many rules – be it formal rules, such as laws and policies, or informal rules, such as conventions, norms, and traditions – are so entrenched in people’s lives that they tend to take those rules for granted and follow them mindlessly.

Rules often play a critical role in guiding individual actions (March et al, 2000). Rules can define the appropriateness of actions in a particular situation. By following rules, individuals can keep their daily lives on track (Schulz, 2008). Let us consider a typical morning for an ordinary person: getting up at 7 o’clock, washing up, having breakfast, driving to work, arriving at office at 9 o’clock and walking to his desk while greeting colleagues. This whole series of behaviors

are all rule-following. From getting up to leaving for work, he follows his own morning routines; on the way to work, he has to follow traffic rules; he arrives at office at 9 in order to obey organizational rules; and he greets other colleagues as conformity to the social norm.

Rules have been considered as primary instruments of organizing and as solutions to problems of social order (Parsons, 1982). Almost all kinds of organizations in contemporary societies, such as companies, schools, hospitals, stock markets, and internet communities, are organized by rules. Rules often can make action predictable and can facilitate coordination between actors. For example, we know that in convenience stores, we can buy things with money at late hours. In this way, social orders and structures arise. Without rules regulating social interactions and binding actions of people with divergent objectives and interests, human societies could decay into chaos. Just as Durkheim argued, anomie can result during the transition from mechanical to organic society, when old rules break down and new rules have not yet established (Durkheim, 1933 [1893]). A variety of negative consequences can ensue, such as “wars of all against all” (Hobbes, 1909 [1651]) and high rate of (anomic) suicide (Durkheim, 1966 [1897])

Nowadays, the world where we live appears to be increasingly rule-intense. It seems that Max Weber’s prophecy that modern society would be trapped in the “iron cage” of bureaucracy is becoming a reality. Think about how much longer it now takes to get through the security to the boarding gates in airports than it used to. After the terrorist attack in the United States on September 11th, 2001, rules related to “homeland security” were significantly elaborated and expanded; the rule intensity at airports all over the world has dramatically increased, and traveling seems to involve more and more “hassle”. Also consider how rules play an increasingly

important role in the economic field, replacing its original focus on self-regulating processes of markets. Since the outbreak of financial crisis in 2008, more governmental intervention and regulations have been called for (e.g. the Volcker Rule). It seems that we can no longer afford to have a market that is regulated by only an “invisible hand”². Moreover, the development of modern technologies has brought about unprecedented social issues that need to be addressed; consequently, new rules are emerging. For instance, the proliferation of the internet has enabled forms of behavior with undesirable outcomes (e.g., cyber scams, Darkmarket, cyberbullying) and has led to demands for more regulations. The digitalization of society has penetrated into everybody’s life and intensified elaboration of privacy rules; and the advancement in genetic engineering has intensified debates on ethical implications and regulations. All of these are calling for serious consideration, which will ultimately result in more elaborated rules and rule systems. Undoubtedly, rules are and will continue to be dominating every aspect of our lives and our societies. Understanding their elaboration will become increasingly important.

1.1.2 Organizational Rule Change – A Brief Review

Rules and other rule-like phenomena are ubiquitous and play an extremely important role in modern organizations. Formal written rules are regarded as the primary feature of modern formal organizations that differentiate them from traditional organizations (Weber, 1968). Rules can take various forms in organizations, such as policies, organizational charts, job descriptions, operating guidelines, conventions, norms, routines, etc. Organizational rules are critical for organizational functioning. They define interrelationships among individuals and subunits,

² See for example, Stiglitz, Joseph. 2010. *Freefall: America, free markets and the sinking of the world Economy*. New York: W. W. Norton & Company.

coordinate actions and behaviors, regulate decision-making processes, channel attention, provide relevant information needed for decision making, and shape structures and workflows.

Given the essential roles organizational rules play to shape and define structures, organizational rule changes tend to have major implications for the change in organizational structures.

Deceleration of rule changes means emergence of stable organizational order, while acceleration of rule changes means transformation of organizational order. Studies of organizational rule change can thereby contribute to our understanding of the emergence of stable organizational structures, and their transformation and growth over time. Weber's exploration of bureaucratization is an early precursor on this line of research. Since then, rule change has found the attention of scholars from diverse backgrounds, including (post-Weberian) bureaucracy theory (e.g., Crozier, 1964; Gouldner, 1954; Merton, 1952), institutional theory (e.g., DiMaggio & Powell, 1983; Meyer & Rowan, 1977), routines (e.g., Becker, 2008), evolutionary economics (Nelson & Winter, 1982), the Carnegie School (March & Simon, 1958; Simon, 1957), and its diverse branches, such as Behavior Theory of the Firm (Cyert & March, 1963), the Logic of Appropriateness (March & Olsen, 2006; Schulz, 2014), organizational learning (Levinthal & March, 1981; Levitt & March, 1988; Schulz, 2002), and the Dynamics of Rules (March, et al., 2000).

As research subject, rule change has only slowly moved into the center of attention of organizational research, although it has always played an important role in the periphery (as a given, e.g., in the form of unchanging "natural laws", or in the form of a premise about the contribution of inert rules to stable social order) of all scholarly reflections on organizational

rules and their outcomes. The interest in organizational rule change can be traced back to the works of classics in sociology and organizations.

Weber regarded rules as the fundamental elements of modern bureaucratic organizations (Weber, 1968). He believed that bureaucratic organizations, governed by rationally and precisely calculated rules, could escape the influence of personal and emotional factors that are often irrational and incalculable, and therefore would be more efficient than traditional organizations. However, in spite of the superiority of rule-based bureaucracy, Weber saw an ominous prospect of modern societies and warned that rules would breed more rules, which would eventually turn bureaucracy into an “iron cage” (Weber, 1988, p. 181). This iron law of bureaucracy vividly depicted the supra-individual process of rule production and expansion in modern organizations and fascinated many organization scholars in the early 20th century. Rule change plays an important role in Weber’s work, but mostly in the context of his studies on bureaucratic organizations. Weber saw bureaucratization as a broader phenomenon that includes rule proliferation and elaboration as primary characteristics (it includes also selection and training of bureaucrats etc). Later, quantitative research on rule change has connected to Weber’s theory, but it was located at the rule population level and explored how Weberian rule proliferation mechanisms affect birth and death rates of organizational rules (e.g., Beck, 2006; Schulz, 1998a).

Post-Weberian scholars, taking Weber’s notion of rules as the fundamental building blocks of bureaucracy, developed natural-system explanations of rule production in bureaucratic organizations, such as the interpersonal tension caused by close supervision (Gouldner, 1954), and “vicious cycles” arising from internal power struggle (Crozier, 1964). Unlike Weber, these

scholars did not view organizations as rational systems, but rather as natural systems, in which informal structures can arise, and are constantly eroding formal structures by bringing in personal and emotional elements. Rule bodies therefore are elaborated to incorporate informal structures into formal structures. From this perspective, rule proliferation is a result of formal structures struggling to sustain facing informal structures (Selznick, 1948). Clearly, rule change plays a role in the work of natural-system scholars, but their writings relate more to the dysfunctional outcomes of rules than to explaining the change of individual rules.

Rule change found more direct attention in the Carnegie School. Rules were seen as “the result of a long-run adaptive process by which the firm learns” (Cyert & March, 1963, p. 113). In this perspective, rules are repositories of knowledge that organizations have learned over time. In this model, rule change serves a function – encoding new lessons from organizational learning (Levinthal & March, 1993; Levitt & March, 1988). The related Dynamics of Rules approach (March, et al., 2000; Schulz, 1992, 1998a; Zhou, 1993) has turned to organizational rule archives and examined rule change quantitatively, on both rule system level and individual rule level. Following this approach, scholars explored critical events of individual rules – rule births, revisions, and suspensions – in order to study processes of organizational learning and adaptation, as well as the resulting changes in the patterns of organizational behaviors and activities (e.g., Beck & Kieser, 2003; Schulz, 2003; Schulz, Jennings, & Patient, 2010).

The brief review of the rule change literature above shows that most prior rule research, especially the classical theories discussed rule change in terms of expansion of bureaucratic systems in general and explored the mechanisms that account for it. However, rule change is not

only occurring on system level (through births and suspensions of rules), in fact, most of the time, it occurs on the level of individual rules, through successive revisions that replace old contents with new rule contents. Since the early 1990s, rule research has begun to include rule level processes into the analysis. Empirical studies began to observe individual rules over time and analyze their revision rates, connecting them to models of learning, attention, and problem solving. Moving the focus of analysis to the individual rule level facilitates a more detailed analysis of rule change processes and can lead to a deeper understanding of underlying change mechanisms. In particular, on individual rule-level, factors come into play, which arise from the individual rule and its immediate environment, in particular ties to other rules and rule networks.

In this study, I will build on prior research to analyze the changes on the individual rule level – rule revisions³. Individual rules can change through revision events that replace the current version of the rule with a modified one. Rule change speeds up when revisions occur sooner after the preceding rule change event (revision or rule birth), and rule change slows down when revisions are delayed. Rule change speed can be captured by the time between revision events, or, equivalently, by the probability of revision events per unit of time⁴. By examining the speed of rule change (or rate of revision) using a collection of hospital rules, I aim to contribute to a deeper understanding of how organizational rules are transformed by rule-level processes, especially the ones related to rule networks.

³ Even though rule births and deaths are outside the scope of this study, I consider them as independent variables in my models. They play an important role in my analysis of the effects of network change events on individual rule revisions (e.g., see chapter 4). I examine how rule birth and suspension events occurring in the ego network of a rule affect the focal rule revisions.

⁴ Note that I do not assume any normative value of rule revisions or revision rates. Revisions can have a diverse range of implications, including desirable, undesirable, and imagined outcomes of the revised rule version (and accelerating or delaying rule revisions). For that reason, it is not possible to attach a universal or normative value to organizational rule revisions. However, for specific domains rule revisions and their delays can appear to have clearer implications, e.g., for “knowledge translation” in the health care sector (see Chapter 3).

1.1.3 Interdependent Rules

Organizational rules are not isolated pieces of text, but rather, they are interdependent, thereby forming rule systems. Rule interdependence can be conceptualized in many different ways. It can arise from belonging to the same rule system or functional area (e.g. urology rules, respiratory rules, cardiology rules, etc.), from being created and maintained by the same rule-making body or at the same time, from being used by the same rule users, or even simply from being displayed proximately in a rule book. More importantly, rules can become interdependent because they address the related issues (e.g. rules regulating skin and wound infection prevention and rules regulating arterial leg ulcer management), are called for in the same situations, or can be combined to facilitate and coordinate workflows. Interdependent rules are intensely interacting to produce outcomes, shaping the context for the use of each other (March & Simon, 1958, p. 149; Simon, 1957) and collectively forming grammars of action that generate repetitive patterns of organizational actions (Pentland & Rueter, 1994).

From an information processing perspective (Egelhoff, 1982, 1991; Galbraith, 1973; Simon, 1957), rule interdependence can reflect interdependencies between different parts of the organizational structures, such as actors, departments, subunits, teams, workflows, and subtasks. To manage and coordinate structural interdependencies, organizations often encode them into the content of relevant rules by explicitly connecting the rules via citation ties. As a result, citation ties between rules represent structural interdependencies, and they form directed rule citation networks that can be directly observed. In that sense, rule citation networks are manifestations of the underlying rule interdependencies, which in turn reflect structural interdependencies within organizations. For example, in a hospital, we might observe a surgery rule cites a pain

management rule. It is because managing pain is important both before and after a surgery. When performing a surgery, surgeons and nurses need to consult and coordinate with pain management experts in order to effectively control and reduce the patient's feeling of pain. These two rules might often be applied together. Hence, the citation tie between the surgery rule and the pain management rule indicates the interdependency between these two rules, which reflects the underlying structural interdependency between the surgery team and the pain management team.

When rules are interdependent, their change (i.e., revisions) becomes interdependent too. The role of interdependencies for organizational change has been recognized in several prior lines of work. For example, a core argument of contingency theorists has been that mechanistic structures – with tight, formalized interdependencies between organizational parts – lack adequate flexibility and fail in fast shifting environments (e.g., Burns & Stalker, 1961; Emery & Trist, 1965; Siggelkow, 2001). Likewise, rules that are interdependent might lack flexibility. Rules that are tightly connected to others might be more difficult to change. Embedded rules might change at lower rates than isolated rules.

This view is further advanced by complexity theory, which mainly seeks to answer the question: How do systems adapt? This theory argues that a complex adaptive system, in which partially connected agents interact and co-evolve with each other, is more adaptive than a system in which agents are either more tightly coupled or more loosely interconnected (Bradach, 1997; Eisenhardt & Bhatia, 2002; Tripsas, 1997; Uzzi, 1997). From the perspective of complexity theory, one can perceive a rule network as a complex adaptive system, in which individual rules

are adaptive agents that interact with one another. Therefore, applying this theory to rule networks, we might expect an inverted-U relationship between interdependencies among rules and individual rule change.

Moreover, research on organizational knowledge evolution suggests that relationships between knowledge elements play a key role for innovation and knowledge creation (W. M. Cohen & Levinthal, 1990; Kogut & Zander, 1992; Zander & Kogut, 1995). Likewise, as repositories of organizational knowledge, rules might evolve faster the more they are connected to other rules. Interdependencies between rules would facilitate changes in individual rules.

Clearly, interdependencies are relevant for organizational and system change. For rules, similar things might hold. It seems conceivable that rule interdependencies (represented by rule networks) affect rule revisions⁵. However, considering the prevalence of rule interdependencies, surprisingly little efforts have been made to understand this relationship. My study presents a first attempt to fill this gap.

A very limited treatment of rule interdependence was part of the Dynamics of Rules at Stanford University (March, et al., 2000). In that study, the authors creatively introduced an ecological perspective into rule research. They argued that individual rule change depends on processes of problem generation and attention allocation occurring in a rule ecology, characterized by competition for problems and contagion of attention between rules. The empirical findings are

⁵ An important implication of this is methodological. If rules are interconnected and affect each other's change, they are not any more statistically independent. This can lead to serious biases if the interrelationships among rules in the models of rule change are not considered. Because prior research has not included rule network effects, my study can serve to shed light on this issue and help to assess the likelihood of specification biases in studies that omit rule citation ties.

intriguing, yet puzzling. For example, they found that in general the rate of revision of a rule was enhanced when there were other rules revised at the same period of time. However, the effect of revisions of other rules occurring at earlier times were less decisive on a focal rule's rate of change (for academic rules, rule change in the same area at earlier times was found to have a positive effect; whereas for administrative rules, it had a negative effect).

To some degree, these inconclusive results might be attributed to the nature of the ecological approach that was adopted for the analysis. Ecological approaches focus on entire populations of units (e.g., organizations or rules) and study change in terms of vital rates (birth and mortality rates) of units. Populations respond to environmental pressures, which usually result from the limitedness of resources, by weeding out the unfit units and keeping the fit ones. Individual units are assumed to be inert, and their change or adaptation is not taken into consideration, neither is the role that their networks play. For that reason, adopting an ecological approach to study individual rule revisions is inherently limiting.

Undeniably, ecological approaches in the Dynamic of Rule study have directed attention to the effects of rule interdependence on rule change (March, et al., 2000; Schulz, 1998a). However, they fall short on explaining the revisions of individual rules that are embedded in networks. In order to explain the revisions of embedded rules, we need to understand the nature of their interdependencies. March and his colleagues (2000) realized the problem and therefore called for future research that can better investigate the structures of rule systems:

[A]n ecological treatment of rule change requires some ideas about the dimensions and metrics of distances among rules, about the ways in which networks of connections create

isolated pockets of rules, and about the forms of autonomy and mutual interdependence typically prevailing among organizational rules (p192).

I build on and further extend the rule-based learning literature and the Dynamics of Rule approach (March, et al., 2000) by following March et al.'s call for incorporating networks into models of rule revisions. My study aims to advance research on interdependent rules by focusing the lens of analysis on rule networks. I believe that a deeper exploration of rule networks can greatly contribute to understanding the revisions of organizational rules, because it helps define the interdependencies between rules and brings the structure of rule ecology into focus by considering (and building models on) the attributes of connected rules, inter-rule ties and rule network structures. My study therefore provides a basis for developing a new theory about how being embedded in rule networks can facilitate or impede individual rule revisions.

In this study, I exclusively focus on networks that consist of rules interconnected⁶ by citation ties. Rules that are interdependent are often connected with citation ties to facilitate their coordination, e.g., when workflows of rules are connected or draw on the same resources. My focus allows me to closely examine rule interdependence and therefore can help to better understand its effects on individual rule revisions. I aim to understand the role of rule citation networks for the revisions of embedded rules, and contribute more generally to developing a deeper (new, rule network-based) understanding of how structures change (and stabilize) in organization.

⁶ Rule interconnections are manifestation of rule interdependence. Rule interdependence is a theoretical concept that is relatively abstract, whereas rule interconnections can be observed (e.g., existence of citation ties between rules). In my study, I assume that citation ties that interconnect individual rules reflect the underlying rule interdependence.

My main research question is: *Do rule networks affect individual rule revisions? If so, how and why do they affect rule revisions over time?* My unit of analysis is individual rule (which may undergo repeated revisions over time), and my analysis is focused on rule-level mechanisms. Treating rules as core units of analysis is relatively uncommon in the social sciences (due to its prevalent focus on human actors), and comparisons between rules (and rule networks) and individual actors (and social networks) are tempting and inspiring, but bear the risk of undue anthropomorphization. It should be noted that I do not intend to attribute human-like features (e.g., volition, etc.) to rules. The core of my argument centers on “exposure”, and different ways how citing rules expose cited rules to change impulses.

I propose that rule citation ties can expose the cited rules to the citing rules’ contexts, including experiences and problems in those contexts. The exposure can cause tension on the cited rules as the experiences and problems they are exposed to tend to be incongruous with those arising from their own contexts. The tension – which I refer to as *rule strain* – triggers learning and thereby intensifies the cited rules’ rate of revision. Rules’ rate of revision depends on the level of strain that they experience as a consequence of being cited by others, which is in turn determined by the characteristics of the citation networks they are embedded in.

I test my theory in a healthcare setting, using the archives of clinical practice guideline (CPG) revision histories from 1989 to 2010 collected from a Canadian regional healthcare organization. In addition to the fairly complete revision histories, the archives also contain the information of the CPGs making references to one another over time. This unusual dataset allows me to

construct rule citation networks and to test my theory of the effects of rule networks on individual rule revisions.

1.2 Written Rules and Unwritten Routines

Research on organizational rules is generally divided into two streams. One is on written rules (Beck & Kieser, 2003; March, et al., 2000; Schulz, 1998a, 1998b; Sullivan, 2010; Zhou, 1993), and the other on organizational routines (Feldman & Pentland, 2003; Nelson & Winter, 1982; Pentland & Feldman, 2005; Pentland & Rueter, 1994). Written rules and routines are sometimes treated alike (Becker, 2004; March & Olsen, 1989), since they share some similarities. First, both rules and routines can shape and maintain organizational structures, because both define behaviors appropriate for certain roles and under certain conditions, regulate and coordinate actions when facing potentially divergent individual interests. Second, both rules and routines are repositories of organizational knowledge. They complement each other. Rules encode knowledge that is intended to be general enough to be applied to various contexts and therefore are likely to be incomplete and “rarely prescribe actions in sufficient detail and clarity” (Kieser, 2008, p. 67). Routines, on the other hand, “fill the void at the heart of rules” (Reynaud, 2005, p. 866) by providing concrete behavioral guidelines.

Written rules, compared with routines, also have some distinct features. First, written rules record organizational histories more systematically than routines. Routines are easily disrupted and distorted without systematic recording as organizational members come and go, especially in large and structurally complex organizations. Organizational histories recorded in routines therefore can be fragmented. Written rules, however, are less influenced by the turnover of

organizational members. They keep organizational actions to a large degree continuous, because anyone, especially new organizational members that have replaced the old ones, can refer to written rules at any time for appropriate actions. Therefore, changes in written rules over time are less likely caused by turnover of organizational members, but rather to more degree reflect organizational histories.

Second, written rules represent hard artifacts and therefore are easy to observe. Written rules, by definition are usually kept in organizational archives, which might be on paper in early days and in electronic databases nowadays. Many of organizations are required to keep the old versions of their rules for legal reasons. These rule archives facilitate researchers to collect data of rule histories, which can be analyzed quantitatively using advanced statistic techniques. On the contrary, routines are often unwritten; they are stored in organizational members' mind and programmed in their behaviors. Therefore, outsiders cannot easily observe these behavioral patterns unless through participatory observation and/or deep interviews. The nature of data on routines explains why most of studies on organizational routines are qualitative.

The research question of this study is easier to be explored with written rules. However, given the similarities shared between written rules and routines, the findings of this study might also contribute to better understanding of the change in organizational routines.

1.3 Rule Ego Networks

There are two basic approaches in network research – complete/whole network and ego-centered network (hereafter ego network). A complete/whole network consists of all members in a

bounded community and the connections among them. When investigating complete/whole networks, researchers usually collect all the relational data between each pair of members. This approach is often adopted for tracing the structural evolutionary trajectory of the whole network. Unlike the complete/whole network approach that takes a bird's view of the whole network in a community, the ego network approach focuses only on single actors (i.e. ego) and their connections with others (i.e. alters), as well as the connections among those others. This approach helps to understand how the focal actor can be enabled or constrained by its network embeddedness.

Since the focus of this study is on the change of individual rules, instead of on the whole rule system, the ego network approach is ideal. Particularly, I examine and model the ego citation network for each rule, which consists of all the rules that are directly connected with the focal rule via citation ties, and analyze how ego networks shape the processes of individual rule revisions over time.

Despite the focus on individual rules' ego citation networks, I believe this study can contribute greatly to the understanding of the evolution of whole rule systems within organizations. First, it directs our attention toward the interconnections among rules, which constitute an important dimension of a rule system and have profound implications for the evolution of the rule system. Consider two rule systems facing the same environment with identical set of rules but different citation ties between them at certain time point. They would likely experience diverging evolutionary paths over time, because the individual rules in these two systems are embedded in different rule networks, therefore adapt and change in a different way.

Second, taking a network perspective, this study also highlights the interaction between individual rules and rule systems. Individual rules do not exist dispersedly in an organization; rather, they are somehow connected with one another to form rule systems. Changes in individual rules therefore are also interdependent. Each rule has an impact on and also is affected by other rules. In this sense, individual rules are transformed by the rule system that they are embedded in; at the same time, they are also continuously shaping the same rule system.

1.4 Sources of Inspiration – Patent, Bibliographic, or Social Networks?

Since there is virtually no prior rule research that has examined the effects of rule networks on individual rule change, I have to turn to other literatures for inspiration. Three literatures appear pertinent: patent networks, bibliographic networks and social networks. In this section, I will briefly compare each of them with rule networks. The comparisons suggest that insights from the social network literature are especially important.

Patents are often considered as a form of codified organizational knowledge, and the number of patents that an organization owns is usually an important indicator for the organization's innovation performance. Patent citation networks are composed by patents that are connected by citation ties. Patents are built upon prior knowledge by citing other patents that were previously granted. Patent citation ties therefore can be viewed as transferring knowledge from the cited patents to the citing ones. The more citation a patent receives, the more important it is considered to be. Quite a few studies have explored the factors that contribute to the importance of a patent

(Fleming, 2001; Fleming & Sorenson, 2001; Fleming & Sorenson, 2004; Podolny & Stuart, 1995).

Patents research sometimes also examines another type of network. With a collection of patents, one can identify underlying technology class networks (Yayavaram & Ahuja, 2008). Each patent usually combines technologies from several technology classes (usually assigned by the patent office). Ties can be drawn between technology classes that are included in the same patents. In this way, a network of technology classes can be constructed, in which ties indicate the coupling of technology classes. Patents in this sense can be regarded as (re)combinations of technology classes. Within an organization, the structure of the technology class network reflects the understanding of coupling between technology classes and the map of search when the organization is engaged in innovation. It therefore can explain the organization's innovation trajectory as reflected by the changes in the technology class network (i.e., changes in structure and node sizes) and the resulted performance in terms of the number of patents granted, as well as their usefulness (Yayavaram & Ahuja, 2008).

Intuitively, the patent network literature seems to be a natural choice that helps to understand rule networks, since both patents and rules have been considered as repositories of organizational knowledge⁷. In fact, neither research on patent citation networks nor technology class networks can provide useful guidelines for understanding embedded rule change, because the change in

⁷ Interestingly, even though both patents and rules are considered as repositories of organizational knowledge, they seem to serve very different functions. Patents are usually associated with innovation, whereas rules are often the opposite. It may be because they contain different types of knowledge that serves different purposes. Rules contain procedural knowledge, stipulating what people should do under certain conditions. Such knowledge is used to maintain the current system by making sure things are working well within organizations. Patents, on the other hand, contain newly discovered scientific and technological knowledge. Organizations seek to combine and recombine them to produce more new knowledge so that they can make profit by commercializing it. It seems that patents often aim to break current procedures.

individual nodes is not the main research focus. When patents are studied as network nodes, change in patents cannot be studied, since patents cannot change once granted. Using ego network approach, researchers often examine the emergence of new ties (i.e., citation) around a patent (Podolny & Stuart, 1995), rather than the change in a patent. When technology classes are studied as network nodes, even though they can change (in terms of the number of patents categorized into a particular technology class), researchers tend to focus more on class memberships (visualized as the sizes of nodes in technology class networks) but less on the represented knowledge. Otherwise, researchers often take the whole network approach to examine how technology class networks of organizations evolve over time, and how it is related to their competitive advantage.

Bibliometric research is more or less similar to the patent research. An article cites others to indicate the intellectual heritages it is based upon. The citing articles usually share something important in common with the cited ones, and also build on and extend the knowledge presented in the cited articles, so that the field is advanced. Even though it is possible that citing other articles might serve other purposes, such as self-promoting, negative citation, window dressing, flattery, etc. (Hummon & Dereian, 1989; MacRoberts & MacRoberts, 1989), it is believed that the correlation between citation rates and affirmative peer judgments holds generally for most disciplines (Garfield, 1979).

The interconnected articles via citation links form bibliographic networks. Following the links, researchers can map the intellectual content of a field and construct its development history (Hummon & Dereian, 1989). Links between two articles can also indicate that they are both cited

by the same article (i.e., co-citation). Visualizing the co-citation network of a field over time can help researchers identify emerging subfields (i.e., clusters) within it and infer the developmental trajectory of a discipline (Culnan, 1986; Di Guardo & Harrigan, 2012). Moreover, a co-citation network across disciplines can also illustrate the communication between different fields.

Bibliographic networks can also be transformed into journal citation networks and coauthor networks. Studies on journal networks examine how many citation ties a journal receives and sends, based on which its influence in a particular academic field can be inferred (e.g., Baumgartner & Pieters, 2003; Garfield, 1972). Studies on coauthor networks contribute to the understanding of the relationships between authors within and across disciplines. They seek to find out if productive authors tend to collaborate with each other, or if highly cited authors tend to cite each other (Ding, 2011; Yan & Ding, 2012).

This brief discussion on the bibliometric literature again shows that it might not be a helpful area to look for insights for rule network research. Researchers in this field seldom use ego network approach to examine changes in various nodes⁸ (i.e., articles, journals, and authors). Many of the studies focus on the development of a discipline and the identification of subfields, using a whole network approach. In general, it is a very intriguing literature, but unfortunately cannot provide much help for the understanding of rule networks.

⁸ Even though the research on journal influence has examined journals' ego networks (e.g., Garfield, 1972), the studies often use exchanged-based power theory to infer the status of journals (i.e., the more cited, the higher status), rather than their contents. Since I do not build my rule-change model based on power, this theory is not useful for studying individual rule changes in rule networks.

Lastly, I turn to the social network literature. Social network research is always a popular topic in social sciences, since social actors – individuals, groups, teams, organizations etc. – are extensively interconnected with each other, composing various networks in societies. Both ego network and whole network approaches are widely used. In that literature, social ties are usually considered as conduits for resources (or constraints), such as information, knowledge, social support, and innovation (sometimes also for negative things, such as hatred, and false information). By connecting to others, actors have the access to the resources embedded in networks that can cause their change, such as achieving better performance, gaining power, getting jobs, higher salaries and promotions.

This model is very close to my theory of rule networks. I conceptualize rule citation networks as exposing rules to other rule contexts, from which they receive experiences and problems that might trigger their changes. Therefore, I will consult the social network literature⁹, especially ego network literature, to build my rule network theory later in Chapter 4 (see Section 4.2 for a review of relevant social network literature). I am fully aware that rule networks and social networks are different. Rules do not have volition or affection, and social networks are not based on citation ties; therefore the psychological mechanisms often used in the social network theory cannot be well translated into rule theory. Bearing that in mind, I will carefully make the analogy between social networks and rule networks.

⁹ Note that I do not aim to contribute to the social network literature in this study. Rather, I draw on social network theories to build a brand new theory on network-dependent rule change.

1.5 Précis of the Dissertation

In this introduction chapter, I have pointed out the central roles that rules play in human societies, and the importance of studying rule change. I have reviewed the literature on organizational rule change, starting from Weberian bureaucracy theory to the Dynamics of Rules approach, and identified a research question that this study seeks to answer.

This dissertation is organized as follows: in Chapter 2, I review eight organization theories related to rules and rule change in more detail. Particularly, I highlight how these theories portray organizational rules and explain the mechanisms of rule change. The review shows that rule network is severely underexplored in the current literature of organization studies. In Chapter 3, I introduce the research context of this study – CPGs in healthcare settings. I particularly discuss the relevance and feasibility of studying rule networks and rule change in the healthcare field. In Chapter 4, I develop a brand new theory of how rule networks can affect individual rule revisions, borrowing theories from the social network research. In Chapter 5, I describe in detail how I collected and coded the CPG archives, constructed the dataset of dynamic rule networks and rule histories, computed dependent variables and dynamic covariates that were included in the fixed-effect logit models, and interpreted the coefficients of the statistic models. The results will be presented in Chapter 6. In the final chapter (Chapter 7), I discuss the implications of the empirical findings. I highlight both the theoretical and practice implications of my findings, point out the limitations of my study and propose directions for future research.

Chapter 2

Organizational Rules and Rule Change

The interest in studying rules in organization studies is undoubtedly fueled by Max Weber's work on modern bureaucracy (Weber, 1968). Weber attributed the rise of bureaucracy to a process of rationalization (Weber, 2009), which took off when Puritan asceticism was "carried out of monastic cells into everyday life" (Weber, 1988, p. 181) where it supported organizational and social structures built on calculated rules. He argued that rational-legal forms of bureaucratic organizations were superior in efficiency to traditional forms of organization. Rationalization thereby gave rise to powerful bureaucracies and facilitated the development of modern capitalism.

Weber's rational-systems perspective resonates in the work of many subsequent scholars. They often regarded rules as functionally necessary. Bureaucracy scholars found that the degree of formalization increases as organizational size and the degree of functional differentiation increase (e.g. Blau, 1970). In their view, formal rules were created to regulate and coordinate activities within organizations and this, in turn, would help to achieve efficiency.

In the 1950s and 1960s, Post-Weberian bureaucracy scholars emphasized the dysfunctional side of bureaucratic rules. Instead of seeing rule prevalence in organizations as the result of rationalization, they emphasized the social, political, and natural drivers of rule proliferation, such as power struggle within organizations (Crozier, 1964), the tension caused by close supervision (Gouldner, 1954), "infusion of value" (Selznick, 1957), and "trained incapacity"

induced by overreliance on rules (Merton, 1952). In this view, rules appeared to serve latent functions and often seemed dysfunctional.

The non-rational focus was combined with a dynamic view in the late 1950s and early 1960s, when the Carnegie School stressed the important role of rules (and related concepts such as “performance programs” and “standard operating procedures”) for organizational adaptation (Cyert & March, 1963; Simon, 1957, etc.). They saw action in organizations predominantly structured by rules that adapt to signals about outcomes. Instead of omnisciently rational systems (embraced by neo-classical economists), these scholars conceived organizations as adaptive systems. Organizations myopically learn by retaining lessons in rules that evolve as new experiences are made and new knowledge becomes available.

In the *Behavioral Theory of the Firm*, rules do not imply a notion of superior rationality as in Weberian bureaucracy, nor a notion of dysfunction as in post-Weberian bureaucracy; instead, rules are dynamic and they adapt to history in a myopic and path-dependent way (Levinthal & March, 1993). Later, in the *Dynamics of Rules* which was built on Carnegie School’s adaptive notion of organizations, rules are considered as repositories of lessons, which have been drawn from prior organizational experiences in a variety of places under a variety of conditions and situations. (Levitt & March, 1988; March, et al., 2000; Schulz, 1998a, 1998b; Zhou, 1993).

The Carnegie School, and the diverse research programs it has spawned, have become one of the most important intellectual pillars of many other organizational theories (Argote & Greve, 2007; Gavetti, Levinthal, & Ocasio, 2007). Several of these theories offer diverse perspectives on how

organizational rules can evolve over time. In the following sections, I briefly review how different theoretical perspectives might contribute to our understanding of organizational rules and rule change. I will also discuss how these perspectives might be connected to my focus on rule networks.

2.1 Weberian Bureaucracy – Rules as a Product of Rationalization

In Weber's bureaucracy theory, rules were regarded as rational and superior instruments of organization and the basis of legitimacy in modern bureaucratic organizations (Weber, 1968). Rules are the most fundamental feature in Weberian bureaucracy. They are based on rational calculation and therefore dehumanized by removing "all purely personal, irrational, and emotional elements which escape calculation" (Weber, 2009, p. 216). In a Weberian bureaucratic organization, bureaucrats must obey the rules associated with his/her position or role, and their actions cannot be driven "by sympathy and favor, by grace and gratitude" (Weber, 2009, p. 216). Rules ensure reliability, efficiency, uniformity, and fairness, thereby differentiating modern bureaucratic organizations from traditional, patrimonial organizations based mainly on loyalty and obedience.

Despite the advantages of bureaucracy, Weber's view of bureaucracy is dark and fatalist. He predicted that bureaucratization would feed on itself and rules would breed more rules by following the iron law of bureaucracy (Weber, 1968), "until the last ton of fossilized coal is burnt" (Weber, 1988, p. 181). He believed that rules proliferated as a result of bureaucratic expansion. More rules are created by control agencies in order to supervise the adherence to rules (Weber, 1968). Rules are also possibly created by officials, who are "generally interested in 'clarity' and

‘orderliness’ of the law” (Weber, 1968, p. 848). Bureaucratic apparatus therefore is a “ceaselessly moving mechanism” (Weber, 1968, p. 988), which once put to work, perpetuates by creating more and more rules. Nobody can escape from this ever-growing “iron cage” (Weber, 1988, p. 181).

The “iron cage” is a powerful metaphor for the ever-expanding bureaucracy that controls many aspects of life in organizations and society. However, the way how the Weberian “iron cage” forms and expands over time is relatively underexplored so far. Although recent research on organizational rules has begun to explore the change of rules and rule systems (e.g., March et al, 2000 and related research), the connections between the rules that form the grid of the “iron cage” have not found much attention in prior research on rules. In that sense, my study presents a first opportunity to explore how the ties between different parts of the “iron cage” can affect its further elaboration.

2.2 Post-Weberian Bureaucracy – Rules as Preserve of Privilege and Values

Weber’s bureaucracy theory is unquestionably influential, which has incited a vast body of literature on modern bureaucratic organizations (see for example, Blau, 1963; Crozier, 1964; Gouldner, 1954; Merton, 1952; Selznick, 1943). However, unlike Weber, most of these post-Weberian bureaucracy theorists question the notion of superiority and rationality of rules¹⁰; instead, they highlight the dysfunctional side of rules and the unintended consequences brought about by strict adherence to rules. For them, rules are not only the organizational tools of

¹⁰ Note that some early post-Weberian bureaucracy scholars confused Weber’s concept of rationality with efficiency; however, Weber’s rationality is much more complex, containing at least for different types of rationality: practical, theoretical, substantial and formal. In his bureaucracy theory, rationality refers to formal rationality (see Kalberg, 1980 for more information).

attaining certain goals, but also the shackles that deprive organizational members of the freedom, power and discretion, which they keep fighting for when interacting with each other and with rules. As a response, organizations create more rules. In that perspective, rules are the products of social and political processes that unfold over time. Change of organizational rules is more the result of natural adaptive processes of fitting into the prevailing “institutional matrix” (Selznick, 1948, p. 25) than it is the outcome of a rational design gauged by specific organizational goals.

This post-Weberian view of organizational rules and rule change is deeply rooted in the notion of organizations as natural systems. It emphasizes informal structures that arise from the ongoing interactions of organizational members within the formal structure (Blau, 1963). Organizational members do not enact assigned formal roles, but rather act as “wholes” (Selznick, 1948). The resulting informal structures are “based on the personal characteristics and relations of the specific participants” (Scott, 2003, p. 59), as opposed to formal structures characterized by “purposefully designed rules that regulate behavior in the service of specific goals” (Scott, 2003, p. 59). Informal structures continuously buttress, erode and transform formal structures. As a result, formal structures “never succeed in conquering the nonrational dimensions of organizational behavior” (Selznick, 1948, p. 25).

The wrestling of formal structures with informal structures gradually transform an organization that was designed as a means of attaining certain goals into an end in itself. Formal rules are continuously created and transformed, no longer as a dedicated means to attain the goals, but rather as an effort to incorporate the emerging informal structures arising from day-to-day activities into the formal structures. As this process continues, the organization turns into a

“recalcitrant tool of action” (Selznick, 1948, p. 35) and gains a life of its own (Selznick, 1966, p. 10).

This process might be depicted as a positive feedback loop between organizational problems caused by informal structures and organizational efforts to resolve them in order to maintain its continuity and survival. For example, Gouldner (1954) pointed out that rules are created to standardize behaviors, thereby alleviating the interpersonal tensions caused by close supervision; at the same time, however, rules also impair employees’ motivation to strive for excellence, which then leads to low performance and a return to close supervision. The process continues, driven by the “abiding distrust of people and of their intentions” (Gouldner, 1954, p. 163). Likewise, Crozier (1964) argued that rules always leave out “zones of uncertainty” that can be exploited by some organizational members to gain discretion and power. New rules are then created that reduce uncertainty and eliminate these sources of privilege and power. As a result, organizations become inevitably locked into a series of inward looking power struggles that produce more and more bureaucratic rules.

In addition to the notion of self-proliferating rules, some post-Weberian bureaucracy theories also highlight the self-limiting features of rule production. They argue that although an organization’s adaptation to its institutional environment induces change in the organization, particularly in its formal structure, stability can nevertheless arise and prevent further change. The stability comes from the process of institutionalization. As organizational responses to internal and external pressures “crystallize into definite patterns, a social structure emerges. The more fully developed its social structure, the more will the organization become valued for itself,

not as a tool but as an institutional fulfillment of group integrity and aspiration” (Selznick, 1957, pp. 15-16). In other words, organizations grow more institutionalized as their rules become “infused with values beyond the technical requirements of the task at hand” (Selznick, 1957, p. 17), and thereby become resistant to change. Rules become symbolic and lose their utilitarian meaning. The organization loses flexibility as it institutionalizes over time (Merton, 1952).

Natural systems scholars highlight the role of natural organizational processes fueling and limiting organizational rule change. Although they explore a range of natural processes (e.g., infusion of value, power struggles, etc.), their explanations have paid little attention to networks that naturally arise between rules in organizations, and how these networks affect rule change. My study examines the role of rule networks for rule change and thereby can potentially offer fresh impulses for explorations of natural-system processes that contribute to the dynamics of embedded rules.

2.3 Public Administration – Rules as Sources of Red Tape

Bureaucracy theory in sociology inspired rule research in the field of public administration in the 1980s. Public administration researchers tend to take a perspective of organizational pathology to see rules as a potential source of red tape¹¹ (Bozeman & Feeney, 2011; Bozeman & Scott, 1996).

Unlike “formalization”, which is usually a neutral concept characterizing organizational

¹¹ Some earlier studies confused formalization (or simply the presence of rules and procedures) with red tape. They argued that red tape could have positive effects on organization, such as to ensure accountability, fairness, and transparency of rule implementation, which in turn facilitate to achieve organizational objectives (e.g., DeHart-Davis, 2009; Goodsell, 1985; Kaufman, 1977). Later, Bozeman and colleagues pointed out that formalization and red tape are two different concepts. Formalization is considered as neutral phenomenon as organizational physiology, whereas red tape is seen as negative as organizational pathology (Bozeman & Scott, 1996). The confusion might also arise from the inconsistent ways of operationalizing red tape. Please refer to Bozeman (2011) for more information.

structures, red tape bears a negative connotation, and is defined as “rules, regulations, and procedures that remain in force and entail a compliance burden for the organization but have no efficacy for the rules’ functional object”¹² (Bozeman, 1993, p. 283). In other words, red tape occurs not because of the sheer number of rules, but when existing rules fail to achieve objectives while they consume compliance resources (Bozeman & Feeney, 2011, p. 41).

Red tape has mostly been used as an independent variable in empirical studies to predict its impact on (at least the correlation with) various individual and organizational outcomes. It has been found that red tape is negatively related to job satisfaction, job involvement and organizational commitment (Baldwin, 1990; Buchanan, 1975; DeHart-Davis & Pandey, 2005; Lan & Rainey, 1992; Snizek & Bullard, 1983), as well as organizational performance, effectiveness, IT innovativeness and productivity (Bozeman & Crow, 1991; Bozeman & Loveless, 1987; Brewer & Walker, 2010; Moon & Bretschneider, 2002; Pandey, Coursey, & Moynihan, 2007).

Given the negative effects of red tape on organizations, public administration researchers have devoted considerable effort on investigating what causes organizational red tape. Focusing on formal organizational rules, Bozeman (1993) proposed an etiology of red tape, which distinguished two types: rule-inception red tape and rule-evolve red tape. Rule-inception red tape

¹² Please note that there is another definition of red tape proposed by Bozeman (1993), which incorporates the values that are posited on rules by different stakeholders. From that perspective, red tape (named as “stakeholder red tape” as a clarification) is defined as “organizational rules, regulations, and procedures that remain in force and entail a compliance burden, but serve no object *valued by a given stakeholder group*” (Bozeman, 1993, p. 284). The conceptualization is originated from Kaufman’s (1977, p. 4) argument that “One person’s red tape may be another’s treasured safeguard”. Although this definition captures the notion that rules are subject to individual subjective interpretation in terms of whether they are red tape or not, which might be very useful for red tape research with individuals as unit of analysis (e.g. measure red tape as individual perception), it has enormous operational problem for rule research, and thus is not relevant here.

refers to rules that are dysfunctional from the first day they were created, due to reasons such as 1) rule-makers' wrong assumption about the relation of means to ends inherent in the rules, 2) illegitimate functions that the rules serve (e.g. to satisfy managers' self-interest (Rainey, Pandey, & Bozeman, 1995)), 3) large number of objectives that are to be served by the rules, and 4) over-control or inflexibility imposed by the rules on employees. In contrast, rule-evolve red tape refers to rules that were originally functional but later transformed into dysfunctional rules. The fundamental reason that gives rise to this transformation is the incompatibility of existing rules with a changed environment, including changes in rule implementation, in the functional object of the rule, and changes in rule ecology (Bozeman, 1993; Bozeman & Feeney, 2011).

Rule networks have not been studied by public administration researchers. How can rule networks produce red tape? At least two connections come to mind. First, dysfunctions of rules might arise from the interdependence of rules, because interdependent rules can clash (and create rule strain). Second, dysfunctional rules can be kept in place when they are embedded in networks. For example, when a dysfunctional rule is embedded in a dense network that maintains a certain practice, it can become shielded from external forces that undermine its appropriateness, and therefore stay unchanged in place. These connections suggest that studies of rule networks can offer new impulses and new perspectives for public administration research on red tape.

Public administration researchers often take a static view of rules and assume individual rules are stable. They do consider change, but mostly in the form of environmental change which eventually renders rules outdated and dysfunctional. Dysfunctional rules that remain in force – in spite of environmental change – are the main source of notorious red tape. The primary challenge

for organizations is therefore to monitor and eliminate dysfunctional rules. In this perspective, rules are essentially fixed. The dynamic nature of organizational rules has not found much attention in public administration research. But it plays a central role in the Carnegie School of organizations, to which I turn next.

2.4 Carnegie School – Rules as Effort to Economize on Information

Processing in Decision Making

Although rules have played an important role in the early sociological theories, change of individual rules was not considered. This changed with the rise of the Carnegie School in the mid 20th century, when researchers took increasingly a dynamic perspective on organizations and rules. In the 1950s and 1960s, led by Herbert Simon, Richard Cyert and James March, the Carnegie School challenged the rationalistic assumptions of neoclassical economics and developed a process-oriented theory of organizations, particularly focusing on the processes of making (repeated) decisions within organizations. The movement embraces the virtues of behavioral realism as a fundamental principle of theory building. Its concept of organizational rules referred to as “performance programs” or “standard operating procedures”) became one of the foundational pillars of the Carnegie School (Argote & Greve, 2007; Gavetti, et al., 2007).

Building on the assumption of bounded rationality, Carnegie scholars postulated that organizations tend to follow rules in order to economize on information processing efforts. In their book *Organizations* (1958), Simon and March observed that organizations react to environmental stimuli by evoking a series of predetermined responses, which they called “performance programs”, or simply “programs”. Programs were derived from the experiences

with prior repetitive stimuli. They allow organizations to react immediately to environmental stimuli without deliberate searching or problem-solving, thereby reducing the need for making decisions about every single situation. Most of the behaviors in organizations are routinized and governed by such programs. They are not only part of the control system in all organizations, more importantly, they also serve as coordination devices. Programs define activity patterns and output characteristics in order to fulfill the need for behavioral and output coordination among organizational members with diverse, or even conflicting, interests.

Building on the concept of “programs”, Cyert and March (1963) further developed “standard operating procedures” (SOPs) as a core element of their behavioral theory of the firm. They argued that organizations tend to avoid uncertainties and instead make decisions by following a set of pre-determined SOPs. The SOPs regulate organizational members’ desires and interests, stabilize their expectations of the environment, and narrow down the range of alternatives considered (Cyert & March, 1963, p. 133). The underlying process of rule-following action is essentially “to [match] a set of rules with a situation by the criteria of appropriateness” (March, 1981, p. 564). The match is established by comparing the situation in question with the one from which the evoked rules were originated. In this sense, organizational rules set the premises for repeated decision making.

Organizational rules can help organizations to economize on scarce information processing resources, but rule making is subject to bounded rationality as well. Organizational learning is myopic and draws inferences from its local experiences and “memorizes” the learned lessons in rules. Given environmental shifts and bounded rationality, organizations lack the capability to

predict the future and they lack the capacity to develop lasting solutions. Organizations learn in a myopic way (Levinthal & March, 1993); the lessons that they encode in organizational rules tend to focus on the short-run, and the rules need frequent updating as the organization adapts to the environment.

In the work of the Carnegie School, rule interdependence was recognized, although its relationship with rule change stayed relatively underdeveloped. Simon and March (1958) described several types of rule interdependence. First, rules are interdependent by drawing on the same organizational resources. This can create allocation problems for organizations due to the limited resources. Second, rules are nested within each other. The content of lower-level rules can be dependent upon the higher-level rules, when the higher-level rules serve as the guidelines for revising the lower-level rules. Third, rules are interdependent in the sense that one execution step of one rule can evoke the execution of another rule. In that sense, rules can be connected into means-end chains that lead to the ultimate organizational goal.

Even though the Carnegie School has touched upon rule interdependence, it did not further explore how the patterns of rule interconnections (reflecting interdependencies among rules) that form rule networks can affect rule change and rule system evolution. My study builds on the Carnegie School model of organizational rules and extends it. It focuses on one type of rule interconnection – citation – and examines how rules' citation networks can affect their change over time. I argue that being cited can expose a rule to different contexts and experience thereby creating rule strain and lead to rule change.

The Carnegie School has influenced the development of many organizational theories, in particular theories of organizational learning that see rules as repositories of organizational knowledge. Research in that domain has begun to explore empirically the change of individual rules and has developed statistical models to estimate parameters and test hypotheses. My study follows that line of research and combines it with a dynamic network analysis. In the following subsection I review prior research on rule-based learning.

2.5 Organizational Learning – Rules as Repositories of Organizational Knowledge

Organizational learning, which is deeply rooted in the Carnegie School, has gained much prominence since the 1960s and has become one of the central themes in the field of organization studies. Organizational learning theories are often developed in order to explain how organizations learn, what drives change of organizational knowledge and what the consequences of organizational learning are.

Rule-based learning theories, which started to burgeon in the late 1980s, consider rules as repositories of organizational knowledge. Studies in this stream of literature take the perspective of organizational learning to investigate how rules and rule systems evolve as organizations learn and adapt. The core of the rule-based learning model is that organizations draw inferences and lessons learned from their own and others' experiences and encode them into rules (Levitt & March, 1988). Organizations learn by adjusting their rules. Rules are created to retain valuable solutions, are revised to incorporate new insights, and are suspended when they cease to serve a useful purpose (Schulz & Beck, 2009, p. 8). Rules therefore are both instruments and outcomes

of organizational learning. Processes of rule change come to reflect the processes of organizational learning.

Organizational learning is by no means intelligent. Facing ever changing and ambiguous environments (Lant & Mezias, 1992), organizations with limited rationality and attention are inevitably myopic (Levinthal & March, 1993). They can be fooled by illusions of performance derived from aspirations adapted to poor performance (Cyert & March, 1963; Lant, 1992; March & Simon, 1958), are often engaged in superstitious learning (Lave & March, 1975), deceived by false lessons extracted from scarce or redundant experience (Beckman & Haunschild, 2002; Haunschild & Sullivan, 2002; Lant & Mezias, 1992; Levitt & March, 1988) and stuck in competency traps (Levitt & March, 1988). As a result, the processes of rule change are fraught with the limitations of myopic learning.

Rule-based learning reflects organizational myopia and can explain empirical patterns of rule change. For instance, Schulz (1998a) found that although rule subpopulations tend to expand over time, there is a negative density-dependent effect on the rate of rule birth. He explained this phenomenon with “problem sorting”. As rule subpopulations expand, rule making shifts from a focus on common problems to a focus on increasingly rare problems. Remaining problems are increasingly rare and provide fewer impulses for rule making. This sorting by problem recurrence produces empirical patterns of negative density dependence of rule birth rates.

The role of networks for myopic rule-based learning has not been explored in prior research. In a rule network, each rule reflects the experiences and lessons of its own position, and each tie

connects a rule to another rule in a different position. Ties between rules serve to reduce myopia and alert participants about relevant other rules that should be considered in a given situation. However, at the same time, ties between rules connect different myopic rule-based learning processes, and this can have unintended outcomes. For rules that become cited, this means they become exposed to the contexts of citing rules, located in different positions, reflecting different lessons and experiences. This brings about uncertainty and surprises to cited rules and thus leading to impulses for learning and their change.

The starting point for my network model is the observation that rules in organizations are not isolated, but rather interdependent. One situation in a rule's application domain can be connected to or can evolve into related situations in other rules' application domains. Rules operate typically in other rules' vicinity. In complex situations (e.g., in healthcare), multiple rules might need to operate together, and this can create connections among rules that evoke each other. Rules are embedded in a network that provides a context for their operation and change. When rules become embedded, the underlying learning processes that transform them become embedded too. Rule change becomes network dependent.

Empirical studies on rule change have not explicitly investigated the effects of rule interdependence on rule change. However, the Dynamics of Rules approach (e.g., March, et al., 2000; Schulz, 1998a) developed the concept of rule ecology. It considers rules as members of interrelated rule subpopulations in an organization. In that conceptualization, rules adjust to the external environment as well as to other subpopulations, relating to other rules via competition, commensalism (with rules in the same populations) or symbiosis (with rules in different

populations) (Hawley, 1968). In rule ecologies, the interrelationships among rule populations shape the flows of problems and organizational attention, and temporal and spatial distances of rules have implications for their change (March, et al., 2000).

In contrast, in a rule network, individual rules (instead of rule subpopulations) are directly connected. Changes in some rules can trigger changes in other rules, through the processes of problem diffusion and attention contagion. Networks draw cited rules into the contexts of citing rules, exposing them to diverse and unpredictable challenges and opportunities. Different positions in a network will be exposed to different experiences and problems. The rules that occupy these positions will evolve in ways that reflect these differences. Embedded rules adapt to experiences that they encounter in their networks and they incorporate lessons drawn from those experiences. Rule networks powerfully shape rule-based learning because they shape what experiences are made and what lessons are incorporated into rules.

Empirical studies of the effects of rule networks on rule change are absent so far. My study aims to fill this gap. I take an ego rule network approach and investigate how individual rules change when they become embedded in rule networks. I focus on rule citation networks. By collecting and analyzing information about citation ties between rules over time, I can reconstruct the dynamics of rule network and study its effects on the change of cited rules.

2.6 Summary

In this chapter, I reviewed five theoretical perspectives that are relevant to organizational rules and rule change with various degrees. Table 1 shows the summary of the review. Most of them

do not include rule interdependence in their main theoretical frameworks. However, as I have pointed out at the end of each section, rule networks offer a fresh angle that can potentially extend these theories into interesting new directions.

Table 1: Summary of Images of Rules and Mechanism of Rule Change

Theories	Images/Functions of Rules	Mechanisms of Rule Change	Interdependence between rules considered	Levels of Analysis	Example Research
Weberian Bureaucracy	Product of rationalization process	<ul style="list-style-type: none"> • Rationalization resulted in the development of capitalist economies 	No	Society	<ul style="list-style-type: none"> • Weber, 1964
Post-Weberian Bureaucracy	Preserve of privilege and values	<ul style="list-style-type: none"> • Self-interest behaviors in organizations • Imperfection of rules 	No	Organization	<ul style="list-style-type: none"> • Merton, 1952 • Gouldner, 1954 • Crozier, 1964
Public Administration	Sources of red tape	<ul style="list-style-type: none"> • Elimination of dysfunctional rules 	No	Rule	<ul style="list-style-type: none"> • Bozeman, 1993 • Bozeman & Feeney, 2011
Carnegie School	Effort to economize on information processing in decision making	<ul style="list-style-type: none"> • Bounded rationality • Uncertainty and complexity of external environment 	Yes, mentioned, but not considered for rule change	Organization	<ul style="list-style-type: none"> • March & Simon, 1958 • Cyert & March, 1963
Organizational Learning	Repertoires of organizational knowledge	<ul style="list-style-type: none"> • Experience • Myopic learning • Problems • Knowledge obsolescence 	Yes, interrelationships between rule subpopulations	Rule population, Rule and rule version	<ul style="list-style-type: none"> • March et al., 2000 • Schulz, 1998a • Zhou, 1993 • Beck & Kieser, 2003

Chapter 3

Rules in Healthcare Settings – Clinical Practice Guidelines

I investigate the effects of ego rule networks on individual rule revisions and test my hypotheses in a healthcare setting. I collected longitudinal data of Clinical Practice Guideline (CPG)¹³ revision histories from a regional health authority that provides comprehensive healthcare services to the residents in part of Greater Vancouver and the Coast Garibaldi area in the Province of British Columbia, Canada. I consider CPGs as a type of organizational rules that exist in health care systems. CPGs share key features with other types of organizational rules that have been studied before and they present an exemplary context for studying dynamic rule networks and rule change.

3.1 What are Clinical Practice Guidelines?

CPGs are “systematically developed statements to assist practitioner and patient decisions about appropriate healthcare for specific clinical circumstances (Institute of Medicine, 1992)”. They aim to standardize healthcare practitioners’ decision making and behaviors by providing scientifically valid recommendations in clinical practice (Grimshaw & Russell, 1994, p. 45).

CPGs have been developed as one of the foundations of efforts to improve healthcare since the early 1990s. CPGs are the product of and an instrument for evidence-based medicine, “an

¹³ CPG is the term officially used by Canadian Institutes of Health Research (CIHR). In this particular organization, CPGs were referred to as Patient Care Guidelines (PCG) before 2009 and as Clinical Practice Documents (CPD) after 2009. However, CPGs remain the same identity and their histories can therefore be traced, because the CPG coding system used in the organization is constant over time. All CPGs are given a code that consists of a letter, a dash and three digits (e.g., C-620).

approach to teaching and practicing medicine that emphasizes ongoing examination and evaluation of evidence from clinical research and incorporating it into practice” (Evidence-Based Medicine Working Group, 1992). Being at the center of evidence-based medicine approach, CPGs are developed based on extensive review and rigorous evaluation of ever changing clinical research and are required to be reviewed and revised whenever needed to align with the state of the art in the healthcare field.

Nowadays, the application of CPGs is prevalent in healthcare systems across most of the western countries. In Canada, CPGs have attracted great attention from the Health Council, the Canadian Medical Association, as well as the provincial governments across the country. CPGs have been identified as one of the priority areas of focus in healthcare to ensure that clinicians across the country deliver “the most evidence-informed care regardless of geography and clinical setting” (Health Council of Canada, 2012).

It is widely believed in healthcare that when developed rigorously and used appropriately, CPGs can bring consistent, effective, and efficient care to patients for several reasons. First, CPGs can effectively reduce insufficient or inappropriate practices across geographical and clinical settings by providing standardized procedures to guide practitioners’ decision making and behaviors. CPGs are supposed to contain the best available evidence and to provide standards of appropriate care. They also identify relevant questions related to clinical practice and provide possible decision options and outcomes for healthcare practitioners to choose from depending on specific situations.

Second, CPGs can help patients to better understand how the decisions are made regarding the care services they receive. Many CPGs include complementary information sheets and patient guides, which are required to be provided to patients. These materials offer a shared platform for both healthcare providers and patients to engage in discussions of care options, so that the needs and particular conditions of patients can be addressed and fulfilled.

Third, CPGs can sometimes help healthcare providers to identify the most cost-effective practices available by including information on the cost implications of the alternative practices for each clinical situation¹⁴. This can benefit both patients and healthcare systems (Woolf, Schünemann, Eccles, Grimshaw, & Shekelle, 2012).

Extensive collections of CPGs are developed by healthcare organizations to guide the work of their practitioners. These guidelines not only integrate research-based knowledge available from the healthcare literature¹⁵, they also reflect the internal practice conditions of the organizations of origin. In this way, research knowledge can be adjusted or elaborated according to specific organizational conditions, and thereby can effectively guide the internal healthcare practice.

3.2 Relevance of CPGs for Organizational Rule Research

In this study, I see CPGs as a form of organizational rules in healthcare organizations. This establishes the relevance of CPGs for organizational rule research. To consider CPGs as

¹⁴ Even though to incorporate economic considerations into CPGs has been recommended in the 1992 report of Institute of Medicine, it in reality poses a major challenge on CPG developers to make recommendations applicable universally, as the cost considerations are usually healthcare-system specific and less transferrable. Therefore, unless explicitly mandated, many CPG developers do not do this. For more information, please refer to Woolf et al., 2012.

¹⁵ Sometimes CPGs in healthcare organizations also make reference to guidelines developed by national and international medical associations and governmental bodies, such as the US Agency for Healthcare Research and Quality in the USA and the National Institute for Health and Clinical Excellence in the UK.

organizational rules bridges and benefits both healthcare research and organization studies. On the one hand, it provides the foundation to apply Dynamics of Rules approach to study CPG change, and thereby help healthcare researchers and practitioners gain deep understanding of the processes in which research-generated knowledge is translated into clinical practice. On the other hand, it also provides a unique opportunity for organizational researchers to extend the theories of rule dynamics into a new direction, in which one can explore how different types of revisions (by encoding knowledge derived from different contexts) can be triggered and jointly shape rule histories over time.

I consider CPGs as a form of organizational rules existing in healthcare organizations, for they share several features with other types of organizational rules that have been studied, such as university rules (March, et al., 2000; Schulz, 1998a) and bank rules (Beck, 2006). First, like other organizational rules, they shape action. CPGs are designed to provide behavioral guidance in particular organizational settings. They are created to guide and standardize healthcare providers' patient-care behaviors by providing appropriate care options so that the quality of care services could keep consistent across time and locations. CPGs contain recommended (i.e., not required) patient-care procedures based on the systematic review and evaluation of the current healthcare literature. They play a key role in the training and testing of healthcare specialists and can become deeply ingrained into practice. Departures from the course of action recommended in CPGs are possible in individual situations, but they can raise issues of appropriateness.

Healthcare providers can decide not to follow a particular CPG based on their own professional expertise and clinical judgment, but they are held accountable for the outcomes of their decisions (Health Council of Canada, 2012). In this regard, CPGs definitely have an impact on healthcare

providers' behaviors regardless of departures. They serve as powerful (and often internalized) decision premises for healthcare providers.

Second, like other organizational rules, CPGs serve as repositories of organizational knowledge. CPGs contain accumulated clinical practice knowledge learned by the healthcare organizations that create and maintain them. As a healthcare organization learns over time, the knowledge derived from the fast changing healthcare domain as well as the lessons extracted from the daily practice within the organization are incorporated into CPGs through successive revisions in order to support the organization to provide effective and efficient healthcare service. In this sense, CPGs that contain healthcare related knowledge, like other types of organizational rules, are both tools and outcomes of learning for healthcare organizations. They have significant implications for healthcare practice, and need to be revised over time.

Third, CPG revisions occur in organizational contexts that are subject to constraints similar to those found around other organizational rules¹⁶. Like other organizational rules, guideline updating depends on the availability of organizational resources, such as research funding, experiences with the use of guidelines (e.g. patient load), time and attention of experts and nurses, etc. CPG revisions often require resources for resolving ambiguities about timing, interpretation of experiences with guidelines, understanding of evidence, and appropriateness of the changes, etc. Given scarce resources, it is likely CPG revisions will be affected by myopic learning processes (Levinthal & March, 1993) that have found to affect rule changes in prior research (e.g., March, et al., 2000).

¹⁶ In several interviews conducted in 2009 and 2010, healthcare professionals working in this organization often mentioned that the challenges to keep CPGs up to date included lack of time and resources, as well as difficulties to assess the quality of research findings.

These similarities between CPGs and other types of organizational rules demonstrate that CPGs can be considered as organizational rules that play a critical role in regulating activities and defining structures in the healthcare domain. CPG evolution can therefore be studied by applying the Dynamics of Rules approach. CPGs are the key to realize evidence-based practice by translating research-based knowledge into clinical practice; therefore, it is crucial to keep them up to date. An empirical study of the speed at which CPGs from an organization become outdated found that the rate of obsolescence was considerable; about half of the guidelines in the study had grown obsolete and needed updating after 5.8 years (Shekelle et al., 2001). However, the transfer of research findings into clinical practice through developing and revising CPGs is in fact “a slow and haphazard process” (Graham et al., 2006, p. 13), perhaps because of the ever enlarging volume of healthcare research. In the regional healthcare organization where I collected the data, many guidelines have actually been kept the same and in force for more than 10 years, even though it is required that each guideline be reviewed and revised every 6 years. Considering that CPGs play such a critical role in translating knowledge from research to practice and thus closing the “research-practice” gap in healthcare, it seems a bit surprising that so little attention has been paid by healthcare researchers to the processes of CPG updating¹⁷. The research on CPG change can help to understand how CPGs are developed, revised and updated over time, which could have a huge impact on healthcare practice. It can also help to understand the mechanisms that impede and facilitate revisions of CPGs, and thus the emergence and evolution of stable organizational structures in healthcare.

¹⁷ It is emphasized in the healthcare field that integrating most updated research evidence into CPGs in a timely fashion is desirable as part of evidence-based practice. This assessment is highly dependent on the quality of the evidence to be integrated and the certainty of returns (or so). Since I do not have data regarding the quality of research evidence (and about returns for the focal organization), I do not assume this in my study, nor do I focus on the performance implications of the speed of integrating research evidence. Rather, I aim to explain acceleration and deceleration of rule changes and believe this will deepen our understanding of how rule systems stabilize and transform. My focus is on the connection between rule change and drivers of rule change (that arise from the rule’s network), not on the outcomes of rule changes or their evaluation.

Studying CPG change also provides a unique opportunity for extending the current theories of organizational rule dynamics. Organizational rules do not interact with only one context; rather, they often face multiple contexts – such as organizational, legal, and institutional contexts – and contain knowledge acquired from each of them. It is conceivable that rule revisions which lead to incorporating knowledge from different contexts can vary in the process and the resources required. Prior research, however, did not provide any insight on how different types of rule revisions are triggered, because it is often difficult to trace the sources of integrated knowledge at each rule revision. This is the first study to examine different types of rule revisions and how they depend on rule networks.

CPGs in a regional healthcare organization face at least two important contexts, and react to the experiences made in these contexts through successive revisions, which incorporate knowledge related to these contexts into their content. The first context that CPGs face is the healthcare research context. Since CPGs are an important tool for transferring research knowledge into the healthcare practice to facilitate healthcare practitioners to make informed decisions, they should be well connected to the healthcare research. The key to ensure that knowledge is transferred from research context into practice is to write CPGs based on extensive reviews of the current literature and systematic analyses of scientific evidence, and to keep CPGs up to date in order to incorporate the most updated clinical and healthcare knowledge (Woolf, Grol, Hutchinson, Eccles, & Grimshaw, 1999).

A second critically important context for CPGs is the internal practice context of healthcare organizations in which they are created, maintained and applied. The internal organizational

context is constantly changing due to a number of factors, such as staff turnover, shortage of funds, changing facilities and technologies, patient load fluctuations, outbreaks of epidemics, etc. CPGs therefore need to react to these situations, incorporate knowledge that reflects changing local conditions and lessons learned, and offer relevant and appropriate guidance to practitioners working in the local setting.

CPG revisions can be focused on adaptation to either of these two contexts and therefore can be categorized into different types. In the CPG collection of this study, many guidelines include a list of the healthcare research articles based on which they are developed. Using the reference list, I can distinguish two types of guideline revisions. If a revision results in change in the reference list of a CPG, it can indicate that the CPG adapts to the external research context and that new healthcare research knowledge is integrated into the guideline. This type of revision, which I refer to as external revision, takes more resources for conducting a systematic review of the relevant literature. In contrast, internal revisions do not involve change in reference list and can be viewed as integrating only knowledge derived from the internal organizational context. The two types of revisions are likely driven by different organizational processes. Therefore, to study CPG change provides a unique opportunity to extend the theories of rule dynamics by distinguishing different types of revisions. It can help to extend and deepen our understanding of the paths along which rules are shaped by different types of revisions over time.

3.3 Development and Revisions of CPGs

The processes of developing or revising a CPG usually start out from the bottom in the healthcare organization of this study. Any staff member, clinical team or group may identify the

need for developing a new CPG or revising an existing CPG, which is usually among the following¹⁸: (1) A new product, equipment or therapy is being introduced; (2) The literature indicates a change in practice; (3) New national standards or guidelines establish new requirements; (4) A problem in practice exists; (5) Quality improvement data analysis has identified a need for an improvement in practice; (6) Review or revision of current guidelines in the CPG collection. Once the need of developing or revising a CPG is identified, the “Practice Advisory Council” is contacted. The council identifies the programs or disciplines (i.e., clinic units) that are affected by the CPG and that should be involved in the process of changing the CPG. It forms and supports a team of CPG developers who are content experts from all affected programs and disciplines.

The CPG developers then start to draft the CPG. They usually start with reviewing the current practices that exist within the system (e.g., workarounds used in other hospitals under the overarching regional healthcare system). If no better practice is identified within the current system, the team would conduct a systematic review of the current literature. Systematic review is a process during which the CPG developers identify relevant literature guided by an explicitly stated clinical question and according to a set of predetermined criteria, critically appraise the results of these studies based on the rigor of the used methodology and synthesize the results into evidence-based recommendations to guide clinical decision making and practice (Jones & Evans, 2000). Based on the result of the search within and/or beyond the system, the team creates the initial draft of the CPG.

¹⁸ Information is acquired from CPG G-076: Clinical Practice Documents – Creation and Revision.

After the initial draft is completed, the CPG developers circulate the draft among all stakeholder groups and seek feedback from them. The stakeholders can include the potential end users of the CPG, affected profession-specific councils (e.g., Infection Control, Pharmacy etc.), supply chain operations (e.g., if the guideline results in change in use of equipment and supplies), and educators or clinicians who will be involved in the implementation of the guideline. The development team will revise the initial draft according to stakeholders' feedback. Revising the initial draft of the guideline is an iterating process of communication between CPG developers and stakeholders until all stakeholders are satisfied. The final draft of the guideline will have to be reviewed and endorsed by directors of all affected units and programs, and finally by the director of Professional Practice, which is the group that maintains guideline collections and keeps the archives of CPGs. Once a new guideline is approved, Professional Practice Office will inform the staff of the (new or revised) guideline.

3.4 Rule Histories in Healthcare Settings

Rule history is a key concept of the dynamic approach to organizational rules. A rule history refers to “the time path of changes an organizational rule experiences during its life” (Schulz & Beck, 2009, p. 10), and consists of critical events during the life course of a rule – rule birth, rule changes, and rule death. Considering rules as repositories of organizational knowledge, rule histories are powerful tools to analyze how organizational knowledge evolves over time. With my unusual dataset of CPG histories, this study can greatly contribute to the understanding of how healthcare knowledge arising from different contexts is encoded and combined over time, forming guidelines that have a deep impact on healthcare practice.

The CPGs that I investigate in this study have been archived since 1989 by the Professional Practice group in the organization. The CPGs were originally kept on paper and bound in several binders. The old version of a guideline would be replaced whenever there was a new version inserted in the guideline book. Although it is impossible to get access to the content of the paper-based versions of the guidelines once they were replaced, the rule histories of most guidelines can still be extracted because each version of a guideline is time stamped and contains the creation date of the guideline and previous revision dates. This information is indicated at the left bottom corner of the document, as shown in Figure 1.

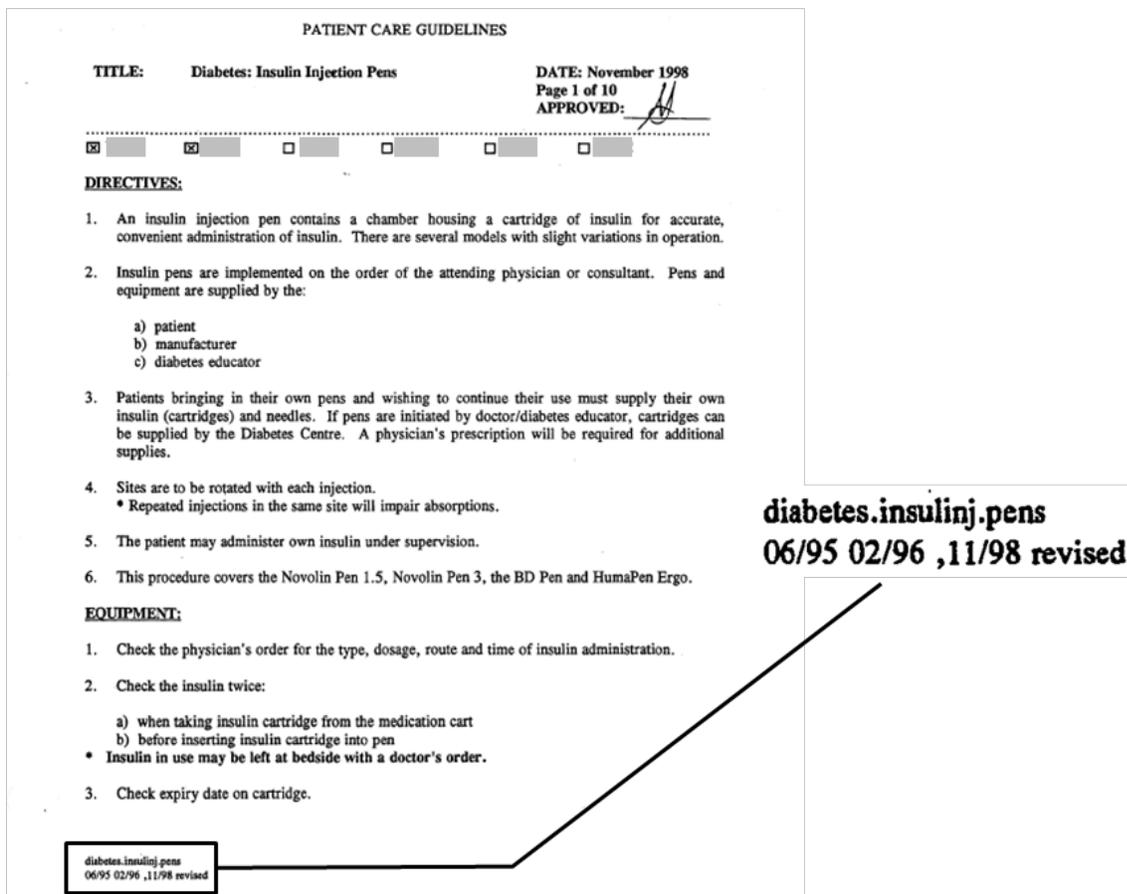


Figure 1: The First Page of a Paper-Based CPG Document with Revision Histories
 (The names of institutions have been covered for confidentiality reasons.)

In 2002, the healthcare organization introduced an intranet system where nurses and other healthcare workers can search particular guidelines currently in use. Figure 2 shows an example of an electronic CPG in the intranet system. In those electronic guidelines, the key content updates and reference changes are highlighted to catch nurses' attention. Each CPG is structured following a common template (despite some minor differences), which includes the following components: CPG code, CPG title, site applicability¹⁹, practice level²⁰, policy statement, equipment and supplies, procedure/protocol/practice guidelines, expected outcomes, patient/client/resident education, documentation, related documents and CPGs, references, unit of origin, endorsing director, date of creation/revision. At the same time, this organization also started creating backup CDs about every 3 to 4 months to store the CPG archives. As a result, the content and rule histories of all versions of all guidelines after 2002 can be completely identified.

The CPG archives that I collected include the last set of the paper-based CPGs bound in three 2-inch binders, the list of newly developed and revised CPGs from 1995 to 2001, and the CD archives from August 2002 to December 2010. These archives allowed me to trace the rule histories of the CPGs in this healthcare organization and construct a dataset of full revision histories of most of them. The dataset contains 807 CPGs and 2111 CPG versions²¹.

¹⁹ The collection of CPGs are applicable in one or more of the four sites, including two acute care hospitals, one residential care center and one rehabilitation center.

²⁰ CPGs vary in the skill sets they require for healthcare practitioners. Practice level specifies the type of healthcare practitioners that is eligible to implement a particular CPG, such as physician, registered nurse (RN), licensed practice nurse (LPN), registered psychiatric nurse (RPN), respiratory therapist, radiologist, social worker, etc.

²¹ It is before data cleaning. The number of CPGs in the regression analyses is smaller. More details will be given in Chapter 5.

CPD C-620

CLINICAL PRACTICE DOCUMENT

Continuous Bladder Irrigation (CBI): Procedure for

SITE APPLICABILITY:
[Redacted]

PRACTICE LEVEL:
RN, LPN

POLICY STATEMENT:

- A physician's order is required for an RN or LPN to initiate a C.B.I.A 3-way (triple lumen) catheter is required for continuous bladder irrigation.
- Bedrest is maintained while C.B.I. is in progress; head of bed is elevated for meals unless otherwise ordered.
- CBI to keep urine clear: nurse can gradually decrease inflow of irrigant if output remains clear.
Note: If CBI is run with roller-clamp wide open, the height of the bag should be no more than 60-80 cm (approx. 2 - 2.5 feet) above the bladder.

NEED TO KNOW:
Continuous Bladder Irrigation is used for the management of gross hematuria.

EQUIPMENT AND SUPPLIES:

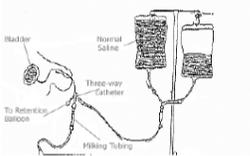
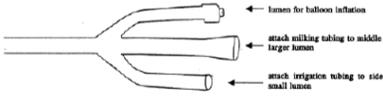
- Normal Saline Irrigating solution
- Irrigation set:
 - Primary and secondary sets, See Diagram 2.
 - T.U.R. Y-set, See Diagram 1.
- 3-way catheter (inserted by RN or LPN)
- Typical size of the 3-way catheters are 20 to 26 Fr
- For easier insertion, use Xylocaine 2% jelly syringe (1 to 2 syringes). You need a physician's order, ensure the patient does not have an allergy.
- If inserting a 3-way catheter refer to [C-200: Catheter-Urinary Insertion of Indwelling or Caudal Catheter](#).
- Sterile urinary drainage set
 - 2L
 - 4L
- Unsterile gloves
- Sterile latex milking tube
- IV pole
- Pail

[Redacted] C.B.I. cart

PROCEDURE:

- Spike irrigating solution with irrigation set.
- Prime tubing.

See Diagram below

- Unclamp irrigation set tubing and regulate flow.

RELATED DOCUMENTS:

- [C-610 - Continuous Bladder Irrigation, Care and Management of the Patient with](#)

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ALTERNATIVE SEARCH TERMS: 3 way catheter catheters urinary catheter

Content change in comparison with the previous version

Hyperlink to a cited CPG

Hyperlink to a cited CPG

Figure 2: Example of an Electronic CPG in the Intranet System
(The names of the individuals and institutions have been covered for confidentiality reasons.)

3.5 Rule Networks in Healthcare Setting

Healthcare is an excellent setting to study the effects of rule networks on rule dynamics, because CPGs are interconnected and embedded in networks. Individual CPGs are usually structured to deal with one single medical condition. However, many patients, particularly seniors, often have multiple diseases with complex medical conditions (i.e., multimorbidities). To treat patients with multimorbidities poses an enormous challenge to the developers and users of CPGs, since there is still a lack of research and evidence on the care of this type of patients. Under this condition, a viable approach is to apply multiple relevant guidelines at the same time. As experiences accumulate with patients that have certain combinations of medical conditions, new linkages between relevant guidelines will be recognized, articulated, and institutionalized over time to make healthcare providers aware of potential complications. One of the common forms of these inter-CPG linkages is citation ties. The connected CPGs via citation ties then comprise a CPG network that can handle complex types of patients.

CPG networks can facilitate not only the treatment of patients with multimorbidities, but also the professional training for healthcare providers. To study CPGs and learn how to search and use relevant CPGs in various clinical situations constitutes an important part in clinician and nurse's training. The citation ties between CPGs can easily direct the attention of a trainee from one CPG to the cited one, which might be related and relevant in certain clinical situations. By doing this, the ties between CPGs can help healthcare providers develop a mental model in which certain clinical situations are connected with others, so that they can make wise decisions in their future work.

All the citation ties are observable in this unusually dataset. Before 2002, when CPGs were kept on paper, cited CPGs were indicated in the text of the citing CPGs, usually in the form of “refer to CPG x-xxx”; sometimes, they were also listed in the subsection of “related documents and CPGs”. After the intranet system was introduced, all cited CPGs can be reached via the corresponding hyperlink from the citing CPGs. As Figure 2 shows, CPG C-620 cites two other CPGs, C-200 and C-610. The two cited CPGs can be reached via the hyperlinks. I went through all available versions of all CPGs and extracted the information on citation ties, which will be used to construct CPG citation networks.

Chapter 4

Rule Networks and Rule Revisions

In this chapter, I mainly draw on two streams of literature to develop my hypotheses. The first is the Dynamics of Rule approach (March, et al., 2000) that discusses how organizational rules evolve over time; and the second is the literature of social network that discusses how individual actors change due to their embedding in social networks. I explore the following research questions: Do rule networks matter to individual rule revisions at all? If so, why and how do they affect individual rule revisions? What roles do citation ties play? How can characteristics of rule networks have impacts on individual rule revisions? To answer these questions, I will build a theoretical framework of rule networks, develop hypotheses accordingly, and test them empirically in a healthcare setting.

4.1 Do Rule Networks Matter?

The concept of rule network seems to be absent in the classical theories of bureaucracy. Both Weber and post-Weberian bureaucracy theorists, despite their different views on the role that rules play in organizations, developed a pessimistic vision of rules breeding more rules. However, they did not explicitly consider the effect of interdependencies among rules in this process.

According to these classical theories, rule self-proliferation is due to the factors such as the rationalization process of the society (Weber, 2009), the ongoing struggles between formal and informal structures within organizations (Crozier, 1964; Gouldner, 1954), goal displacement (Merton, 1952), and organizational challenges of communication and coordination (Blau, 1970). From this perspective, rule networks do not seem to have any impact on change in rule systems.

Furthermore, most of the classical theories of bureaucracy generally reflected on rules and the processes of rule volume expansion. In those theories, individual rules and their interdependencies were outside the focus of analysis. Individual rules were implicitly assumed as invariant and homogenous and the interdependencies among them were much underdeveloped.

Therefore, according to the classical bureaucracy theories, one would expect that rule networks do not matter much to individual rule change. Rules are conceived as independent; and rule networks do not have any effect on the rates of individual rule revision. I take this as my null hypothesis, which serves as a point of departure for both theoretical and empirical analyses subsequently.

However, rules may not be independent. Interdependence between rules has found attention in the Dynamics of Rules approach (March, et al., 2000), which was developed about 15 years ago. The researchers have presented empirical evidence suggesting that rules might be interdependent with one another. They found rules to be embedded in rule ecologies, which would impinge on how individual rules change. For instance, they showed that rule density in a rule ecology could impede further rule births, whereas rule suspension could intensify subsequent rule births (March, et al., 2000; Schulz, 1998a). Moreover, they also showed that change in rules at one time and place could either stimulate or suppress rule changes at other times and places, depending on the temporal and spatial distance between rules (March, et al., 2000).

The Dynamics of Rules approach, taking a learning perspective, views organizational rules as fundamental repositories of organizational knowledge. In that view, “knowledge does not exist as isolated kernels” (March, et al., 2000, p. 191). Rather, knowledge nodes are typically connected to other knowledge nodes. The relatedness among knowledge elements constitutes a fundamental aspect of organizational knowledge and can become an explicit part of a knowledge base when symbolic representations of associations between knowledge nodes are added.

In organizational knowledge bases, citation ties arise when relevant associations between knowledge nodes are recognized and articulated. In effect, citation ties are codified associations that bring relevant knowledge from the contexts of the cited nodes into the contexts of the citing nodes. Cited nodes thereby can provide support for citing nodes (e.g., when a cited rule guides the performance of an important subtask of the citing rule). At the same time, citation ties extend cited nodes (e.g., the encoded lessons, assumptions) to the contexts of citing nodes, exposing them to potential differences, revealing contradictions (e.g., in assumptions) that can produce tensions and induce shifts in cited nodes (e.g., rethinking of their assumptions).

Likewise, in rule systems, rules can be connected through explicit citation ties between them. Inter-rule citation ties expose cited rules to citing rules (and their encoded knowledge), and thereby can produce tensions that impinge on the cited rules’ rates of change. Therefore, the guiding assumption of this study is that rule networks affect the rates of individual rule revisions.

If rule networks do matter, naturally another question will follow: Why and how do rule networks affect individual rule change? Because this is the first study that examines effects of

rule networks on individual rule change, I have to turn to other literature for insights. As discussed in section 1.4, the social network literature can be helpful for the development of my rule network theory. The basic tenet of social network research is that individual actors (organizations or individuals) are not atomized entities scattered in society, but rather they are interconnected; hence, all human action is embedded in social networks (Granovetter, 1985). Individual actors can often change their capacities, behaviors or attitudes, depending on the structure of social networks in which they are embedded. Likewise, rules are interconnected by citation ties and thus form rule networks. It is therefore reasonable to conjecture that change in individual rules might depend on rule networks, which can be understood with the aid of social network models of individual actor change.

Before developing specific hypotheses regarding the effects of rule network structures on individual rule change, in the next section I will first briefly review the social network literature on how structures of ego networks can lead to changes in the embedded individual actors. After that, I will develop my rule network framework and propose hypotheses on how rule networks can drive the change in individual rules.

4.2 Social Network – Access to Social Resources

In the social network literature, researchers often use an ego network approach to examine how social networks impact on social actors. A large part of the social network research regards networks as providers of social resources. An ego network connects a focal actor to others through social ties, which provide the focal actor with access to resources that are located in others, such as information, knowledge, trust, social and emotional support, etc. Hence, the

network provides potential access to valuable resources which, if obtained by the focal actor, can then facilitate their change, such as getting jobs (Bian, 1997; Granovetter, 1973, 1974; Petersen, Saporta, & Seidel, 2000), higher salaries (Seidel, Polzer, & Stewart, 2000), and increased power (Brass & Burkhardt, 1993; Burkhardt & Brass, 1990).

Despite the resource advantages of having networks, actors' ego networks do not guarantee that desirable resources will be transmitted to the focal actors. Rather, they shape the *access* of the focal actors to the resources that are available from others. This suggests that what resources the focal actors can obtain from their ego networks depends on the characteristics of their ego networks.

The ego network of an actor (ego) includes: 1) nodes (i.e., alters) connected with the focal actor (in the social network literature, actors can be individuals, organizations, or subunits within an organization); and 2) ties that interconnect the nodes with one another. Accordingly, an ego network can be characterized by the features on three different levels: a) on the node level: the attributes of alters, b) on the tie level: the characteristics (especially strength) of ties connecting the ego and alters as well as those among alters, and c) on the network level: the structural features of ego networks. Empirically, these features are often intertwined; therefore, to understand how networks can bring about change in egos, we need to take into consideration the characteristics of their ego networks on all three levels together in order to examine how networks shape the *access* of egos to network resources and opportunities.

Besides the above three levels, there is another dimension of ego networks: time. Ego networks are dynamic. Over time, members in networks are evolving, ties may grow stronger or fade away, new alters may join in the network, and old ones may withdraw. The shifts of ego networks change the access to external resources and thereby can stimulate or impede the change in egos. In the following subsections, I will review the social network literature, especially on how ego networks can lead to changes in the focal actor, and explore how social network research can inspire rule network research.

4.2.1 Node Attributes

The attributes of the contacts in an actor's ego network determines what resources the focal actor is exposed to (e.g., Lavie, 2006; Lin, Ensel, & Vaughn, 1981). Only when the contacts have resources available, can social ties transfer those resources to the focal actor (Gulati, 1998). This reflects a fundamental insight of social networking: What matters is not what you know, but who you know, and most importantly, what kind of resources they can provide.

Prior research on ego networks has provided ample evidence showing that the attributes of alters are consequential to ego's change. For example, Hays and Oxley (1986) examined the effect of freshmen's network composition on their transition to college and found that students with networks made up with fellow university students would experience a smoother transition to college than those with networks made up with primarily family, neighborhood, or work friends. It is because fellow university students have similar experiences and can provide more relevant information to freshmen, which then can facilitate their adaptation. Moreover, changes of alters' attributes can lead to egos' behavioral change. It has been found that establishing friendship or

romantic relationships with prosocial peers can serve as a turning point that helps adolescents to cease delinquency and break the chain that links adolescent delinquency to adult crime (Giordano, Cernkovich, & Holland, 2003; Simons, Stewart, Gordon, Conger, & Elder, 2002).

Likewise, on the organizational level, certain attributes of alters can also facilitate ego's change. This line of research is particularly conspicuous in the strategic alliance literature (e.g., Ahuja, 2000; Baum, Calabrese, & Silverman, 2000; Podolny, 1994). Shifts in the alliance networks of high tech companies can trigger large-scale strategic changes (Dittrich, Duysters, & de Man, 2007). Related research shows that firms grow faster, learn and innovate better when allying with partners that have higher status (Baum, et al., 2000; Stuart, 2000), technological and commercial prominence (Stuart, Hoang, & Hybels, 1999), good reputation (Saxton, 1997), heterogeneous experience (Beckman & Haunschild, 2002), and similar knowledge base and structures (Lane & Lubatkin, 1998).

In social networks, actors are connected with others and thereby have access to the resources held by them. What resources ego can access depends on who it is connected to. In rule networks, the situation is similar: Rule networks expose rules to other, connected rules and thereby can produce tensions and impulses for rule change. Moreover, what kinds of experiences the focal rules are exposed to might depend on the attributes of those connected rules. The data allow me to examine if exposed to new experiences resulting from connected rules' recent revisions can intensify a focal rule's rate of change (see Hypothesis 5 in section 4.4.3).

4.2.2 Tie Characteristics

The most studied characteristic of social networks is probably tie strength. Tie strength reflects the history of the interaction as well as the quality of the relationship between two actors. It determines what kinds of resources can be effectively transferred between actors (see for example, Hansen, 1999; Podolny & Baron, 1997; Rowley, Behrens, & Krackhardt, 2000). Weak ties can serve as bridges between social cliques, thereby connecting actors to others who might possess different information from that in their own cliques (Granovetter, 1973; Lin, et al., 1981; Seibert, Kraimer, & Liden, 2001). The strength of weak ties thus lies in its advantage in reaching nonredundant information. Individual actors maintaining weak ties can benefit from nonredundant and valuable information, and are more likely to get a job (Granovetter, 1974), to be promoted (Seibert, et al., 2001), to receive more useful knowledge (Levin & Cross, 2004), and to increase innovation capacity (Ruef, 2002). Unlike weak ties, strong ties do not have information advantages. They connect actors that are similar to each other. Therefore, the information actors receive via strong ties is often redundant to what they have already known.

In rule networks, it is often difficult to conceptualize tie strength. What does a “strong citation tie” mean? It seems that in rule networks, presence and absence of ties are more meaningful than strength of ties. Therefore, in this study, I do not directly explore the effect of tie strength on rule revisions. However, I do explore the relationship between redundancy of ties and rule revisions by examining the effect of rule network density on rule change (see Hypothesis 3 in section 4.4.2).

Apart from tie strength, recently, researchers started to explore another tie characteristic – tie age (Baum, McEvily, & Rowley, 2012; McEvily, Jaffee, & Tortoriello, 2012; Min & Mitsuhashi, 2012; Rhee, 2007). As time passes by, the nature and the function of relationships between actors can change, for example, from weak ties to strong ties, from ties transferring nonredundant information to ties transferring complex knowledge. This research has yielded some interesting results. For instance, Baum and his colleagues' (2012) examined all the underwriting syndicates formed by Canadian investment banks between 1952 and 1990, and reached the conclusion that the effects of a certain network structure (i.e., closure, bridging) on focal investment banks' performance change as the ties comprising the networks are aging.

Rule networks can also change as citation ties are aging. Newly added citation ties expose focal rules to new rule contexts and new experiences. Newness of the experiences in those new contexts can serve as a salient signal that can induce changes in the focal rules. However, newness cannot last long and fades away as time passes by. Conceivably, the newness inherent in the experiences in those contexts declines as ties age, resulting in drop of rule revision rates (see Hypothesis 4 in section 4.4.3).

4.2.3 Network Features

The most prominent feature of a network is its structure, which refers to the configuration pattern of ties among nodes. The structure of an ego network is a result of the number of alters ego is connected to and the absence or presence of ties among alters. It defines the position of ego in its network. The position of an individual actor in its ego network can shape its attitudes and behaviors, as well as the opportunities and resources flowing toward it (Ahuja, 2000; Brass, 1984;

Brass & Burkhardt, 1993; Erickson, 1988; Friedkin & Johnsen, 1999; Gulati, 1999; Powell, Koput, & Smith-Doerr, 1996).

Consider first degree centrality, which is captured by the number of alters that ego is connected to (i.e. ego network size). An actor who is connected to a large number of alters occupies a highly central position in its ego network, which can generate high visibility (Powell, et al., 1996), shape reputation (Baum, et al., 2000; Powell, et al., 1996), give power (Brass, 1984; Brass & Burkhardt, 1993), and provide access to timely information and knowledge (Ahuja, 2000; Rothaermel & Hess, 2007). Particularly, given the advantage of central actors in getting access to information and knowledge, centrality has great implications for learning. For example, it is suggested that organizations with higher centrality in alliance networks can bring a variety of skills and experience together, thereby potentially generating more innovative (re)combinations (Gilsing, Nooteboom, Vanhaverbeke, Duysters, & van den Oord, 2008).

For rules, the advantages of centrality are less clear. It is more likely that centrality exposes rules to more change impulses. When rules occupy central positions, they are connected to many other rules and thereby exposed to those rules' contexts and thus new and divergent experiences. The misalignment of experiences can trigger learning and induce the focal rules' change. Furthermore, the change pressure (and rate of rule revision) should increase as focal rules' ego networks grow (see Hypothesis 2 in section 4.4.1).

Besides network size, network density has also been greatly discussed in the social network literature. Indeed, the social network researchers have devoted much attention to the dichotomy

between closure (i.e. dense) and bridging (i.e. sparse) networks. Closure networks are characterized by dense and persistent interaction among the members (Coleman, 1988, 1990; Ingram & Roberts, 2000). They lack the nonredundant-information advantage, because actors that are tightly connected with one another tend to share the same information. In contrast to closure networks, bridging networks consist of sparsely interconnected actors and therefore are rich in structural holes (Burt, 1992; Obstfeld, 2005). They help an actor gain advantage in competition by providing privileged and timely access to diverse information and other valuable resources, as well as the opportunities to broker novel information and resources between unconnected parties (Burt, 1992).

When embedded in dense networks, rules are exposed to more redundant change impulses, and when they are embedded in sparse networks, they are exposed to more nonredundant impulses. Therefore, sparse networks might produce more salient signals and attract rule makers attention faster and lead to intensified rule change (see Hypothesis 3 in section 4.4.2).

4.2.4 Dynamic Networks

Networks are by no means static; rather, they evolve over time. The dynamics of social networks has been receiving increasing attention. In the strategy literature, there have been quite a few studies that examine the effects of evolving ego networks on focal organizations' yearly innovation performance (e.g., Ahuja, 2000; Rothaermel & Hess, 2007; Schilling & Phelps, 2007). Research in this stream has tried to understand how shifts in organizations' ego network properties can influence the learning from their network partners (and ultimately performance).

Similar to social networks, rule networks change too. The shifts in any of the rule network characteristics (e.g., arrival and departure of members, changes in their characteristics, network size, network density, etc.) can lead to the change in the rate of change of focal rules. This means that the empirical analysis of dynamic rule networks necessarily involves dynamic covariates. The statistic techniques I use in this study (fixed-effect logit models), allows me to control for all the rule specific characteristics and test how dynamic levels of ego network properties affect rule changes.

4.2.5 Network Change “Events”

The above dynamic network perspective mostly focuses on continuous changes in network characteristics, which can be regarded as shifts in network “states” (e.g., the shift from the “state” of isolate to “state” of dyad or triad or so). In addition to that, there is another perspective that considers each incident of a network change as an “event”. The network change “event” can also impact on the focal actors, because they can produce salient signals and present new conditions to the embedded egos, which compel egos to make adjustments.

Network change events can have powerful outcomes. Sociologists have examined the effects of life course events on individuals. For example, in a study that examined young gang-affiliated women’s life courses in a poor, black community in Champaign, Illinois, Fleisher and Krienert found that the self-reported violence of those young women was positively associated with gang memberships, but dropped dramatically at the onset of the first pregnancy of gang girls.

Pregnancy, as a life course event that changes these girl’s networks (i.e., baby as a network node), can bring those girls back into the community and reconstruct social ties around them. This

disruptive shift in gang girls' networks changed their behavior such that they became less involved in violent behaviors (Fleisher & Krienert, 2004). Similarly, in a study that investigates the relationships between marital life course events and risks of smoking among 81,000 individuals from Sweden in the period of 1980-2000, Nystedt presented evidence that getting married (different from being married) was associated with lower smoking risks, while getting divorced (different from being divorced) was associated with higher risks of taking up smoking (Nystedt, 2006).

Rule networks can also undergo such "events" (i.e., the occurrence of discontinuous network changes), such as a new tie being added, or a connected rule being revised. These "events" expose rules to new experiences and change impulses and induce rule changes. I will explore how network change "events" affect the rate of rule change (see Hypotheses 4 and 5 in section 4.4.3).

4.2.6 Summary

The influence of social networks on the change in individual actors has been widely acknowledged. Ego networks can provide egos with access to opportunities and resources controlled by others and thereby can impede and facilitate their change (depending on the alters' attributes, tie characteristics, and network structure). More importantly, networks are dynamic, and their change can have powerful impact on change of egos.

I now draw on social network ideas to build my model of network-driven rule change. Rule networks share many features with social networks, although there are also important differences.

One commonality is network-related conceptualization. Like social networks, rule networks are characterized by nodes (i.e., individual rules), ties among the nodes (rules citing each other), and of network structure (rule ego networks of cited rules). Like social networks, rule networks undergo change, and their shifts and change events can impinge on individual rule change.

What is also common is the notion that ego networks affect the change of egos. The social network literature frames most its arguments in terms of “*access*”. Ego networks provide individual actors with *access* to resources that can potentially bring about their change. I articulate my network-based rule change model in terms of “*exposure*”. I argue that rule ego networks *expose* focal rules to other connected rules and shape their exposure to experiences and problems, which can affect their change.

Despite the attractiveness of the comparison between social networks and rule networks, I recognize that there is at least one difference between the two. Since rules are not agents with volition that can strategically choose the members in their networks, nor can they manage their networks to reach an optimal outcome, rule change affected by rule networks cannot be explained by psychological mechanisms as in the social network research. Instead, in rule networks, rules adapt in more primitive ways, much more like bacteria and fruit flies do.

In the rest of this chapter, I will develop a rule network framework based on and extending the social network literature. I first introduce the key concepts – rule citation network, inbound network, and exposure. I then develop hypotheses on how the characteristics of the rule networks, as well as its change over time, affect individual rule change.

4.3 Rule Citation Networks – Exposure to Change Impulses

In rule systems, related rules often become connected through direct citation ties. Citation ties channel the attention to other rules potentially relevant to the citing rule and thereby transport knowledge (or encoded solutions) from the cited rules to the application context of the citing rule. As a result, citation ties expose the cited rules to the experience and problems in the contexts of the citing rules. The exposure can reveal tensions between the two rules, which can provide the cited rules with learning opportunities and accelerate their change.

4.3.1 A Focus on Inbound Network

To address my research questions, I take an ego network approach and examine the effects of individual rules' ego citation network on their rate of change. The ego network of a focal rule consists of rules that are connected with the focal rule through citation ties, as well as the citation ties among themselves²². Citation ties are directed and are not necessarily symmetric. For example, in my data, a guideline on post-surgery patient care cites another guideline on pain management, but the pain-management guideline does not refer back to the post-surgery-patient-care guideline. It might reflect asymmetric relevance. Rules cite others that are relevant to their contexts; however, the citing rules might not be relevant for the contexts of the cited rules.

Given the directedness of citation ties, a focal rule can be connected with other rules through two types of ties – outbound ties and inbound ties. An outbound tie is a citation tie pointing from the focal rule to another rule (i.e., the focal rule is the citing rule), whereas an inbound tie is the opposite, which is a citation tie pointing toward the focal rule from another rule (i.e., the focal

²² Since this is the first study on rule network, to keep it simple, I only consider direct ties. However, indirect ties are worth being explored in the future research.

rule is the cited rule). If two rules cite each other, the relationship between them is reciprocal.

Figure 3 illustrates an example of rule citation network. The tie from the focal rule to Rule D is an outbound tie, which indicates that the focal rule cites Rule D; and the tie from Rule E to the focal rule is an inbound tie, which indicates that the focal rule is cited by Rule E. The relationships between the focal rule and Rules C and D are nonreciprocal; however, the relationship between the focal rule and Rule C is a reciprocal one, because they cite each other.

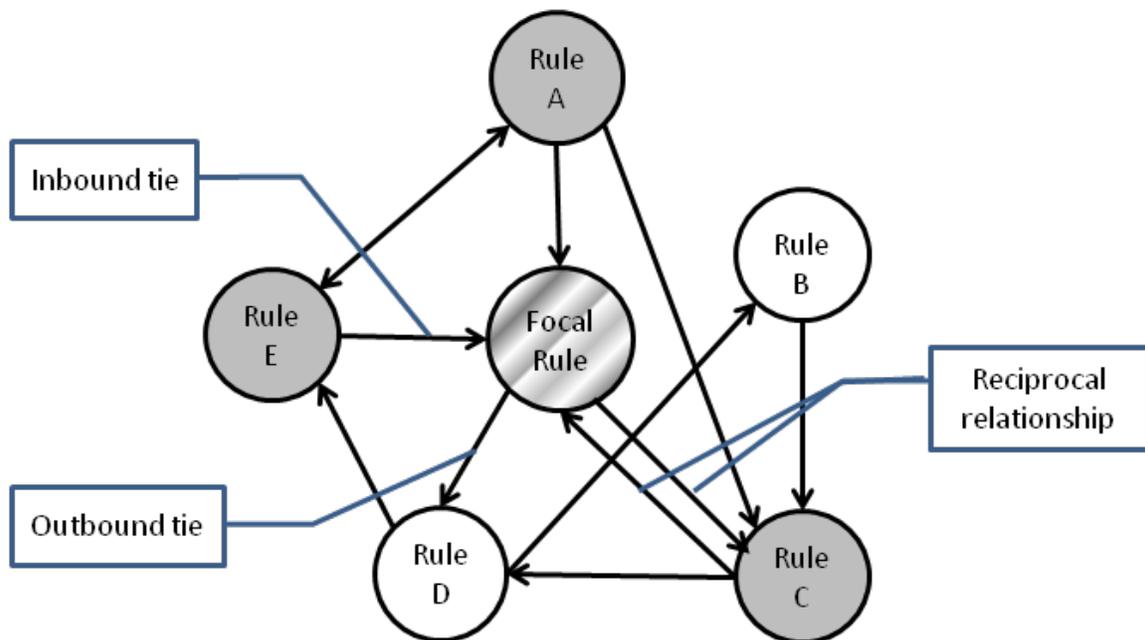


Figure 3: An Example of Rule Citation Network

Given the two types of citation ties, the ego network of a focal rule can be divided into two subnetworks – outbound network and inbound network. The outbound network is composed by all rules that the focal rule cites, and the ties among them. In Figure 3, the outbound network of the focal rule includes Rule C and Rule D, as well as the ties among them. The inbound network consists of all rules that cite the focal rule, and the ties among them. As shown in Figure 3, the inbound network of the focal rule includes Rule A, Rule C and Rule E (filled with grey shade), as well as the ties among them.

In this study, I mainly focus on inbound networks of rules, because I believe inbound ties are more relevant to rule change. Inbound ties connect focal rules to citing rules, thereby bring the relevant knowledge from the focal rules to bear on the situations that are matched to and call for the citing rules. In this way, inbound ties expose the focal rules to the experiences present in the contexts of the citing rules. This exposure of the focal rules can provide them with learning opportunities that intensify their change. In this sense, inbound ties can be sources of change impulses for the focal rules. Although I do not specify any hypothesis on the effects of outbound networks, in the empirical analyses presented in Chapter 6 I control for and explore the effects of having outbound networks on individual rule change.

4.3.2 Exposure and Rule Change

Rules are surrounded by their own contexts, in which they are created, maintained and applied (Schulz, 1998b). The concept of “rule context” in this study is broad, including many elements nested within each other, such as the organizational subunit that a rule originates from and the resources within it (e.g. equipments, technologies, human capital, budget, supplies, attention, and problems, etc.), the team that maintains the rule, the actors (both internal and external) that impinge on the maintenance and revisions of the rule, subjects of the rule, users of the rule (e.g., their work and task structure, etc.), and other tacit dimensions that arise from daily routines, norms and culture, etc.

Inbound ties expose rules to the contexts of citing rules. When cited, rules can potentially be applied in the citing rules’ contexts where they are exposed to experiences arising from those

contexts. Thus, rules adapt to multiple rule contexts, including their own contexts and the contexts of other rules that cite them. Their revisions can then incorporate knowledge arising from the experiences made both in their own contexts and in the citing rule's contexts. The experiences made in different contexts might be incongruous and can produce tensions for the focal rule. I refer to this tension – a result of rules' being exposed to other rule contexts – as rule strain.

The concept of rule strain is inspired by a classic sociological concept – role strain – from role theory. This approach sees social institutions as being made up by roles (instead of individuals) and role relationships (Goode, 1960). Individuals engage in multiple role relationships simultaneously at a particular time or place; and each of them demands several activities and responses that might be inconsistent or even contradictory. Consequently, individuals have to “face a wide, distracting, and sometimes conflicting array of role obligations” (Goode, 1960, p. 485). Since individuals possess only limited role resources, they are likely to experience role strain, which is defined as “the felt difficulty in fulfilling role obligations” (Goode, 1960, p. 483). To reduce role strain, actors either manipulate their role structure by entering or withdrawing from a role relationship or by moving from one role relationship to another through a sequence of decision making processes or “role bargains” (Goode, 1960). Individuals' actions of reducing role strain determine the allocation of role performances (or “role price”), which in turn affect the function of social institutions and social structure. In other words, individuals take actions to manage their role structures and to reduce role strain, and the balances (or imbalances) of role strains thus have implications for change or persistence of social institutions (Goode, 1960).

Similar to role strain as a result of individuals' responding to multiple role obligations simultaneously, rule strain can arise when a rule becomes exposed to other rule contexts that can impose inconsistent or even conflicting demands on it. Rule strain triggers learning, gives change impulses to the focal rule, attracts the attention of rule makers, and increases the chances of its revisions that incorporate new knowledge and relieve the tension²³.

Figure 4 illustrates an example of how becoming cited (i.e., starting to be cited) by another rule can intensify the change in the focal rule. In my data, CPG C-430 specifies how to care and manage patients with a pleural chest tube in the Chest Center. When it is not cited by any other CPGs, it is applied only in the Chest Center context to treat patients admitted in the Chest Center. This changes when it begins to be cited by CPG C-020, a guideline stipulates how to take care of patients who have undergone cardiac surgery at the Cardiac Surgery Intensive Care Unit (CSICU), because it becomes exposed to the context of CPG C-020 – the CSICU. The two contexts that CPG C-430 is now facing are very different in terms of the composition of the health care teams, technologies used, types of admitted patients, and facilities etc. Take patients as an example. The patients treated with CPG C-020 in the CSICU differ to some extent from those treated with CPG C-430 in the Chest Centre in the aspects of syndromes, potential complications, needs, and etc. When patients treated by CPG C-020 are routed to CPG C-430, due to the differences between the two contexts (e.g., different expertise of the healthcare teams, different facilities used, etc.), their potential complications might not be fully recognized or their

²³ Note that my model of rule strain differs from performance feedback (Greve, 1998, 2003). The concept of rule strain is closer to “role strain” in role theory (Goode, 1960) than to performance relative to adaptive aspirations. Rule strain captures the stress that arises from differences between connected rules. It does not imply a pre-defined aspiration level (e.g., compared to other rules' performance); and in fact, it is often difficult to define a clear aspiration level for rule performance (e.g., when new aspirations emerge after outcomes have occurred).

needs might not be completely fulfilled. This can lead to the perception that CPG C-430 is not functioning properly, and therefore cause the review and revision of this particular guideline.

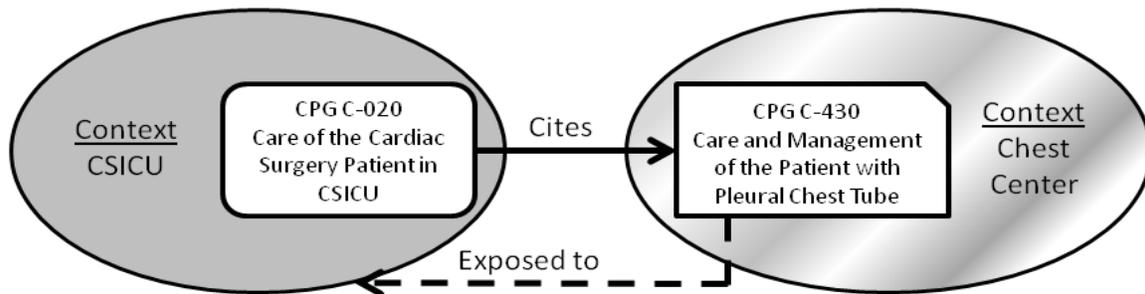


Figure 4: An Example of One CPG Citing Another

In summary, when an individual rule starts to be cited by other rules, it becomes exposed to other rule contexts. The exposure can reveal the misalignment between these contexts and the focal rule's local context, which can then cause rule strain for the focal rule. Rule strain triggers learning and gives change impulses to the focal rule, thereby increases its chances of being revised. This leads to the following hypothesis:

Hypothesis 1: When rules become cited, their rate of revision increases.

4.4 How Do Inbound Networks Affect Rule Change?

Inbound networks comprise inbound citation ties that expose rules to the contexts of citing rules, and this can result in rule strain for the focal rules. The exposure of individual rules to other rule contexts can be shaped, thus producing rule strain of different levels, depending on inbound network characteristics. I focus on three important dimensions of exposure: intensity, nonredundancy and newness. I argue that these three dimensions of exposure impinge on the strength of rule strain experienced by individual rules.

Exposure intensity refers to the degree to which a focal rule is exposed to citing rules' contexts, which can generate experience streams that might be different from those arising from its own context. The misalignment of the experiences from different rule contexts can cause rule strain that induce rule change. The more rule contexts a rule is exposed to, the more salient the rule strain is, and the more likely the rule is revised. Exposure nonredundancy indicates the extent to which a focal rule is exposed to citing rules' contexts that can generate nonredundant experience streams. A rule that receives diverse experience streams can encounter higher level of rule strain and is more likely to be revised. It is important to note that exposure intensity and exposure nonredundancy are two independent concepts. For example, it is entirely possible that a rule is intensively exposed to redundant contexts. In that case, the exposure intensity of this particular rule is high, whereas the exposure nonredundancy is low.

Unlike exposure intensity and nonredundancy, exposure newness is a transient quality that captures the presence of novelty in the contexts that a focal rule is exposed to. Exposure newness reflects the pulses of an inbound network, whose shifts can give rise to an immediate surge of novelty in the contexts that the focal rule is exposed to. The surge of novelty not only can cause rule strain but also immediately attracts attention that makes rule strain more salient. Exposure newness only comes with recent occurrence of inbound network change events, and therefore its effect dwindles as time passes (without change in the inbound network).

The three dimensions of the exposure to citing rules' contexts – intensity, nonredundancy and newness – vary with inbound networks. Their shifts over time affect the strength of rule strain experienced by focal rules. Rules will experience stronger or more salient rule strain when they

are intensely exposed to other contexts, when they are exposed to nonredundant contexts, and when they are exposed to contexts that are high in newness as a result of recent changes in inbound networks.

4.4.1 Exposure Intensity – Network Size

Exposure intensity refers to the degree to which a focal rule is exposed to other rule contexts (i.e., citing rules' contexts) at a given point of time. It is captured by the size of the inbound network, which is defined in this study as the total number of rules that cite the focal rule at a given time point. As a focal rule is cited by more other rules, it is exposed to and responds to demands from more rule contexts. As a consequence, a rule with a large network is more often to be applied in other rule contexts than a rule with a small network, as the applications in other rule contexts do not likely occur simultaneously. The uniform application of the rule in the contexts of other rules (i.e., its citing rules) generates experience streams that reflect the differences in the contexts between the focal rule and the citing rules and thus can cause tensions – rule strain – at the focal rule. Therefore, rules with larger networks can experience rule strain more often. This creates a salient signal that can attract attention of rule makers and increases the chances of rule change.

In the same vein, as an inbound network grows larger over time, the focal rule will be exposed to more contexts, and its exposure to other rule contexts will be increasingly intense. As a consequence, it will experience more salient rule strain that can attract attention and accelerate the rate of rule revision.

The following is an example that shows how expanding inbound network may cause stronger rule strain on a particular rule (i.e. CPG) in the healthcare setting (Figure 5). CPG S-155 (Skin and Wound Management: Infection Prevention and Control) is cited by CPG P-330 (Pin sites care). CPG S-155 is a generic guideline that stipulates how to prevent and control skin and wound infection. CPG P-330 is applied mainly in the surgical practice context and guides nurses to take care of orthopedic patients to prevent pin site infection²⁴. When CPG S-155 is exposed to and applied in the context of CPG P-330, it may experience rule strain, because the generic skin and wound care might not be sufficient in the surgical practice context. Therefore, this guideline might have to be adjusted in order to fulfill the surgical practice demands in that context.

The degree of rule strain CPG S-155 experiences can become stronger when another guideline CPG S-126 (Arterial Leg Ulcer Management) starts to cite it. CPG S-126 can also be applied in surgical context, but is mainly applied in the medical practice context to guide nurses to take care of the patients with chronic leg ulcer due to arterial insufficiency and to educate the patients to manage and monitor the wound themselves. The application of this guideline involves a complex decision-making process, requiring taking multiple decision premises into consideration, such as whether revascularization surgery is performed or not, the causes of ulcer, and types of wound and pain, etc. When exposed to and applied in such a complex context, CPG S-155 again may experience rule strain, because the generic skin and wound care procedures might not be able to accommodate so many different demands.

²⁴ Metal pins can be inserted into bone segments through small incisions in the skin and may be left protruding through the skin. They are used in skeletal traction, as fracture fixation devices or to support an external fixator. The skin entry points are known as pin sites. These percutaneous pins, being foreign bodies and remaining in contact with the external environment, including surrounding skin, have a high risk of infection. Infection could cause the pin to loosen or require its removal, and in turn the failure in fracture healing (Holmes, Brown, & Pin Site Care Expert Panel, 2005).

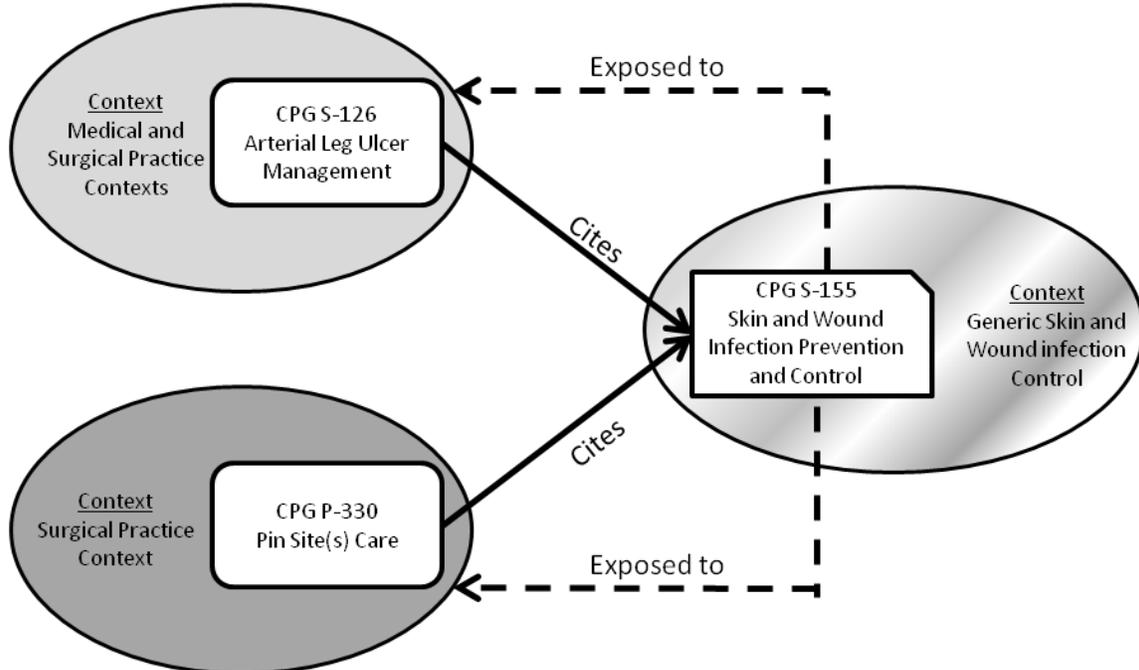


Figure 5: An Example of One CPG Being Cited by Other Two

From the moment when CPG S-155 starts to be cited by CPG S-126, it is exposed to two rule contexts that are different from its own (even though there is some overlap between these two contexts), and therefore is likely to be applied in rule contexts other than its own more often. The guideline can experience rule strain arising from its application in the context of either CPG S-126 or CPG P-330. The rule strain can arise from problems encountered in the course of applying CPG S-155 in either of these two rule contexts. Rule strain grows more salient as more other CPGs cite CPG S-155. This is likely to attract the attention of CPG coordinators, who then will lead a team, consisting of interdisciplinary experts in skin and wound management, to work on the revision of CPG S-155 in order to ensure its functioning in both practice contexts of CPGs P-330 and S-126. Presumably, the rule strain on CPG S-155 will be further intensified if it becomes cited by more other guidelines, since it will be exposed to more foreign contexts that

can potentially impose challenges on it. The above arguments and example suggest the following hypothesis:

Hypothesis 2: As inbound networks grow, the rate of rule revision increases.

4.4.2 Exposure (Non)redundancy – Network Density

Exposure nonredundancy captures, at any given point of time, the degree to which a focal rule is exposed to contexts that offer nonredundant change impulses. Nonredundant exposure provides a focal rule with experience streams that are more likely to be inconsistent and potentially even contradictory than redundant exposure does. It therefore can result in stronger rule strain for the focal rule and increases the chance of the rule being revised. My argument here resonates, to some extent, with Zollo and Winter's (2002) statement: "The application of the routines in diverse contexts generates new information as to the performance implications of the routines employed" (p. 344). I argue here that such new information reflects rule strain, which easily attracts attention of rule makers and intensifies rule change. As rules exposed to contexts that are increasingly nonredundant, it will experience increasingly stronger rule strain. As a result, their rate of change accelerates.

As I discussed above (in section 4.2), in the social network literature, dense networks are usually conceived as less likely to provide nonredundant resources to the embedded actors, because actors are tightly interconnected with each other and tend to share similar information. In contrast, in sparse networks, actors are only loosely connected, leaving many structural holes between them. Spanning those structural holes can facilitate flows of nonredundant resources from diverse sources to the structural hole spanner (Burt, 1992).

In a dense ego inbound network, the focal rule is embedded in a network of citing rules that are interconnected with one another (Figure 6, right). In that case, the focal rule is likely to be exposed to similar contexts, and thus subject to weaker rule strain. By contrast, when the citing rules are only loosely (or not) interconnected (Figure 6, left), the focal rule is embedded in a sparse network. It essentially occupies a position spanning many structural holes, and thereby is exposed to diverse contexts and receives diverse impulses for change. The focal rule thus will experience stronger rule strain, because these contexts are unlikely to be similar to one another and tend to impose very different demands on the focal rule.

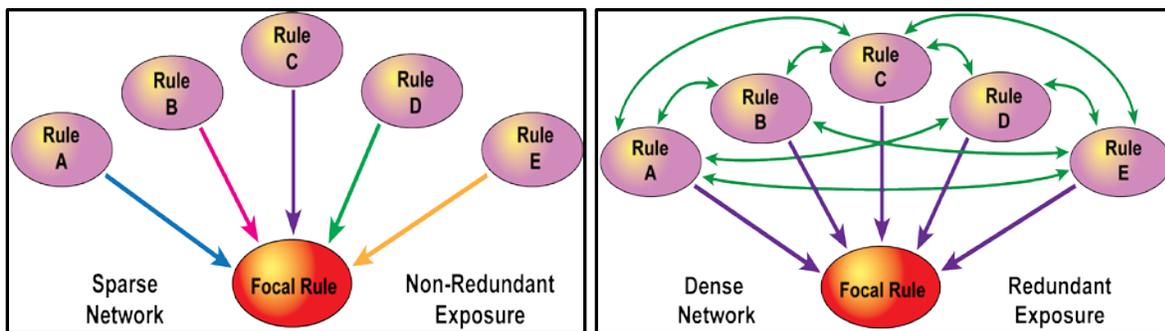


Figure 6: Network Density and Exposure Redundancy

When a focal rule's inbound network density shifts, it will be exposed to different levels of rule strain and thus may display different levels of rule change. Given a fixed inbound network size, when network density increases, i.e., because ties between the citing rules are added, citing rules' contexts will increasingly overlap with one another. Consequently, the focal rule will be exposed to more redundant experiences in citing rules' contexts, and thus experiencing weaker rule strain; the rate of rule change will decelerate. In contrast, when the inbound network density decreases, i.e., because ties between the citing rules are eliminated, the focal rule will be exposed to

experiences of higher nonredundance, and therefore suffer stronger rule strain; the rate of rule change will accelerate. Therefore, I predict the following:

Hypothesis 3: Holding network size constant, when rules' inbound networks become denser, the rate of rule revision declines.

4.4.3 Exposure Newness – Arrival of New Ties & Recent Revisions of Citing Rules

Exposure intensity and nonredundancy (“state” variables) capture the current “states” of rule networks. Their effects indicate how different levels of network characteristics can affect embedded individual rules’ rate of change, and keep constant until the changes in the “states” of rule networks (Figure 7, solid line). They are very different from exposure newness (“event” variables), which refers to the presence of novelty (caused by recent network change “events”) in the citing rules’ contexts that a focal rule is exposed to at a given time point. The effect of exposure newness is immediate and lasts for only short period of time (Figure 7, dashed line), because it captures the impact of the onset of recent network change “events”, the attention on which lasts for only a limited period of time and then shifts to other news.

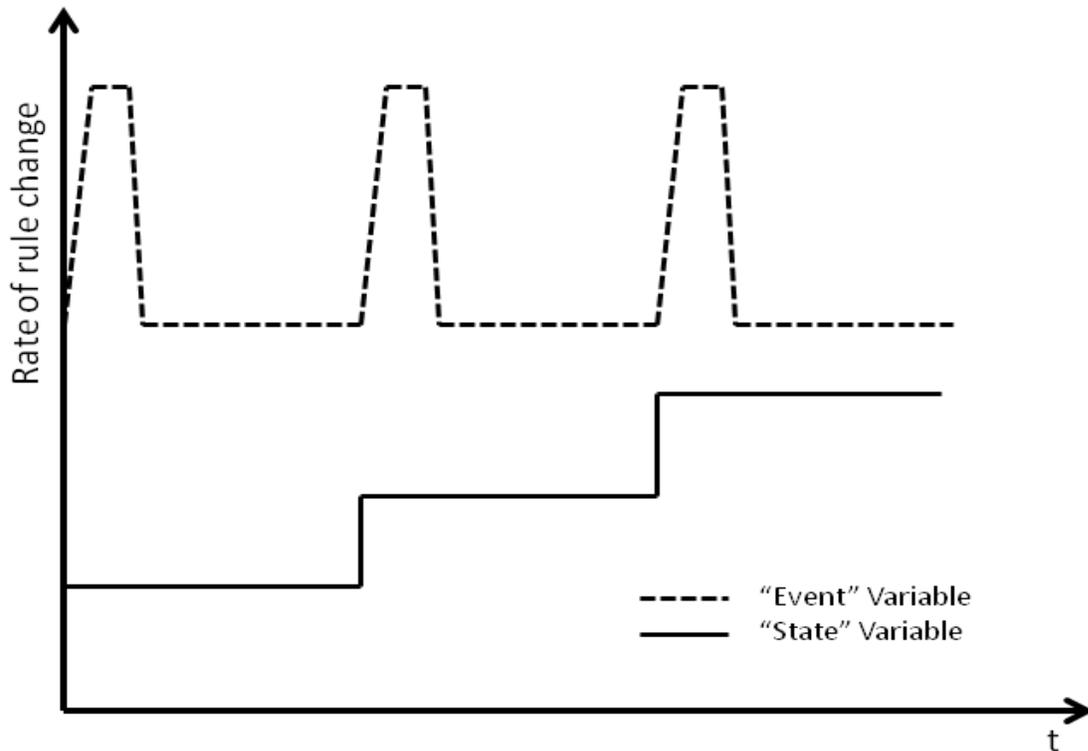


Figure 7: Effects of "State" Variables and "Event" Variables

Newness has attracted some attention in organization studies since Stinchcombe proposed the notion of “liability of newness” (Stinchcombe, 1965). It captures the idea that new organizations and organizational forms suffer a greater risk of failure than old ones. It is because that new organizations lack routines that can effectively define organizational members’ roles and coordinate their activities; meanwhile, new organizations tend to receive less support from the external environment due to the absence of routines of interacting with outside stakeholders. “Liability of newness” has found empirical support in numerous early studies (e.g., Carroll, 1983; Freeman, Carroll, & Hannan, 1983; Singh, Tucker, & House, 1986). Later, researchers also found that not only new organizations suffer “liability of newness”, but also do the organizations that have just undergone changes, because changes can disrupt the established organizational routines, thereby reduce organizational performance and sever their linkages with the environment (Amburgey, Kelly, & Barnett, 1993).

Newness is not only disruptive; it can also provide learning opportunities. Newness is often associated with uncertainty, problems and challenges for social actors, thereby creates salient signals and can attract more attention that facilitates the production of new knowledge. For example, prior research found that in multinational corporations, exposure to newness could stimulate a unit's knowledge production and knowledge outflows (Schulz, 2001). Likewise, for organizational rules, it is conceivable that being exposed to newness can trigger learning and producing new knowledge, which can then induce changes in rules.

Newness seems to come with recent changes, such as a recent founding of an organization, a recent emergence of a new organizational form, or a recent organisational change. The recency of newness implies that its effect on an actor might be strong during only a very short period after the occurrence of the event. The newness that rules are exposed to (i.e., exposure newness) can come from recent change events in their ego networks. In this study, exposure newness arises from two types of events in rule networks: (1) new ties are added into an inbound network, and (2) citing rules are revised.

To study how newness resulting from recent changes in rule ego networks affects focal rules' rate of change, I turned to the social network literature. Surprisingly, newness has not found much attention in that literature, except that a few researchers have argued that networks can be used by organizations to buffer them from "liability of newness" (Baum, et al., 2000; Hager, Galaskiewicz, & Larson, 2004). The question of how newness arising from recent network changes can impact on the embedded egos has not been well studied yet. My study on rule

networks may shed some light on this question, because I am exploring the effect of exposure newness on rule change. In the following, I argue that exposure newness caused by recent changes in rule networks can enhance rule strain that focal rules experience, and thereby can intensify rule change.

Arrival of New Ties

Exposure newness can arise from the arrival of new ties. A new tie arises when a rule that did not cite the focal rule starts citing it. When a new tie is added to a focal rule's inbound network, the focal rule becomes exposed to a new foreign context. The application of the focal rule in this new context will present new challenges, as it generates streams of new experiences that might be different from those the focal rule has been exposed to (and adapted to) in the past. The new challenges arising after the onset of the new tie can boost the level of rule strain and intensify the change impulses that the focal rule experiences and thereby lead to rule changes. This effect only lasts for a limited time period, as newness of the new tie diminishes fast and attention is distracted quickly. Therefore, I propose the following hypothesis:

Hypothesis 4: When a new rule joins the inbound network, the rate of focal rule revision increases for a limited newness time period.

Recent Revisions of Citing Rules

Exposure newness of a cited rule can also arise from a form of rejuvenation of its citing rules. When citing rules are revised, their requirements and application contexts can change. For

example, in healthcare settings, after a CPG is revised, the way how patients are treated stipulated by this particular CPG might be different, and the required facilities, equipments, and expertise of the nurses who are eligible to apply this CPG might also be different from before. As a result, when citing CPGs undergo change, the cited CPG becomes exposed to new experiences, which will escalate the level of rule strain it suffers. We would thus expect that recent revisions of citing rules in inbound networks lead to acceleration of the change in the focal rules during a limited time period following their occurrence.

Hypothesis 5: When a rule in the inbound network is revised, the rate of focal rule revision increases for a limited newness time period.

4.5 Exploration of Different Types of Rule Revisions

In the previous literature, researchers have simultaneously examined rule revisions and rule suspensions as two types of rule change, and have found that they can be triggered by different change signals (e.g., Schulz, 2003; Zhou, 1993). Likewise, it is conceivable that one can distinguish different types of rule revision, which might result from rules responding to different kinds of change signals. For example, rules can respond to weak change signals with incremental revisions and to strong change signals with radical revisions. Embedded in rule networks, individual rules can be exposed to different kinds of change signals over time, depending on the dynamics of their ego networks' structure. Each individual rule responds to a series of change signals with corresponding types of revision, which form a unique path of evolution that comprises a string of revisions of different types.

CPGs are facing and adapting to two different contexts – the *internal* organizational (including clinical practice) context of the healthcare organization they belong to, and the *external* healthcare research context (which produces relevant evidence-based knowledge). Revisions of CPGs can therefore incorporate knowledge arising from either or both contexts. The underlying processes that lead to CPG revisions might operate in different ways or with different levels of intensity, depending on the context to which a guideline adapts. Adaptation to one context might lead to revisions that elaborate a guideline into one direction, while adaptation to another context might elaborate it into another (related or unrelated) direction.

Revisions of guidelines can be focused on adaptation to the external or the internal context. In the CPG collection of my study, I observe revisions that change the list of the cited healthcare literature of a guideline and revisions that do not, and I refer to these two types as “external” and “internal” revisions. Of course, adaptations to different contexts can become coupled, and revisions can reflect adaptations to both contexts simultaneously. But often revisions take a dominant focus on the adaptation to one context or the other because the organizational processes that drive them are different. In my study context, external and internal revisions proceed quite differently. External revisions require that CPG developers go beyond the organizational boundaries, comprehensively search for and systematically review relevant healthcare literature, extract and synthesize research-based evidence, and incorporate the evidence that is compatible with the internal organizational contexts into CPGs. Internal revisions, on the other hand, are much easier and less resource-consuming. CPG developers only need to conduct local search for advice from experts and lessons acquired from the daily work experience of front line healthcare practitioners, from which they extract knowledge and

incorporate it into CPGs. These two types of CPG revisions are very different in terms of search and development processes (e.g., time and energy required, search range), as well as outcomes (e.g., implications for practice).

Given these differences, it is likely that external revisions reflect the incorporation of knowledge from the external healthcare research context, and internal revisions reflect the incorporation of knowledge from the internal organizational context. The underlying processes that lead to these two types of revisions reflect different forms of learning and knowledge production, and it is likely that they respond to different impulses from the inbound network of rules. From the perspective of organizational learning, external and internal revisions can be seen as reflecting exploratory and exploitative learning, respectively (March, 1991). In the context of my study, it is conceivable that inbound networks expose rules to other rule contexts in ways that may induce exploration or exploitation, and thereby intensify revisions that incorporate knowledge produced by these two forms of learning. Some forms of exposure (e.g., intense, nonredundant) might lead to external revisions, while other forms (e.g., weak or redundant) might primarily lead to internal revisions.

In order to explore whether and how the two types of rule revision are triggered differently, I formulated models that test my hypotheses for both generic revisions and for the two sub-types – internal and external revisions. To my knowledge, this study is the first one that explores and compares two types of rule revision simultaneously. I believe that my exploration will lead rule research into a new direction which can produce new impulses for rule-based learning theories

and will contribute to a deeper understanding of the role of rule networks for the direction and speed of rule revisions.

Chapter 5

Method

The empirical analyses are based on the archives of CPGs that are developed, used and stored at the acute care facilities of a Canadian regional healthcare organization in the Province of British Columbia. In this chapter, I describe how I built rule histories of CPGs, constructed the representations of the rule networks, and created dynamic covariates. I also discuss the fixed-effect logit models that I used to test the hypotheses.

5.1 Building CPG Revision Histories

As I mentioned in Section 3.3, the CPG archives I collected consist of two parts: the paper-based collection and the electronic collection. The electronic archives are very complete and contain all the CPG versions created after August 2002. The electronic CPGs were updated by replacing old versions with new versions. All the versions were backed up on CDs every 2 to 4 months, and the backup CDs were kept by the organization, constituting the archives of the electronic CPG collection. The electronic archives contain complete records of the content and change dates of all CPG versions that were in effect between 2002 and January 1st, 2011 (the end of my observation period). They provide an excellent source to reconstruct the rule histories of all CPGs in the electronic collection.

Before the electronic collection was introduced, the CPGs of the healthcare organization were kept on paper and bound in binders. When CPGs were revised, the old versions would be taken out and replaced by new ones. Unfortunately, the organization did not keep the archives of those

old paper-based CPG versions, except for the last set of paper-based CPGs which were in use until August 2002 when the intranet system was launched. Fortunately, many of the paper-based CPGs of the last set contain information about the prior revision histories (as shown in Figure 1 in Section 3.3), including the birth dates and revision dates of earlier versions (though not the text of prior CPG versions). This allowed me to reconstruct the rule histories of the CPGs in the paper-based collection before the beginning of the electronic collection (tracing back to 1995, and occasionally to earlier dates).

Across these two collections, different versions of a particular individual CPG can be identified because they share a common code, which consists of a letter and three digits, e.g., C-620 was used for the CPG on “Procedure for Continuous Bladder Irrigation (CBI)”. Successive versions of a CPG comprise its rule history. The earliest CPG version in the archives was released in April 1989, which I consider as the starting point of my observation period. My observation period ends on January 1st, 2011. CPGs which were still in force at that time are regarded as right censored.

I extracted information from the document of each CPG version, and manually coded the rule histories of all the CPGs in Excel. Figure 8 displays the codes for a set of CPG versions. Each row represents a CPG version record, which contains information about the CPG version’s effective date and other CPGs it cites. I used the former to build CPG revision histories and the latter to construct dynamic CPG citation networks. Apart from this, each CPG version record also includes other information, such as Version ID, CPG code (e.g., S-150), CPG title, if it is a CPG birth version, number of words, etc. I started with the most recent version of each CPG and

traced it back to previous versions until the very first one that can be identified. The raw data coded in the Excel spreadsheet contains 807 CPGs and 2111 CPG versions. I reported how I coded the CPG archives in a coding manual to make sure the coding for all CPG versions is consistent.

1	Vers_ID	PCG_Code	Pred	Succ	PostDat	JanetDat	OrigDat	Title	AppSite	TypeofCh	PracLevl	NumWords	NumChar	OrgUnit
498	148000	C-620			15/09/2009		September, 2009	Continuous Bladder Irrigation (CBI). Procedure for	VGH, UBCH		1 RN, LPN	478	2653	Gyne/Urology
499	148010	C-620			21/04/2006	4/6/2006	April, 2006	Continuous Bladder Irrigation (CBI). Procedure for	VGH, UBCH		1 RN, LPN	392	2070	Urology - T10
500	148020	C-620					March, 2000	Continuous Bladder Irrigation (CBI). Procedure for	VGH, UBCH			301	1671	Urology, E7
501	148030	C-620					January, 1996	Continuous Bladder Irrigation (CBI). Procedure for						
502	148040	C-620	-99				July, 1995	Continuous Bladder Irrigation (CBI). Procedure for						
503	149000	C-625	798000			5/1/1997	May, 1997	Continuous Positive Airway Pressure (CPAP) via Nasal or Full Continuous Positive Airway	VGH, UBCH			376	2114	Respiratory Therapy
504	149010	C-625	-99				November, 1993	Continuous Positive Airway Pressure (CPAP) via Nasal or Full						
505	150000	C-630			09/08/2007	8/7/2007	August, 2007	Corneal Graft, Penetrating Keratoplasty of Full Thickness	VGH, UBCH		1 RN	404	2187	Eye Care Centre
506	150010	C-630					September, 2000	Corneal Graft, Penetrating Keratoplasty of Full Thickness	VGH, UBCH			491	2778	W7A
507	150020	C-630					January, 1996	Corneal Graft, Penetrating Keratoplasty of Full Thickness	VGH, UBCH			522	2748	W7A
508	150030	C-630	-99				November, 1989	Corneal Graft, Penetrating Keratoplasty of Full Thickness						
509	151000	C-640		-99			August, 2010	Assisted Cough for Clients with Weak or Absent Cough Ability						
510	151010	C-640					May, 1995	Assisted Cough for Clients with Weak or Absent Cough Ability	VGH, UBCH, GFS			444	2422	ASCU
511	152000	C-660				11/1/1998	November, 1998	Craniofacial Surgery	VGH			472	2620	Burn/Plastic Surgery Unit
512	152010	C-660	-99				June, 1995	Craniofacial Surgery						
513	153000	C-670			07/09/2006	9/6/2006	September, 2006	Care of the Patient following a Craniotomy	VGH, UBCH, GFS, GPC		1 RN	767	4503	Neurosciences
514	153010	C-670					June, 1995	Craniotomy	VGH			649	3865	Neurosciences
515	154000	C-680			20/06/2007	6/7/2007	July, 2007	Critical Care Flow Sheet	VGH		2	2014	10705	ICU
516	154010	C-680					August, 1998	Critical Care Flow Sheet/ Special Care Nursing Assessment Record	VGH, UBCH			1462	7506	ICU
517	154020	C-680	-99				February, 1997	Critical Care Flow Sheet/ Special Care Nursing Assessment Record						

1	Vers_ID	PCG_Code	AssoPcg	AssoPcg1	AssoPcg2	NumAsPcg	NewAsso	NewAsso1	NewAsso2
498	148000	C-620	PCG C-610; PCG C-200	PCG C-610; PCG C-200		2	NA	NA	
499	148010	C-620	PCG C-610; PCG C-200	PCG C-610; PCG C-200		2	PCG C-200	PCG C-200	9
500	148020	C-620	PCG C-610	PCG C-610		1	NA	NA	
501	148030	C-620							
502	148040	C-620							
503	149000	C-625	PCG R-020	PCG R-020		1	NA	NA	2
504	149010	C-625							
505	150000	C-630	NA	NA		0	NA	NA	2
506	150010	C-630	NA	NA		0	NA	NA	
507	150020	C-630	NA	NA		0	NA	NA	
508	150030	C-630							
509	151000	C-640							
510	151010	C-640	NA	NA		0	NA	NA	2
511	152000	C-660	NA	NA		0	NA	NA	2
512	152010	C-660							
513	153000	C-670	PCG I-070; PCG C-350; PCG S-280; PCG A-070; PCG C-660; PCG S-340; PCG F-030; PCG P-240; PCG I-020; PCG S-060; PCG S-070; PCG R-030	PCG I-070; PCG C-350; PCG S-280; PCG A-070; PCG C-660; PCG S-340; PCG F-030; PCG P-240; PCG I-020; PCG S-060; PCG S-070; PCG R-030		12	PCG P-240; PCG I-202	PCG P-240; PCG I-202	20
514	153010	C-670	PCG C-650; PCG I-070; PCG C-350; PCG S-280; PCG A-070; PCG C-660; PCG S-340; PCG F-030; PCG R-030A; PCG S-060; PCG S-070	PCG C-650; PCG I-070; PCG C-350; PCG S-280; PCG A-070; PCG C-660; PCG S-340; PCG F-030; PCG R-030A; PCG S-060; PCG S-070		11	NA	NA	
515	154000	C-680	NA	NA		0	Critical Care Flowsheet - Form M-344, Rev 3-2007	Critical Care Flowsheet - Form M-344, Rev 3-2007	48
516	154010	C-680	NA	NA		0	NA	NA	
517	154020	C-680							

1	Vers_ID	PCG_Code	NumIwAss	NwAsPcg	NumIwPcg	RefData	NumRef	IwRfData	NumIwRf	Keywrds	Keywrds1	Keywrds2
498	148000	C-620	0	NA		0 1992, 1993	2	NA	0	3 way catheter, Catheters, Urinary 3 way catheter, Catheters, Urinary catheter	3 way catheter, Catheters, Urinary 3 way catheter, Catheters, Urinary catheter	43
499	148010	C-620	0	PCG C-200		1 1992, 1993	2	NA	0			43
500	148020	C-620	0	NA		0 1992, 1993	2	NA	0	NA	NA	
501	148030	C-620										
502	148040	C-620										
503	149000	C-625	0	NA		0 1990, 1992	2	NA	0	NA	NA	2
504	149010	C-625										
505	150000	C-630	0	NA		0 1987, 1991	2	NA	0	Cornea, Eye surgery, Corneal transplant	Cornea, Eye surgery, Corneal transplant	39
506	150010	C-630	0	NA		0 1987, 1991	2	NA	0	NA	NA	
507	150020	C-630	0	NA		0 1987, 1991	2	1991	1	NA	NA	
508	150030	C-630										
509	151000	C-640										
510	151010	C-640	0	NA		0 NA	0	NA	0	NA	NA	2
511	152000	C-660	0	NA		0 1990, 1991, 1996	3	1996	1	NA	NA	2
512	152010	C-660										
513	153000	C-670	2	PCG P-240; PCG I-202		2 1994, 1997	2	1994, 1997	2	ICP, Crani, Cranio, Neuro pt	ICP, Crani, Cranio, Neuro pt	28
514	153010	C-670	0	NA		0 1992	1	NA	0	NA	NA	
515	154000	C-680	1	NA		0 1995	1	NA	0	24hr fluid balance, Tubefeed, CC flowsheet	NA 24hr fluid balance, Tubefeed, CC flowsheet	42
516	154010	C-680	0	NA		0 1995	1	NA	0	NA	NA	
517	154020	C-680										

Figure 8: Snapshots of the Coding Spreadsheet

To reconstruct the CPG rule histories, the birth date of each CPG version needs to be identified. A version birth date is the date when a CPG version becomes effective. It is also the date when its predecessor fell obsolete and was replaced (i.e., version death date of the predecessor). The version birth date information is presented in each CPG version document, but usually only accurate to the month. I used other two sources to identify the day of the month of version birth dates. One is a document I obtained from the administrator who manages and maintains CPG collections and archives in the organization. This document lists all CPG versions that were effective in August 2008, including the exact effective date for each of them. I used this as the primary information source to code the days of CPG version birth dates. The other source is the index page of each back-up CD archive (as shown in Figure 9), which lists all the CPGs that were created or revised within half a year before the CD was created. For each CPG listed, an exact date is given indicating when the new version was posted on the intranet. This is the secondary source and used only when the primary source is unavailable for a CPG version (because a CPG version might become effective before it is posted). Combining information from these two sources made the birth dates of most CPG versions accurate to the day. For the

rest of the versions whose exact day of their birth dates cannot be identified, I interpolated the day by assuming they became effective on the 15th of the month indicated in the version documents.

<p>March 10, 2010 D-220: Estimating Additional Water Needs for Enterally Fed Patients</p> <p>February 5, 2010 P-120: Passy-Muir Tracheostomy Valve</p> <p>January 11, 2010 H-300: Herpes B Virus - Guidelines for ER Treatment P-090: Epidural Catheter, Nursing Management of the Patient - Acute Care P-100: PICRA, Nursing Management of the Patient D-250: Transition from Continuous to Intermittent Tube Feeding D-290: Nutritional Management of Patients with Diabetes in Acute Care</p> <p>November 30, 2009 C-525: Pleural Chest Tube: Pneumostat Chest Drain Valve F-045: Femoral Artery Sheath/Line: Removal & Groin Clamp P-250: Pre-Post PCI and Angiogram, Care & Management of Patient</p> <p>November 9, 2009 Respiratory Equipment Recommendations for Confirmed or Suspected Influenza in Acute Care</p> <p>September 30, 2009 P-340: Pharyngeal Airways - Insertion, Removal and Tracheal Suctioning P-095: Inhaled Pentamidine Administration R-377: TGV Simulator for Jaeger System R-368: Reprocessing Equipment in the Pulmonary Function Lab</p> <p>September 21, 2009 O-001: Omnicell Dispensing Cabinets</p>

Figure 9: Index Page of a CPG Backup CD Archive

5.2 Constructing Dynamic CPG Networks

In the Excel coding spreadsheet, for each CPG version, I recorded all CPGs it cites in a single cell, comma separated. Using a SAS program, each cell was parsed out into a list of individual CPGs cited by a CPG version. The association between one CPG version and a list of CPGs it cites (its outbound cites at the beginning of the version) is the foundation to construct dynamic CPG networks.

I fed the above information into a FORTRAN program (RHistGen_52.f90, Schulz, 2013) to identify the dynamic network structure and compute time-paths of inbound network characteristics, such as inbound network size, inbound network density, and age of the youngest tie in inbound networks. For each CPG version, the program ran over all the CPGs that it cites and identified the records of time-overlapping versions of each cited CPG and added to these records relevant variables related to the citing CPG version and the inbound network. The program output, for each CPG version, data on time-paths of inbound network characteristics (in effect merging rule level, network level, and tie event level data with the version level data).

The time-paths data of inbound network characteristics from the FORTRAN program was read into a spell-splitting SAS program (see Section 5.3) that created dynamic covariates for my regression analyses. The spell-splitting program created a dataset of sub-spells (time slices) that contains variables about the outcome events (in particular the occurrence of CPG revisions within the durations of sub-spells) as well as the level of covariates – on both network and version levels – at the sub-spell beginning (see Section 5.4).

5.3 Analyses

I tested my hypotheses by estimating fixed-effect logit models (Beck, Brüderl, & Woywode, 2008), in order to avoid biases from unobserved population heterogeneity in my dynamic analyses. To prepare the dataset, I split the waiting time elapsed for each rule i until a change occurs into sub-spells of the same length. I experimented the length of the sub-spells from 2 months to 1 year. I chose 1 year as the upper bound of my test range because it is a common interval length to use for panel studies or event history studies. I chose 2 months as the lower

bound because this is the finest sub-spells I can have. Even though the estimates are more accurate with shorter sub-spells because this can capture more fluctuation in dynamic variables, I am limited by the lack of accuracy of the data. Since the revision dates of some CPGs are only accurate into months, the length of the sub-spells cannot go below one month. My analysis showed that different lengths of sub-spells did not produce any substantial differences of results. The presented results in Chapter 6 were based on the analyses using the dataset of sub-spells with the length of 1/5 year.

With fixed-effect logit models, I examined if a rule revision event did occur during each sub-spell, updating the covariates at the beginning of each sub-spell. The basic form of the fixed-effect logit model is:

$$P(Y_{it} = 1) = \frac{\exp(\beta' X_{it} + v_i + \varepsilon_{it})}{1 + \exp(\beta' X_{it} + v_i + \varepsilon_{it})},$$

where $P(Y_{it} = 1)$ represents the probability that a rule revision event of rule i occurs during a sub-spell t . X_{it} represents the vector of covariates (i.e., independent and control variables) that vary over time and are updated at the beginning of sub-spell t , β' indicates the vector of estimated coefficients. $v_i + \varepsilon_{it}$ denotes the error term, with v_i indicating the rule-specific time-constant error term and ε_{it} the time-varying term. Fixed-effect models allow v_i to be correlated with X_{it} , and use conditional likelihood function to condition it out. For each rule, with experiencing revisions for s_i times, the conditional likelihood function is derived by dividing the conventional likelihood by the probability of having s_i revisions. The resulting likelihood does not contain the term v_i any more. The conditional likelihood of the whole sample is then the product of such

likelihoods of all rules. One can then maximize this likelihood in order to estimate β' (P. D. Allison, 2005).

As a result of using fixed-effect models, my parameter estimates represented true within-subject (i.e., within-rule) effects, because the between-subject variation was controlled for. This approach thus allowed me to infer the causal relationships between the changes in the characteristics of CPGs' inbound networks and their rates of revision over time.

The fixed-effect models automatically excluded those guidelines that have not experienced the designated event. As a consequence, the reduced dataset for estimating the rates of overall guideline revision contains 428 guidelines and 22,188 observations (i.e. sub-spells), the one for estimating the rates of internal revision contains 311 guideline and 15,722 observations, and the one for estimating the rates of external revision contains 213 guidelines and 11,830 observations.

5.4 Interpretation of Fixed-Effect Logit Coefficients

I interpreted the coefficients of fixed-effect logit models using probability multipliers, which is the quotient of two probabilities. I defined the reference probability of a rule revision as:

$$P(Y_i = 1 | X_i) = \frac{\exp(\beta X_i + \gamma)}{1 + \exp(\beta X_i + \gamma)}, \quad (1)$$

where X_i represents the independent variable in question at the reference level, and β indicates the estimated coefficient of the independent variable. γ is a constant that represents the linear combination of all other covariates in the model. When X_i changes by ΔX , the probability of a rule revision becomes:

$$P'(Y_i = 1 | X_i') = \frac{\exp(\beta X_i' + \gamma)}{1 + \exp(\beta X_i' + \gamma)}, \quad (2)$$

where $X_i' = X_i + \Delta X$. The multiplier is the quotient of equation (2) being divided by equation

(1):

$$M = \frac{P'}{P}. \quad (3)$$

If $A = \beta X_i + \gamma$ and $B = \beta X_i' + \gamma$, plugging (1) and (2) into (3) can lead to the following:

$$M = \frac{\exp B + \exp(A + B)}{\exp A + \exp(A + B)}. \quad (4)$$

The interpretation of a coefficient is that when X increases by one unit, the probability of revising a focal CPG increases/decreases by $|M-1|\%$.

5.5 Variables

All variables in my study are time-variant. All independent variables and control variables are updated at the beginning of each sub-spell. In this section, I introduce how I constructed dependent, independent and control variables, respectively.

5.5.1 Dependent Variables

In Chapter 4, I proposed a theory of how rule networks affected the rate of individual rule change. Therefore, the main dependent variable is the rate of guideline revision. To validate my models, I compared different types of rule revision.

As aforementioned in Section 3.2, CPGs of regional healthcare organizations are facing two critical contexts – the healthcare research context and the internal practice context – and integrate knowledge from the both through successive revisions. I distinguished two sub-types of guideline revision, which represent different types of rule content change. External revisions incorporate external knowledge that is derived from healthcare research, while internal revisions integrate internal knowledge that arises from experiences in the internal healthcare conditions and practice context. I thus have three measures of guideline revisions in total: *rate of guideline revision*, *rate of external revision*, and *rate of internal revision*.

To capture the difference between the two sub-types of revision, I used the information about the references included in the CPG version documents. Most of these references are published journal articles or academic books related to healthcare. CPGs citing references indicates that they integrate knowledge derived from healthcare research. At each guideline revision event, I compared the cited references in the guideline before and after the revision. If there were new references added²⁵, I coded the revision events as external revisions, otherwise as internal revisions. All three dependent variables are categorical: if a guideline revision event occurs during the sub-spell, I coded it as 1, and 0 otherwise. My empirical explorations of these two revision subtypes serve to better understand underlying mechanisms and to strengthen the validity of my models.

²⁵ References can also be eliminated after a guideline revision. I do not consider revisions that only eliminate references as integrating external knowledge. A reference is likely eliminated in two situations. First, the reference is obsolete. In this case, the obsolete reference will usually be replaced by a recent one. Second, the practice recommended by the reference is not fit in the internal organizational conditions. This case is closer to integrating internal knowledge, because whether certain practice is fit or not is a piece of internal knowledge that can only be learned through practitioners' using it in their daily work.

5.5.2 Independent Variables

The independent variables measure characteristics of CPGs' inbound networks at the time when a sub-spell t begins. To test the effect of inbound networks (hypothesis 1), I captured network exposure with a dummy variable *having an inbound network*. If a focal CPG is being cited by others at the beginning of sub-spell t , it indicates the presence of an inbound network and I coded this variable as 1, and 0 otherwise.

To explore the effect of exposure intensity (hypothesis 2) on rate of rule change, I examined the size of inbound networks. *Network size* was measured as the number of CPGs that are citing the focal guideline when a sub-spell begins. To reduce the potential biases caused by outliers, the square root of *network size* was used in the analyses (J. Cohen, Cohen, West, & Aiken, 2003, p. 245).

I examined the effects of exposure nonredundancy (hypothesis 3) by measuring *network density*. Density of a guideline's inbound network actually captures exposure redundancy and is negatively related to exposure nonredundancy. This variable was computed as the ratio of the number of ties among the focal guideline's alters (i.e. citing rules) m_t to the maximum number of potential ties among them $n_t \cdot (n_t - 1) / 2$ at the beginning of sub-spell t , where n_t represents the number of alters in the focal guideline's inbound network (i.e., network size).

Finally, to test the effects of exposure newness (hypotheses 4 and 5), I constructed two dummy variables to indicate tie newness and citing version newness respectively by using the ages of the youngest tie and the youngest version of the citing CPGs in a focal guideline's inbound network,

since the youngest tie is the most recently added tie (i.e., new tie), and the youngest version of citing CPGs is the outcome of the most recent revision of citing CPGs. At the beginning of each sub-spell t , I computed the *minimum (youngest) tie age* and the *minimum (youngest) citing version age*. If these age variables are less than W months, it means that a network change event (i.e., a new tie is added, or a citing guideline is revised) had occurred during the last W months, and I coded the corresponding newness dummy variables (i.e., tie newness, citing version newness) as 1, and otherwise 0. Here, W represents the length of the newness window (the time period during which a new tie or recent revision is “new”). In the context of this study, many administrative processes (reporting, review) run on an annual clock, and one should assume that after a year, most events have lost their newness. However, perceptions of newness are likely to vary across guidelines and contexts, and so we should expect that newness effects might be present for a range of specifications of W . I therefore explored models with various lengths of the newness window ($W = 4$ months, 6 months, 8 months and one year). In addition, in order to test the long-term effect of a tie or a citing version that might potentially be nonlinear, I also included linear and squared terms (i.e., second degree polynomial transforms) for *minimum tie age* and *minimum citing version age* into the regression models.

5.5.3 Control Variables

I included six control variables to eliminate misspecification biases. The first one captures the effects of change on the rule system level, which is a linear *time trend* in the models to control for the changes of the general pattern that the healthcare organization revises the CPGs over

time²⁶. It will be computed as the differences (in years) between the date of each sub-spell beginning and January 1st, 1900.

I controlled for four variables that characterize a focal CPG version. They have all been found to play a role in rule revision in prior research. First, I controlled for rule size, which is captured by the *number of words* a CPG version has. Prior research has shown that rule size has a positive effect on the rate of rule change (Beck & Kieser, 2003). In this healthcare setting, longer CPGs might attract wider attention and thus tend to be cited by more other CPGs. Without controlling for it, the effects of inbound networks would likely to be contaminated.

Second, I controlled for the *number of references* a CPG cites. To integrate research knowledge is a time-consuming job. CPG developers, among many other job responsibilities, have to review the relevant research extensively and evaluate each of the studies systematically and then make the decisions whether to incorporate the extracted evidence into the CPGs in question. Therefore, even though it is required by organizational policy that the CPGs have to contain most updated research evidence, given the limited attention span available, CPG developers might only feel stronger pressure to revise those with fewer cited references.

Third, I controlled for the age of each guideline version (i.e., *version age*) at the beginning of each sub-spell. Version age reflects the accumulation of knowledge and experiences not yet

²⁶ I have also explored model specifications that control for two other rule-system level factors that might affect guideline revisions. One is *guideline density*, which is measured as the total number of CPGs in the CPG collection at the end of each year. *Guideline density* is highly correlated with *time trend* ($r = 0.968$). Replacing *time trend* with *guideline density* had no substantial effect on the results. The second set of controls that I explored was time period dummy variables. I constructed three time period dummy variables: (1) Before August 1, 2002, when the organization first launched the intranet system of CPGs; (2) August 1, 2002 – December 31, 2005; and (3) After January 1, 2006, when the organization started the process of regionalizing CPGs. When time period dummies were added to the models, estimates of other model parameters were not substantially affected.

encoded and might affect rule revisions (March, et al., 2000; Schulz, 1998b, 2003). The effect of version age might be confounded with that of rule networks, because rule networks might change as a result of focal rules' revision. When a rule is revised (i.e., when version age is 0), it is likely that it starts to be cited by another guideline, or stops being cited by a guideline. Version age therefore co-evolves with age of citation ties. To capture the effects of rule networks on the rate of rule change, net of the effect of version age, version age needs to be controlled for.

Fourth, I controlled for *number of prior revisions*, which has also been found to affect rule revision in prior research (e.g., March, et al., 2000). The effect of prior revisions, if not controlled for, could also contaminate the effects of rule networks. The inbound networks of CPGs that have changed a lot can be more volatile. The changes in focal CPGs might cause the changes in the citing CPGs, which can in turn affect focal CPGs' change. Therefore, it is necessary to control for the number of prior revisions of a focal CPG. In order to reduce the impact of outliers on the estimates, I included the square root terms of the above four control variables – *number of words*, *number of references*, *version age* and *number of prior revisions* – in my regression models.

Finally, I also explored the effects of outbound networks. The preliminary results showed that neither the presence of an outbound network nor the size of the outbound network had any effect on the focal guidelines' rate of change. However, to test my network-exposure thesis, I still included the dummy variable *having an outbound network* into the analyses. At the beginning of each sub-spell, if a focal guideline cites others, I coded this variable as 1, and 0 otherwise. The effects of inbound networks could potentially be spurious if the effects of outbound networks

were not controlled for, because there are two alternative explanations of the network-exposure thesis. First, it is possible that the presences of inbound and outbound networks are interrelated. CPGs that cite many others might also be cited a lot. In this case, the effects of inbound networks are confounded with the effects of outbound networks. Second, the exposure to other CPGs' contexts might be a result of a CPG being interconnected to (i.e., both citing and being cited by) others, instead of only being cited. If that is the case, without controlling for the effects of outbound networks, the effects of inbound networks can be overestimated.

5.6 Description of the Dataset

As I mentioned in Section 5.1 that the content of some earlier CPG versions could not be observed, therefore, I could not identify the information regarding their networks. Due to the missing values, I eliminated those versions. This procedure yielded the final dataset that consists of 802 CPGs and 1568 CPG versions. During the period from 1989 to 2010, totally 548 CPG births and 1267 CPG revisions are observed.

The number of CPGs in use has been increasing ever since 1989. Figure 10 displays the expansion of the CPG collection. At the beginning of 1989, there were only 13 CPGs; this number was continuously rising to 312 in 1995 and until 712 at the beginning of 2010. By the end of 2010, there were 677 CPGs that are in use²⁷. The speed of CPG expansion has been slowing down since 2006. It might reflect a negative density dependence of rule births (Schulz, 1998a), but can also be caused by the efforts of this organization to “regionalize” the CPGs. The CPGs in this study are developed and used in the acute care facilities which are only part of this

²⁷ The right censoring date is January 1st, 2011.

regional healthcare organization. Starting from 2006, they have been working on creating a collection of regional CPGs that can standardize the healthcare practice across all facilities. As a consequence, more and more CPGs in this collection were revised and became regional guidelines which I can no longer get the access to.

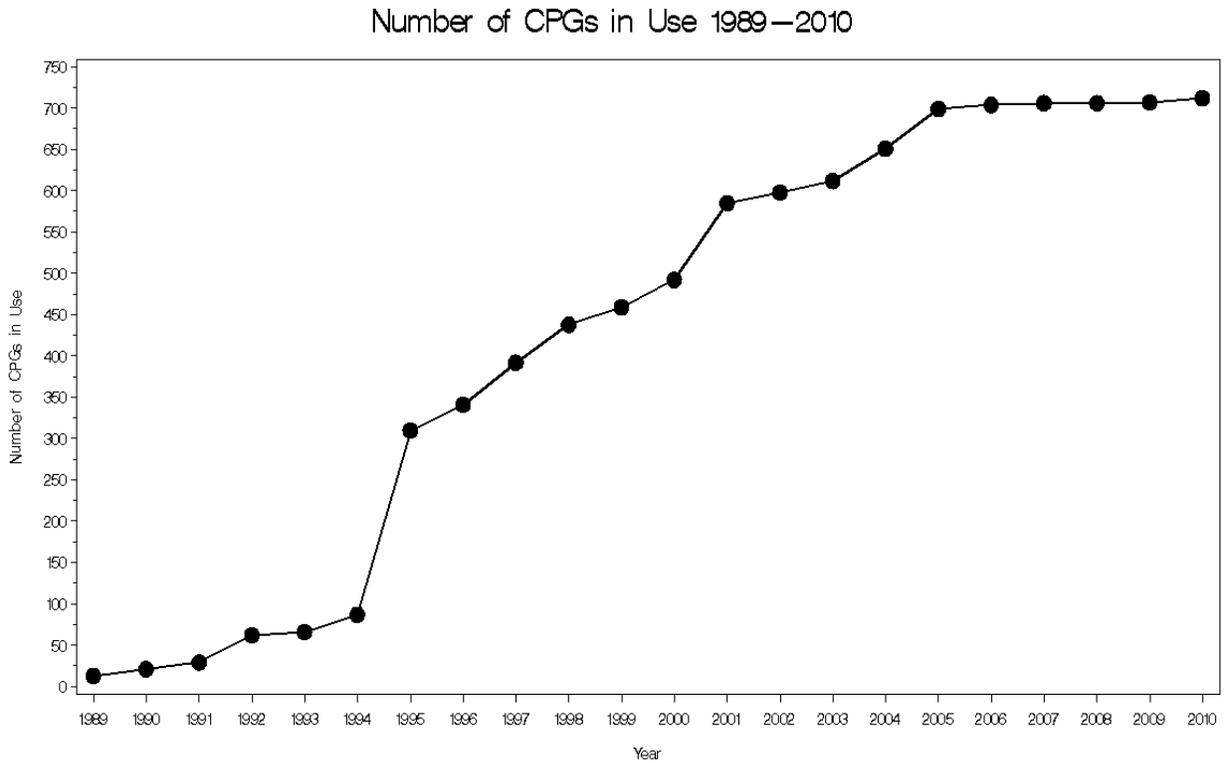


Figure 10: The Expansion of the CPG Collection in the Healthcare Organization

Table 2 presents the descriptive statistics and correlation matrix of the variables included in my analyses. Of the 37,966 sub-spells, I observe 2.0% in which a guideline revision occurs, among which 1.3% are internal revisions, and 0.7% are external revisions.

Table 2: Descriptive Statistics and Correlation Matrix

	Mean	S.D.	Min	Max	1	2	3	4	5	6	7	8	9	10	11	12	13
1 Rate of CPG revision	0.020	0.141	0.000	1.000													
2 Rate of external revision	0.007	0.084	0.000	1.000	0.588												
3 Rate of internal revision	0.013	0.114	0.000	1.000	0.802	-0.010											
4 Time trend	105.098	3.720	90.366	110.998	0.023	0.025	0.010										
5 Number of words ^a	25.600	11.144	5.916	87.321	0.043	0.017	0.041	0.078									
6 Number of references ^a	1.263	1.051	0.000	5.568	0.034	0.039	0.014	0.061	0.394								
7 Version age ^a	1.720	0.850	0.000	3.975	-0.021	0.032	-0.049	0.363	-0.104	-0.073							
8 Number of prior revisions ^a	0.830	0.725	0.000	3.606	0.054	0.031	0.043	0.217	0.195	0.288	-0.249						
9 Having an outbound network	0.354	0.478	0.000	1.000	0.018	0.006	0.018	0.122	0.189	0.157	-0.083	0.118					
10 Having an inbound network	0.336	0.472	0.000	1.000	0.047	0.022	0.041	0.113	0.210	0.178	-0.021	0.244	0.258				
11 Inbound network size ^a	0.485	0.760	0.000	4.359	0.045	0.021	0.040	0.135	0.201	0.164	-0.003	0.248	0.239	0.896			
12 Inbound network density	0.038	0.146	0.000	1.000	0.020	0.001	0.024	0.102	-0.004	-0.001	-0.054	0.156	0.184	0.368	0.402		
13 Min tie age	1.196	2.416	0.000	15.530	0.026	0.022	0.016	0.212	0.137	0.140	0.148	0.222	0.161	0.696	0.546	0.174	
14 Min citing version age	0.841	1.843	0.000	15.515	0.021	0.019	0.013	0.150	0.129	0.096	0.151	0.126	0.140	0.642	0.487	0.116	0.815

^a. Square root

N=37966

Chapter 6

Results

In this chapter, I report the results of the statistical analyses of the rates of guideline revision. I found that in general inbound networks have significant effects on revision rates of guidelines. This means inbound citation networks matter for guideline revisions. The presence of an inbound network and the characteristics of the network can accelerate and decelerate revisions, and they can induce different types of guideline revisions. The findings that I report below reveal how the inbound citation networks of guidelines shape their speed and direction of change.

6.1 Network Exposure

Hypothesis 1 predicts that rates of rule revision intensify when rules become cited by others. I derived this hypothesis by arguing that becoming cited exposes focal rules to other rule contexts, where they can experience rule strain that in turn intensifies their rates of revisions. I capture network exposure of CPGs with a dummy variable that indicates whether (or not) a focal CPG has an inbound network at time t . According to H1, I would expect that the presence of an inbound network has a positive effect on the rates of CPG revision.

Table 3 shows the parameter estimates of network exposure effects. Models 1, 3 and 5 contain only the control variables; In Models 2, 4 and 6, I added the inbound network exposure dummy. As predicted, the parameter was positive and significant in all three models, which suggests that becoming cited by others intensifies focal guidelines' rates of revision. Hypothesis 1 was thus supported. The network exposure effects are quite strong. Holding all the other variables

constant at their mean levels²⁸, when a guideline becomes cited, the probability of revising it will be 2.8 times (Multiplier=2.795) of that if it was not cited, the probability of incorporating new healthcare research knowledge will increase by 60.8% (Multiplier=1.608), and the probability of revising it without integrating any new research will increase by 115% (Multiplier=2.152).

Table 3: Effects of Network Exposure on Rates of CPG Revision

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Dependent Variables	Rate of CPG revision		Rate of External Revision		Rate of Internal Revision	
Time trend	0.329** (0.026)	0.336** (0.026)	0.385** (0.058)	0.383** (0.058)	0.299** (0.030)	0.307** (0.031)
Number of words ^a	0.063** (0.013)	0.054** (0.013)	0.053+ (0.028)	0.050+ (0.028)	0.075** (0.016)	0.066** (0.016)
Number of references ^a	-0.291* (0.133)	-0.254+ (0.132)	-1.056** (0.249)	-1.007** (0.250)	0.297+ (0.178)	0.320+ (0.177)
Version age ^a	0.358** (0.082)	0.336** (0.082)	1.864** (0.226)	1.822** (0.226)	-0.108 (0.093)	-0.124 (0.093)
Number of prior revisions ^a	-3.415** (0.182)	-3.644** (0.186)	-3.491** (0.458)	-3.607** (0.466)	-3.181** (0.201)	-3.384** (0.205)
Having an outbound network	0.349+ (0.194)	0.208 (0.199)	-0.090 (0.397)	-0.198 (0.401)	0.437+ (0.244)	0.281 (0.253)
Having an inbound network		1.834** (0.255)		1.332** (0.500)		1.694** (0.298)
Log-likelihood	-2366.48	-2337.58	-791.559	-787.600	-1579.42	-1561.07
χ^2	620.844	678.651	472.941	480.858	335.440	372.125
<i>df</i>	6	7	6	7	6	7
Observations (sub-spells)	22188	22188	11830	11830	15722	15722
Number of CPGs	428	428	213	213	311	311

Standard errors in parentheses

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

^a. Square root

It is noteworthy that the dummy variable of having an outbound network had much weaker effects on the rates of CPG revision. In Models 1 and 5 that predict the rates of generic CPG revision and internal revision respectively, the estimates were positive, but only marginally significant. After inbound network dummy variable was added (Models 2 and 6), the effects of outbound networks disappeared. In both models predicting the rate of external revision (Models

²⁸ One exception is the dummy variable of having an outbound network, which is set at 1.

3 and 4), the estimates were not significant at all. These results provide support to my fundamental thesis that inbound networks have stronger impacts on rule revisions than outbound networks. They also provide a rationale for focusing this study on inbound networks and examining their characteristics on rates of CPG revision.

6.2 Exposure Intensity

Hypothesis 2 predicts that rates of rule revision should increase with size of inbound networks. The results of the tests of this hypothesis are shown in Table 4. Model 1 predicts the rates of overall CPG revision, Model 2 the rate of external revision and Model 3 the rate of internal revision. In all three models, the dummy variable of having an inbound network remained significantly positive. However, adding inbound network size did not produce a significant improvement of model fit for generic CPG revisions, nor did it affect the rates of either sub-type of revision. Hypothesis 2 was thus not supported.

Table 4: Effects of Network Intensity on Rates of CPG Revision

	Model 1	Model 2	Model 3
Dependent Variables	Rate of CPG revision	Rate of External Revision	Rate of Internal Revision
Time trend	0.339** (0.026)	0.387** (0.058)	0.305** (0.032)
Number of words ^a	0.054** (0.013)	0.051+ (0.028)	0.066** (0.016)
Number of references ^a	-0.247+ (0.132)	-0.993** (0.250)	0.317+ (0.177)
Version age ^a	0.334** (0.082)	1.826** (0.226)	-0.123 (0.093)
Number of prior revisions ^a	-3.643** (0.186)	-3.591** (0.467)	-3.384** (0.205)
Having an outbound network	0.205 (0.199)	-0.206 (0.400)	0.282 (0.253)
Having an inbound network	2.025** (0.411)	2.008* (0.872)	1.633** (0.466)

	Model 1	Model 2	Model 3
Dependent Variables	Rate of CPG revision	Rate of External Revision	Rate of Internal Revision
Network size ^a	-0.158 (0.268)	-0.605 (0.636)	0.052 (0.300)
Log-likelihood	-2337.41	-787.151	-1561.06
χ^2	678.998	481.755	372.154
<i>df</i>	8	8	8
Observations (sub-spells)	22188	11830	15722
Number of CPGs	428	213	311

Standard errors in parentheses

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

^a. Square root

To better understand the effects of inbound network size, I adopted a non-functional specification of inbound network size. Instead of a square root term, I included eight dummy variables, each capturing a different size of inbound network (e.g., network size =1, 2, 3, etc.). The results are shown in Table 5. As shown in Model 1, almost all the dummy variables were significantly positive (except for the network size of 7), but the numeric values of the coefficients were very similar. That means CPGs with inbound networks of any size are more likely to be revised than when they are not cited (i.e., the reference category). This is essentially the effect of having an inbound network. Figure 11 shows the relationship between inbound network size (x-axis) and the logits of guideline revision rates²⁹ (y-axis). An initial jump in the rates of guideline revision can be clearly observed when inbound network size changes from 0 to 1; as network size continues to grow, the rates of revision level off. Further statistic tests (the results are not shown here) also confirmed that given an inbound network the rates of revision of CPGs did not change significantly when the number of citing guidelines increases from 1 to

²⁹ For all the figures in this chapter, the y-axis represents the logits of guideline revision rates, holding all other covariates at 0. Note that I used discrete-time methods to analyze event histories, and defined the discrete-time hazard rate by a probability $P_{it} = \Pr[T_i = t | T_i \geq t, \mathbf{x}_i]$, which is a conditional probability that a rule revision event occurs at time t, given that it has not occurred (after the last revision). I estimated this probability using fixed-effect logit models.

more. I found a quite similar pattern for the rate of internal revision, which is shown in Model 3 of Table 5 and graphically depicted in Figure 12.

Table 5: Probing the Effects of Exposure Intensity

	Model 1	Model 2	Model 3
Dependent Variables	Rate of CPG revision	Rate of External Revision	Rate of Internal Revision
Time trend	0.338** (0.026)	0.380** (0.059)	0.304** (0.032)
Number of words ^a	0.055** (0.013)	0.058+ (0.029)	0.066** (0.016)
Number of references ^a	-0.247+ (0.133)	-1.022** (0.256)	0.336+ (0.181)
Version age ^a	0.337** (0.083)	1.885** (0.230)	-0.119 (0.093)
Number of prior revisions ^a	-3.641** (0.186)	-3.563** (0.470)	-3.381** (0.205)
Having an outbound network	0.196 (0.200)	-0.212 (0.402)	0.283 (0.255)
Cited by 1 CPG ^b	1.854** (0.267)	1.442** (0.526)	1.666** (0.309)
Cited by 2 CPGs ^b	1.882** (0.310)	1.100+ (0.622)	1.829** (0.372)
Cited by 3 CPGs ^b	1.704** (0.362)	0.439 (0.748)	1.716** (0.423)
Cited by 4 CPGs ^b	1.732** (0.446)	0.868 (0.909)	1.407* (0.563)
Cited by 5 CPGs ^b	1.234* (0.604)	-1.139 (1.322)	1.629* (0.693)
Cited by 6 CPGs ^b	1.380* (0.696)	0.464 (1.401)	2.062* (0.851)
Cited by 7 CPGs ^b	1.354 (1.156)	-0.780 (5.721)	2.212+ (1.196)
Cited by 8+ CPGs ^b	2.321* (0.965)	13.350 (459.566)	2.028* (0.959)
Log-likelihood	-2336.44	-783.351	-1560.35
χ^2	680.923	489.357	373.569
<i>df</i>	14	14	14
Observations (sub-spells)	22188	11830	15722
Number of CPGs	428	213	311

Standard errors in parentheses

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

^a. Square root

^b. Reference group: not cited by any CPG

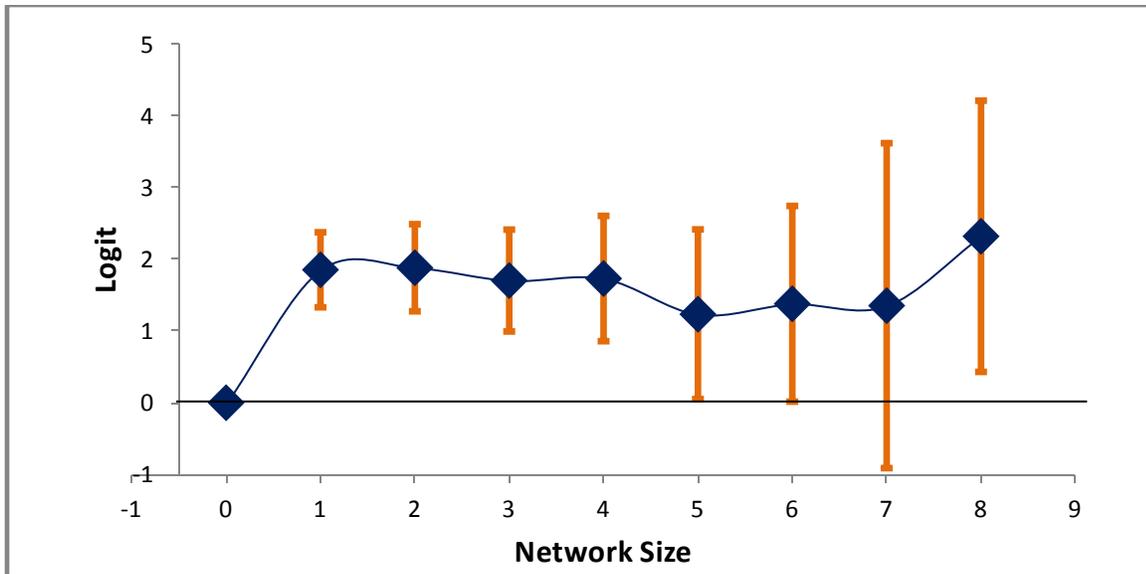


Figure 11: Probing Exposure Intensity Effects on Rate of CPG Revision

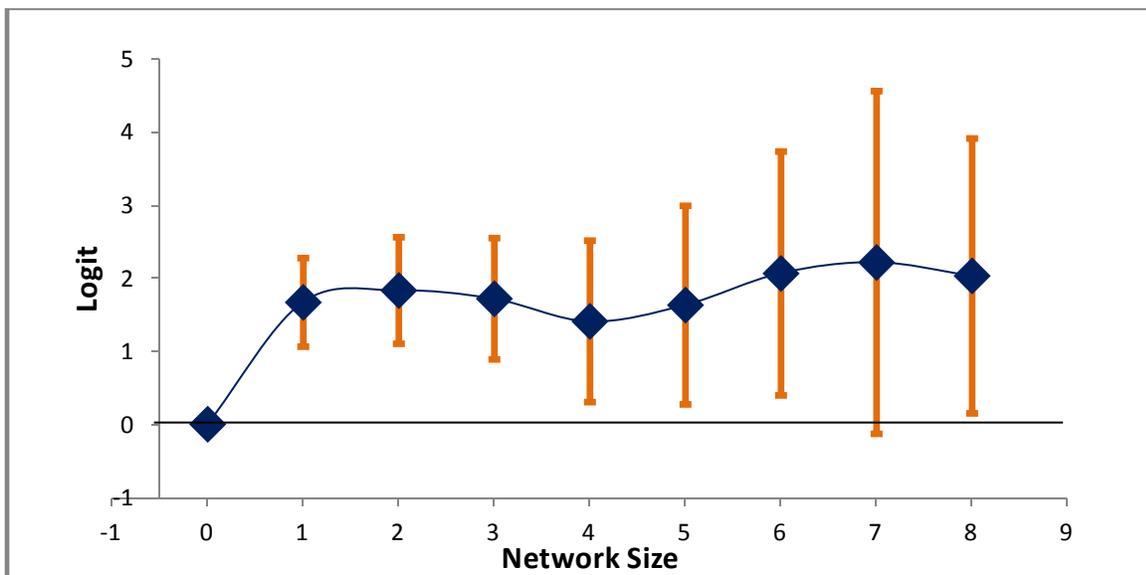


Figure 12: Probing Exposure Intensity Effects on Rate of Internal Revision

Model 2 in Table 5 predicts the rate of external revision. The effects of the dummy variables of inbound network size displayed a slightly different pattern, but could lead to the same conclusion. As shown in Figure 13, only the first dummy (cited by 1 CPG) had a significantly positive effect (the error bar is above level of 0), suggesting that only one inbound citation tie is enough to significantly increase the chances of incorporating new research-based knowledge into CPGs.

This effect was absorbed by the inbound network dummy variable that caused the insignificance of network size as shown in Model 2 of Table 4.

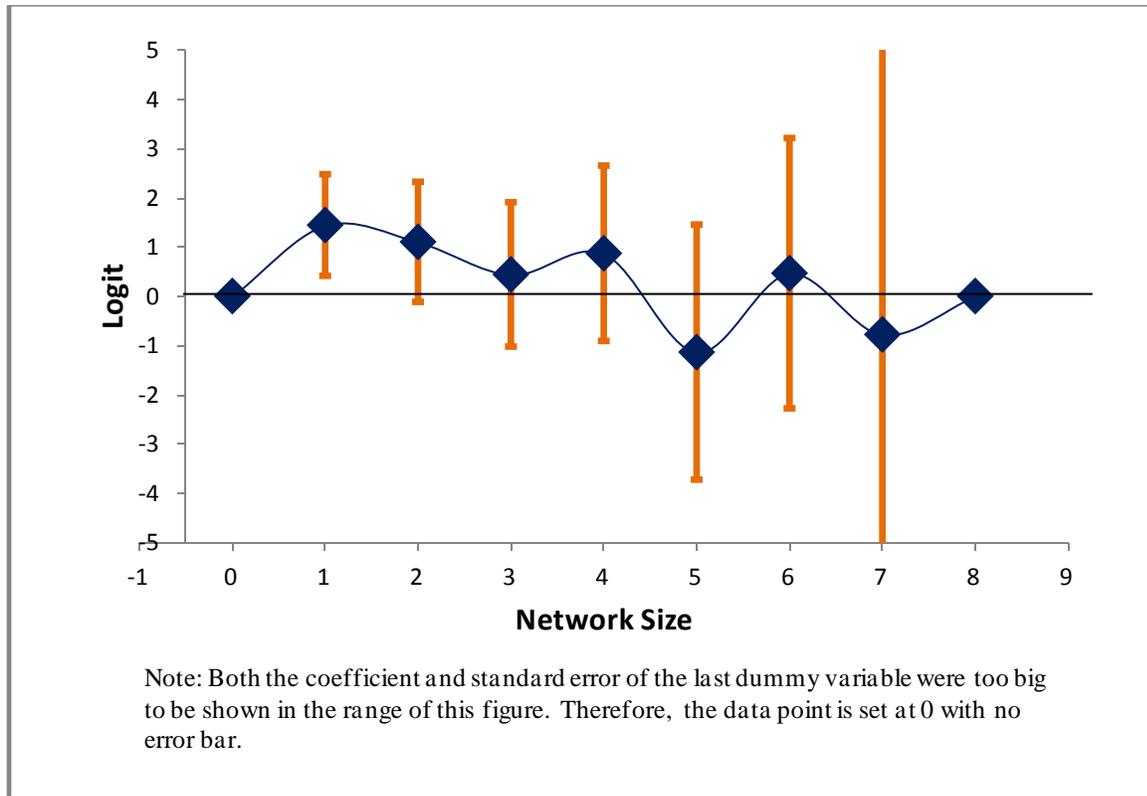


Figure 13: Probing Exposure Intensity Effects on Rate of External Revision

In sum, network size has no systematic effect on the rates of CPG revision. This means that there is no exposure intensity effect. The combination of the significant network presence effect and the insignificant network size effect suggests that being exposed to a network of any size can intensify guideline revisions. What matters is that guidelines are exposed to other contexts; increasing the number of contexts that a guideline is exposed to does not boost the rates of its revision.

6.3 Exposure Nonredundancy

Exposure nonredundancy was hypothesized to elevate the rates of CPG revision (Hypothesis 3). It is reversely captured by inbound network density; therefore, a negative effect is expected for inbound network density. Table 6 shows the results of this hypothesis test. In Model 1, inbound network density did not show any significant effect. When further exploring this effect by looking at the two sub-types of revisions, I found that inbound network density did have a negative effect, but only on external revisions (Model 2), not on internal revisions (Model 3). Hypothesis 3 was thus only partially supported³⁰.

Compared to the non-significance of inbound network density in predicting internal revisions, its strong negative effect on the rate of external revision is rather interesting and striking. As inbound network density increases from 0 to 0.1, the likelihood of integrating research knowledge into CPGs will drop by 7% (Multiplier=0.930). This probability will drop by 44% (Multiplier=0.560) if density grows up to 0.5. When all citing rules are interconnected (i.e., density=1), the probability of integrating research-based knowledge into the focal CPGs is only 17.7% (Multiplier=0.177) of that when citing rules are disconnected. This finding supports my interpretation that as CPGs' inbound networks become sparser and richer in structural holes, they are exposed to other rule contexts and experiences that are less redundant. Nonredundant exposure can produce stronger rule strain and trigger a guideline update. More importantly, rule strain that results from nonredundant exposure is so strong that it can induce non-local search and the integration of external knowledge into CPGs.

³⁰ In order to check the model specification, I explored situations in which network size is 1. I estimated models that add a dummy variable indicating if focal guidelines' network size is 1. It had no effect and the network density effects remained the same.

Table 6: Effects of Exposure Nonredundancy on Rates of CPG Revision

	Model 1	Model 2	Model 3
Dependent Variables	Rate of CPG revision	Rate of External Revision	Rate of Internal Revision
Time trend	0.336** (0.026)	0.393** (0.058)	0.305** (0.031)
Number of words ^a	0.054** (0.013)	0.044 (0.028)	0.067** (0.016)
Number of references ^a	-0.254+ (0.132)	-1.002** (0.250)	0.305+ (0.178)
Version age ^a	0.335** (0.083)	1.812** (0.224)	-0.119 (0.093)
Number of prior revisions ^a	-3.643** (0.186)	-3.533** (0.465)	-3.390** (0.205)
Having an outbound network	0.208 (0.199)	-0.258 (0.401)	0.293 (0.254)
Having an inbound network	1.836** (0.258)	1.603** (0.527)	1.656** (0.301)
Inbound network density	-0.029 (0.545)	-3.193* (1.404)	0.490 (0.608)
Log-likelihood	-2337.58	-784.475	-1560.76
χ^2	678.654	487.108	372.758
<i>df</i>	8	8	8
Observations (sub-spells)	22188	11830	15722
Number of CPGs	428	213	311

Standard errors in parentheses

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

^a. Square root

6.4 Exposure Newness

Hypotheses 4 and 5 concerned the impact of the onset of recent network change “events” – arrival of new ties and revisions of citing CPGs – on guideline revisions. I argued that these “events” expose guidelines to new contexts, which are often associated with uncertainties, problems and new challenges. That can enhance rule strain and intensify the revisions of the focal guidelines. Furthermore, I expected the newness effects to last for only a limited time period. To explore these dynamic effects, I included newness dummy variables in my models, assuming that there is an initial, limited time period after the occurrence of a network change event during which propensities of guideline revisions are elevated. At the same time, I also

explored how revision rates vary subsequently with the passing of time after the occurrence of a network change event. The models capture both how guideline revision rates react to shocks from network change events, and the long-term effects of network change events.

6.4.1 Arrival of New Ties

In the models that I used to test Hypothesis 4, I included several control variables. I included the dummy variable of having an inbound network and the (continuous) variable of inbound network density in the analysis, as both have been shown to affect the rates of guideline revision in the previous analyses. I also controlled for minimum citing version age in these models, because adding a new tie can reset the minimum citing version age (e.g., a guideline is revised and the new version starts to cite the focal guideline; in that case, minimum citing version age is reset to 0), and this can lead to biases of the estimated effect of minimum tie age (and potentially the effect of new tie arrival).

Table 7 shows the effects of new tie arrival on the overall CPG revision rate. All models show a similar pattern, except that some of the coefficients in Model 4 are not significant. In Models 1 to 3, the newness dummy variable is positive and significant, which means that new tie arrival has a shocking effect that can immediately boost the rate of guideline revision during a limited time period. For example, Model 1 shows that when a new tie was added within the last 4 months, the focal CPG would be 20.12% (Multiplier=1.2012) more likely to be revised, holding all other covariates at the mean. The nonsignificance of 1-year newness window in Model 4 seems to support that the newness effect can last for only a very short period of time, which might be less than 1 year. On top of the effect of tie newness, minimum tie age also appears to have a significant effect. The negative sign of its quadratic term suggests an inverted U-shaped

relationship between minimum tie age and the rate of CPG revision. These results demonstrate that the effect of new tie arrival can be divided into two parts: A shocking effect during a short period time right after the onset of the occurrence, and a long-term effect as the tie ages.

Table 7: Effects of New Tie Arrival on Rate of CPG Revision

	Model 1	Model 2	Model 3	Model 4
Dependent Variable	Rate of CPG Revision			
Time trend	0.321** (0.027)	0.325** (0.027)	0.324** (0.027)	0.330** (0.027)
Number of words ^a	0.053** (0.013)	0.053** (0.013)	0.053** (0.013)	0.053** (0.013)
Number of references ^a	-0.242+ (0.133)	-0.242+ (0.133)	-0.243+ (0.133)	-0.239+ (0.133)
Version age ^a	0.365** (0.086)	0.352** (0.085)	0.354** (0.085)	0.337** (0.085)
Number of prior revisions ^a	-3.618** (0.190)	-3.645** (0.190)	-3.641** (0.190)	-3.682** (0.190)
Having an outbound network	0.210 (0.200)	0.212 (0.200)	0.215 (0.200)	0.217 (0.200)
Having an inbound network	1.454** (0.295)	1.484** (0.306)	1.340** (0.320)	1.509** (0.336)
Inbound network density	0.078 (0.550)	0.064 (0.551)	0.066 (0.550)	0.031 (0.551)
Minimum citing version age	-0.082+ (0.049)	-0.084+ (0.049)	-0.085+ (0.049)	-0.085+ (0.049)
Minimum tie age	0.270** (0.091)	0.259** (0.094)	0.307** (0.100)	0.251* (0.106)
Minimum tie age (squared)	-0.017* (0.008)	-0.016* (0.008)	-0.019* (0.008)	-0.015+ (0.009)
Minimum tie age <= 4 months	0.624** (0.231)			
Minimum tie age <= 6 months		0.437* (0.223)		
Minimum tie age <= 8 months			0.554* (0.222)	
Minimum tie age <= 1 year				0.276 (0.223)
Log-likelihood	-2331.26	-2332.90	-2331.68	-2334.04
χ^2	691.288	688.003	690.447	685.735
<i>df</i>	12	12	12	12
Observations (sub-spells)	22188	22188	22188	22188
Number of CPGs	428	428	428	428

Standard errors in parentheses

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

^a. Square root

Figure 14 shows the combined effects of tie newness and minimum tie age on the rate of CPG revision across 8 years (i.e., 96 months) after a new tie is added, with various settings for the tie newness window. The pattern is clear and consistent. We see an immediate surge of revision rate during the first few months (i.e., within the newness window) after a new tie is added in a focal guideline’s inbound network. It is followed by a drastic drop of revision rate, which then increases again as the new tie ages, but with decreasing increments.

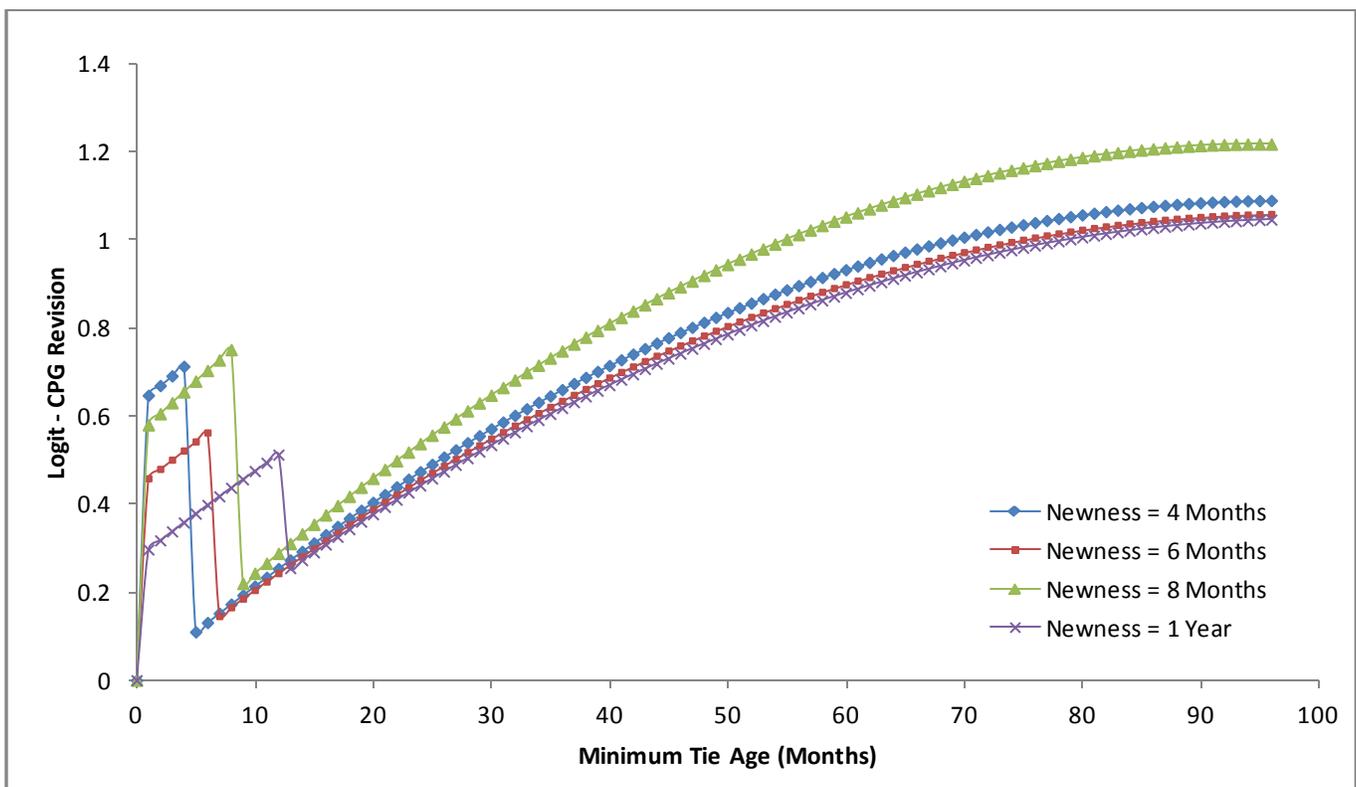


Figure 14: Combined Effects of Tie Newness and Tie Age on Rate of CPG Revision

The results for the two sub-types of revision, however, are mixed. Table 8 shows the results for CPG internal revision. The pattern seems to be very similar to that of overall CPG revision. In Modell, the newness dummy variable is positive and significant. It means that during the first 4 months after a new tie is added in a focal guideline’s network, it is 13.67% (Multiplier=1.1367) more likely to be revised without any reference changes, holding all other covariates at the mean.

The effect of minimum tie age above and beyond tie newness effect was much weaker and seemed to display only a linear relationship with the rate of internal revision. The estimates in Models 2 and 3 implied the similar pattern, but the newness dummy variables were only marginally significant. In Model 4, either tie newness or minimum tie age is significant, which might indicate that the specification of newness window as one year does not fit well with the data. It again suggests that the newness window of a tie might be shorter than one year. The combined effects of tie newness and minimum tie age estimated in Table 8 are shown in Figure 15. Similar to Figure 14, the rate of internal revision increases initially and then drop drastically after a short period of time before it slowly increases again. All the lines are close to each other, except for the one that represents the estimates of Model 4 (newness window is one year), implying its poorer model fit.

Table 8: Effects of New Tie Arrival on Rate of CPG Internal Revision

Dependent Variable	Model 1	Model 2	Model 3	Model 4
	Rate of CPG Internal Revision			
Time trend	0.284** (0.033)	0.288** (0.033)	0.290** (0.032)	0.297** (0.032)
Number of words ^a	0.063** (0.016)	0.063** (0.016)	0.063** (0.016)	0.063** (0.016)
Number of references ^a	0.337+ (0.179)	0.337+ (0.180)	0.337+ (0.180)	0.343+ (0.180)
Version age ^a	-0.059 (0.098)	-0.074 (0.098)	-0.079 (0.097)	-0.101 (0.097)
Number of prior revisions ^a	-3.313** (0.211)	-3.345** (0.211)	-3.355** (0.210)	-3.403** (0.210)
Having an outbound network	0.302 (0.254)	0.305 (0.254)	0.310 (0.254)	0.302 (0.254)
Having an inbound network	1.357** (0.344)	1.370** (0.358)	1.322** (0.373)	1.596** (0.393)
Inbound network density	0.577 (0.610)	0.561 (0.612)	0.552 (0.612)	0.519 (0.614)
Minimum citing version age	-0.089 (0.060)	-0.090 (0.060)	-0.091 (0.060)	-0.090 (0.061)
Minimum tie age	0.205+ (0.110)	0.200+ (0.116)	0.216+ (0.121)	0.119 (0.128)
Minimum tie age (squared)	-0.010 (0.009)	-0.010 (0.009)	-0.011 (0.010)	-0.003 (0.010)

	Model 1	Model 2	Model 3	Model 4
Dependent Variable	Rate of CPG Internal Revision			
Minimum tie age <= 4 months	0.604* (0.260)			
Minimum tie age <= 6 months		0.459+ (0.254)		
Minimum tie age <= 8 months			0.457+ (0.257)	
Minimum tie age <= 1 year				0.082 (0.262)
Log-likelihood	-1556.55	-1557.58	-1557.61	-1559.16
χ^2	381.173	379.112	379.045	375.953
df	12	12	12	12
Observations (sub-spells)	15722	15722	15722	15722
Number of CPGs	311	311	311	311

Standard errors in parentheses

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

^a Square root

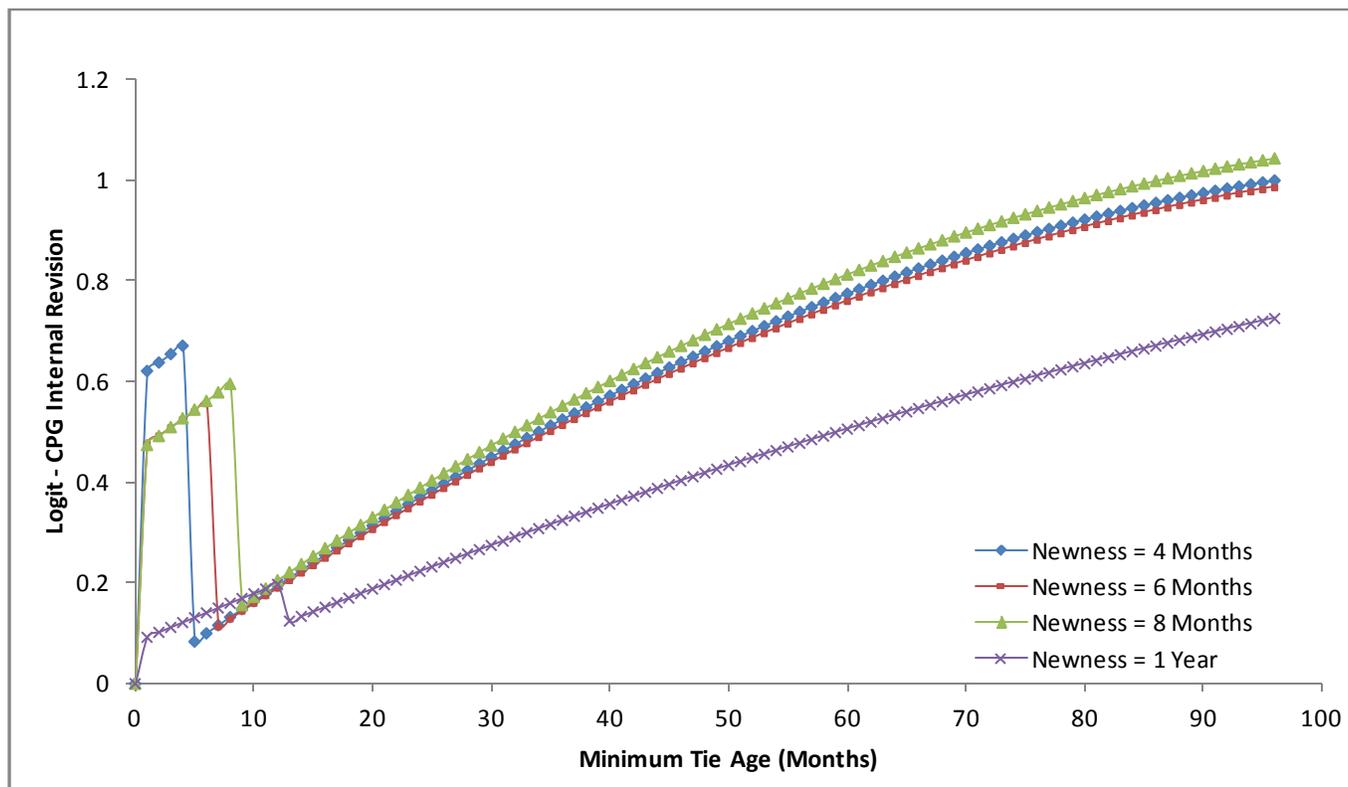


Figure 15: Combined Effects of Tie Newness and Tie Age on Rate of Internal Revision

The results for CPG external revision is shown in Table 9. I did not find tie newness effect. None of the tie newness dummy variables was significant, meaning that the arrival of a new tie does not boost the likelihood of integrating healthcare research-based knowledge into the focal guideline. Minimum tie age, however, showed a strong curvilinear relationship with CPG external revision rate. As it is shown in Figure 16, as a new tie ages, the rate of external revision increases until about 6 years and then it starts to decline.

Table 9: Effects of New Tie Arrival on Rate of CPG External Revision

	Model 1	Model 2	Model 3	Model 4
Dependent Variable	Rate of CPG External Revision			
Time trend	0.408** (0.060)	0.410** (0.061)	0.406** (0.061)	0.404** (0.060)
Number of words ^a	0.044 (0.028)	0.044 (0.028)	0.044 (0.028)	0.045 (0.028)
Number of references ^a	-1.147** (0.259)	-1.143** (0.260)	-1.151** (0.258)	-1.158** (0.258)
Version age ^a	1.749** (0.229)	1.744** (0.229)	1.755** (0.229)	1.764** (0.229)
Number of prior revisions ^a	-3.757** (0.487)	-3.771** (0.489)	-3.744** (0.486)	-3.744** (0.486)
Having an outbound network	-0.443 (0.416)	-0.444 (0.415)	-0.440 (0.418)	-0.442 (0.419)
Having an inbound network	0.861 (0.633)	1.060 (0.649)	0.573 (0.691)	0.357 (0.721)
Inbound network density	-3.678* (1.544)	-3.715* (1.540)	-3.621* (1.550)	-3.618* (1.554)
Minimum citing version age	-0.015 (0.091)	-0.015 (0.091)	-0.015 (0.091)	-0.015 (0.091)
Minimum tie age	0.614** (0.189)	0.555** (0.193)	0.698** (0.211)	0.773** (0.227)
Minimum tie age (squared)	-0.052** (0.017)	-0.048** (0.017)	-0.059** (0.019)	-0.065** (0.020)
Minimum tie age <= 4 months	-0.385 (0.689)			
Minimum tie age <= 6 months		-0.717 (0.620)		
Minimum tie age <= 8 months			0.218 (0.512)	
Minimum tie age <= 1 year				0.428 (0.477)
Log-likelihood	-775.307	-774.740	-775.384	-775.074
χ^2	505.444	506.579	505.289	505.909

	Model 1	Model 2	Model 3	Model 4
Dependent Variable	Rate of CPG External Revision			
<i>df</i>	12	12	12	12
Observations (sub-spells)	11830	11830	11830	11830
Number of CPGs	213	213	213	213

Standard errors in parentheses

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

^a Square root

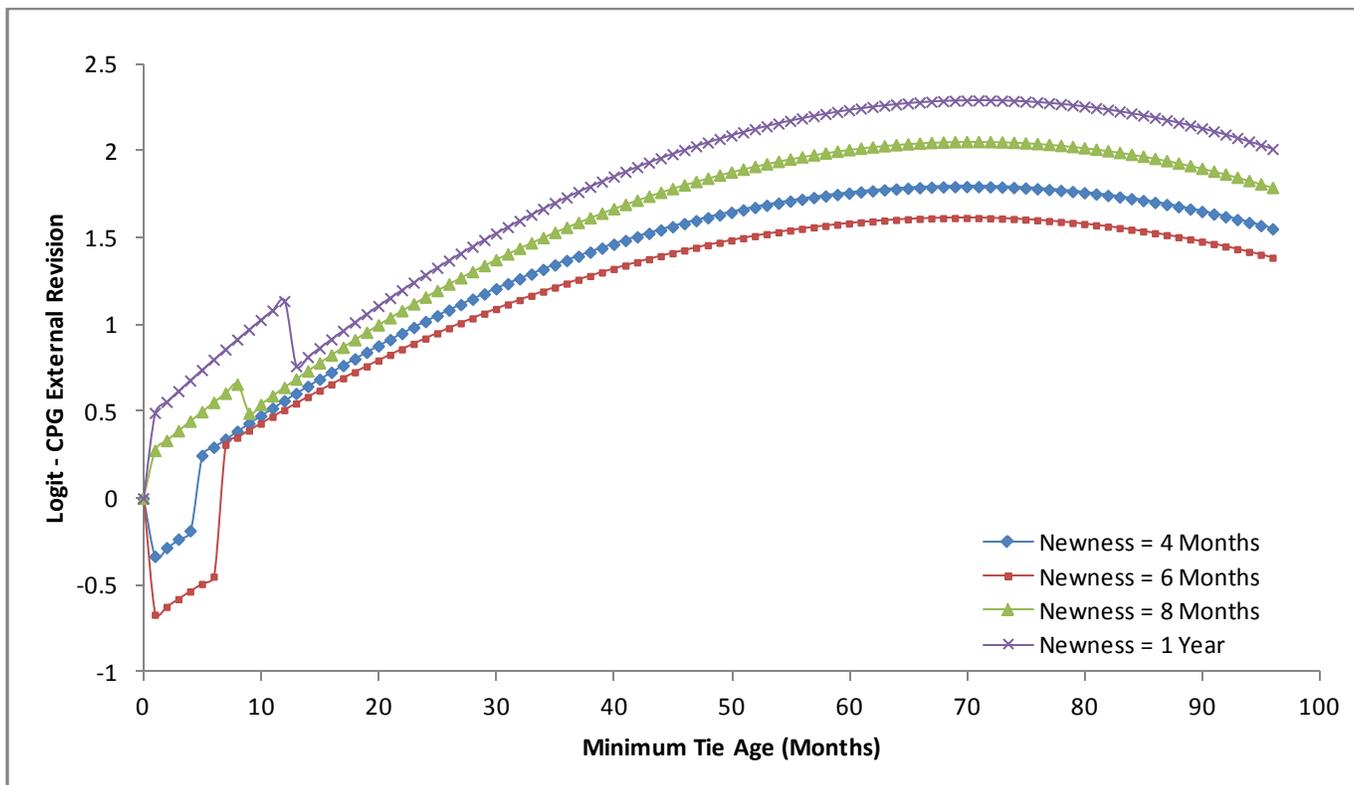


Figure 16: Combined Effects of Tie Newness and Tie Age on Rate of External Revision

To sum up the above results, I did find exposure newness effects arising from new tie arrival on the rates of CPG revision, but the results are different for the two sub-types of revision. When a CPG is exposed to new contexts (i.e., when new ties are added), its internal revisions (with no reference change) are elevated during a limited newness period, while its rate of external revision (with reference change) is not affected. Hypothesis 4 was thus partially supported. It seems that most of the time CPGs respond to exposure newness in a way of “putting out fire” (Radner,

1975). New ties can create urgent problems that need to be resolved immediately (with small, quick fixes). Given that the newness window is short and attention to newness (and the associated problems) shifts away quickly, solutions that work good enough will be adopted and incorporated through internal revisions.

Apart from the initial shocking effect of a tie when it is added into a network, I also found consistent positive long-term effects. In general, estimates of minimum tie age parameters appear to be consistent with obsolescence mechanisms (March, et al., 2000; Schulz, 1998b). As a tie ages, more rule strain can be revealed and accumulate over time, thus increasing the likelihood of the focal CPG's revision. The short-term shocking effect and long-term obsolescence effect coexist and jointly reflect a complex relationship between the dynamics in guidelines' ego networks and their revisions.

6.4.2 Revisions of Citing Guidelines

In this subsection I test Hypothesis 5 by exploring the effects of exposure newness that results from revisions of citing guidelines. Revisions of citing guidelines can introduce newness into the inbound network, and I argue that this can create rule strain and trigger guideline revisions. I adopted the same approach that I used for exploring the effects of new tie arrival. I estimated the newness effect and long-term effect of revisions of citing guidelines simultaneously, controlling for the presence of inbound network, network density, and minimum tie age.

Table 10 shows the effect of citing guideline revisions on the rate of CPG revision. I found some evidence that provides support for Hypothesis 5. In two out of the four models, the parameter of the newness dummy variable is positive and significant, suggesting that revisions of citing

guidelines can create “shocks” that boost the rate of revision of the focal guidelines. For example, the estimates in Model 1 mean that during the first 4 months after a revision of a citing guideline, the focal CPG is 13.98% (Multiplier=1.1398) more likely to be revised, holding all the other covariates at the mean. Minimum citing version age, net of the effect of citing version newness, displayed a significant U-shaped relationship with guideline revisions, as indicated by the positive sign of its quadratic term in all the models. Figure 17 displays the combined effects of citing version newness and minimum citing version age over time. The overall pattern is that after a citing guideline is revised, there is an immediate surge of the guideline revision rate, which drops severely after a limited time period; the rate of revision further declines in a more gentle fashion and then slowly increases again after the version age reaches about 4.5 years.

Table 10: Effects of Citing CPGs’ Revisions on Rate of CPG Revision

	Model 1	Model 2	Model 3	Model 4
Dependent Variable	Rate of CPG Revision			
Time trend	0.310** (0.027)	0.314** (0.027)	0.312** (0.027)	0.316** (0.027)
Number of words ^a	0.051** (0.013)	0.051** (0.013)	0.052** (0.013)	0.051** (0.013)
Number of references ^a	-0.198 (0.133)	-0.196 (0.133)	-0.202 (0.133)	-0.194 (0.133)
Version age ^a	0.425** (0.086)	0.413** (0.086)	0.416** (0.085)	0.406** (0.086)
Number of prior revisions ^a	-3.572** (0.187)	-3.604** (0.187)	-3.590** (0.187)	-3.626** (0.187)
Having an outbound network	0.257 (0.199)	0.267 (0.199)	0.257 (0.199)	0.275 (0.199)
Having an inbound network	1.736** (0.292)	1.859** (0.303)	1.575** (0.321)	2.014** (0.341)
Inbound network density	0.095 (0.546)	0.077 (0.547)	0.100 (0.546)	0.060 (0.547)
Minimum tie age	0.084* (0.038)	0.084* (0.038)	0.085* (0.038)	0.084* (0.038)
Minimum citing version age	-0.202* (0.100)	-0.259* (0.105)	-0.141 (0.113)	-0.328** (0.121)
Minimum citing version age (squared)	0.025* (0.011)	0.030** (0.011)	0.020+ (0.012)	0.036** (0.012)

	Model 1	Model 2	Model 3	Model 4
Dependent Variable	Rate of CPG Revision			
Minimum citing version age <= 4 months	0.489** (0.187)			
Minimum citing version age <= 6 months		0.235 (0.188)		
Minimum citing version age <= 8 months			0.519** (0.199)	
Minimum citing version age <= 1 year				0.023 (0.209)
Log-likelihood	-2324.77	-2327.39	-2324.68	-2328.17
χ^2	704.271	699.023	704.452	697.467
<i>df</i>	12	12	12	12
Observations (sub-spells)	22188	22188	22188	22188
Number of CPGs	428	428	428	428

Standard errors in parentheses
 ** p<0.01, * p<0.05, + p<0.1
^a. Square root

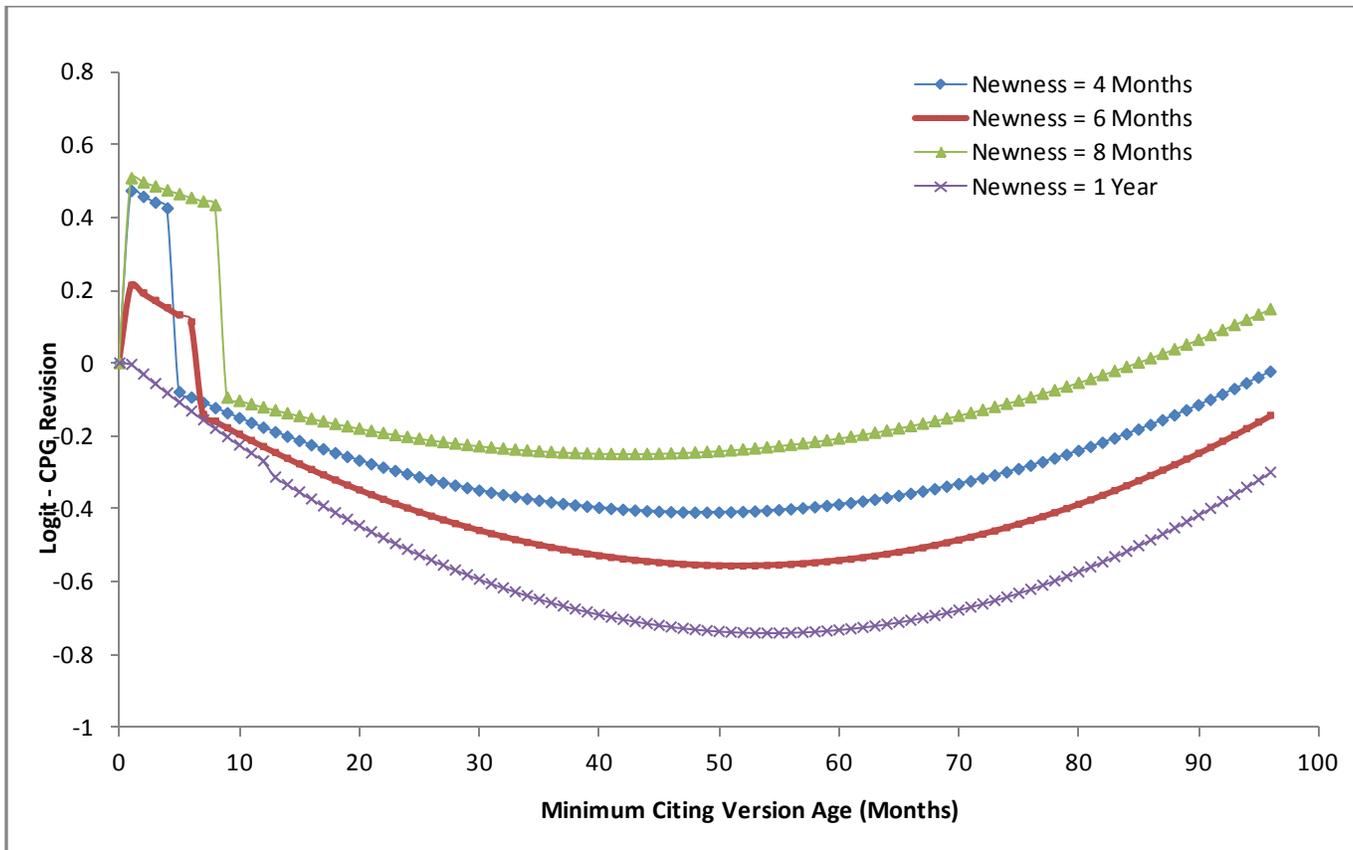


Figure 17: Combined Effects of Citing Version Newness and Citing Version Age on Rate of Revision

The two sub-types of guideline revision again display different effects, as shown in Table 11 and Table 12. I found that citing version newness had a consistent and positive effect on the rate of internal revision, while it had no significant effect on the rate of external revision. Likewise, I found that minimum citing version age affected the two sub-types of guideline revisions differently. On the rate of internal revision, minimum citing version age generally has a U-shaped effect. It means that after the newness effect of the most recent citing guideline revision has faded, the focal CPG's rate of internal revision initially declines with the new citing version age and increases later (see Figure 18). On the rate of external revision, minimum citing version age has only statistically weak effects, although the parameter estimates suggest an inverted U-shaped relationship (see Figure 19).

Table 11: Effects of Citing CPGs' Revisions on Rate of CPG Internal Revision

	Model 1	Model 2	Model 3	Model 4
Dependent Variable	Rate of CPG Internal Revision			
Time trend	0.265** (0.032)	0.271** (0.032)	0.271** (0.032)	0.276** (0.032)
Number of words ^a	0.060** (0.016)	0.061** (0.016)	0.061** (0.016)	0.061** (0.016)
Number of references ^a	0.377* (0.179)	0.378* (0.180)	0.377* (0.180)	0.379* (0.180)
Version age ^a	0.038 (0.099)	0.021 (0.099)	0.021 (0.099)	0.008 (0.099)
Number of prior revisions ^a	-3.256** (0.207)	-3.296** (0.207)	-3.292** (0.206)	-3.329** (0.206)
Having an outbound network	0.356 (0.253)	0.367 (0.253)	0.362 (0.253)	0.380 (0.253)
Having an inbound network	1.561** (0.343)	1.674** (0.358)	1.436** (0.381)	1.786** (0.409)
Inbound network density	0.581 (0.607)	0.566 (0.609)	0.576 (0.608)	0.555 (0.611)
Minimum tie age	0.086+ (0.046)	0.085+ (0.046)	0.086+ (0.046)	0.084+ (0.046)
Minimum citing version age	-0.296* (0.121)	-0.349** (0.129)	-0.251+ (0.138)	-0.404** (0.150)
Minimum citing version age (squared)	0.039** (0.013)	0.044** (0.014)	0.035* (0.014)	0.049** (0.015)

	Model 1	Model 2	Model 3	Model 4
Dependent Variable	Rate of CPG Internal Revision			
Minimum citing version age <= 4 months	0.574** (0.220)			
Minimum citing version age <= 6 months		0.337 (0.226)		
Minimum citing version age <= 8 months			0.558* (0.242)	
Minimum citing version age <= 1 year				0.153 (0.260)
Log-likelihood	-1545.27	-1547.57	-1545.95	-1548.52
χ^2	403.726	399.139	402.363	397.235
<i>df</i>	12	12	12	12
Observations (sub-spells)	15722	15722	15722	15722
Number of CPGs	311	311	311	311
Standard errors in parentheses				
** p<0.01, * p<0.05, + p<0.1				
^a . Square root				

Table 12: Effects of Citing CPGs' Revisions on Rate of CPG External Revision

	Model 1	Model 2	Model 3	Model 4
Dependent Variable	Rate of CPG External Revision			
Time trend	0.387** (0.060)	0.388** (0.060)	0.387** (0.060)	0.388** (0.060)
Number of words ^a	0.044 (0.028)	0.044 (0.028)	0.045 (0.028)	0.043 (0.028)
Number of references ^a	-1.090** (0.255)	-1.082** (0.256)	-1.108** (0.254)	-1.079** (0.257)
Version age ^a	1.766** (0.228)	1.763** (0.228)	1.774** (0.228)	1.764** (0.228)
Number of prior revisions ^a	-3.634** (0.479)	-3.636** (0.479)	-3.636** (0.480)	-3.633** (0.478)
Having an outbound network	-0.387 (0.414)	-0.383 (0.412)	-0.396 (0.417)	-0.379 (0.413)
Having an inbound network	1.094+ (0.604)	1.252* (0.622)	0.702 (0.662)	1.280+ (0.685)
Inbound network density	-3.342* (1.479)	-3.341* (1.474)	-3.328* (1.489)	-3.336* (1.475)
Minimum tie age	0.080 (0.074)	0.081 (0.074)	0.077 (0.074)	0.081 (0.074)
Minimum citing version age	0.334+ (0.203)	0.264 (0.212)	0.499* (0.232)	0.255 (0.244)
Minimum citing version age (squared)	-0.036+ (0.021)	-0.030 (0.022)	-0.051* (0.024)	-0.029 (0.024)

	Model 1	Model 2	Model 3	Model 4
Dependent Variable	Rate of CPG External Revision			
Minimum citing version age <= 4 months	-0.007 (0.418)			
Minimum citing version age <= 6 months		-0.242 (0.390)		
Minimum citing version age <= 8 months			0.439 (0.381)	
Minimum citing version age <= 1 year				-0.187 (0.383)
Log-likelihood	-780.222	-780.028	-779.555	-780.103
χ^2	495.614	496.003	496.947	495.851
<i>df</i>	12	12	12	12
Observations (sub-spells)	11830	11830	11830	11830
Number of CPGs	213	213	213	213

Standard errors in parentheses
 ** p<0.01, * p<0.05, + p<0.1
^a Square root

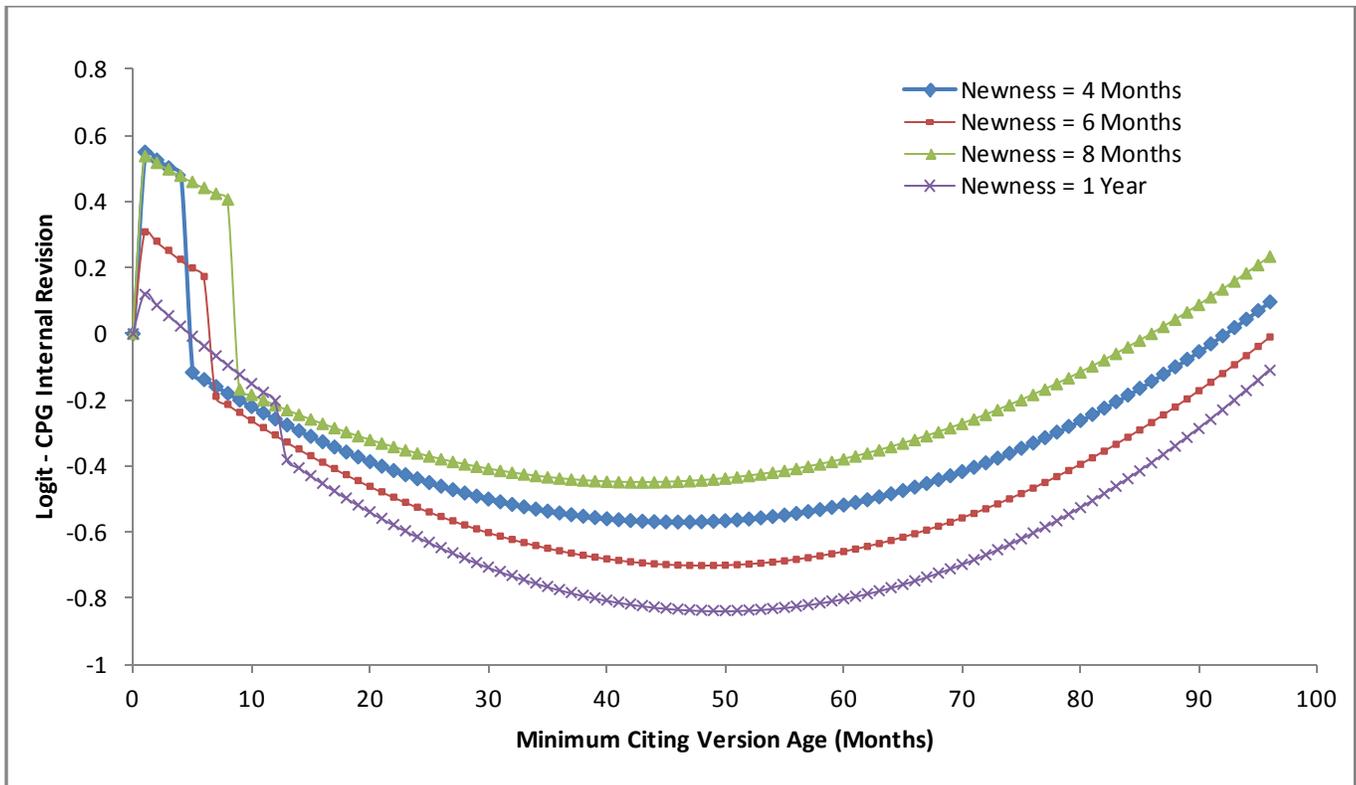


Figure 18: Combined Effects of Citing Version Newness and Citing Version Age on Rate of Internal Revision

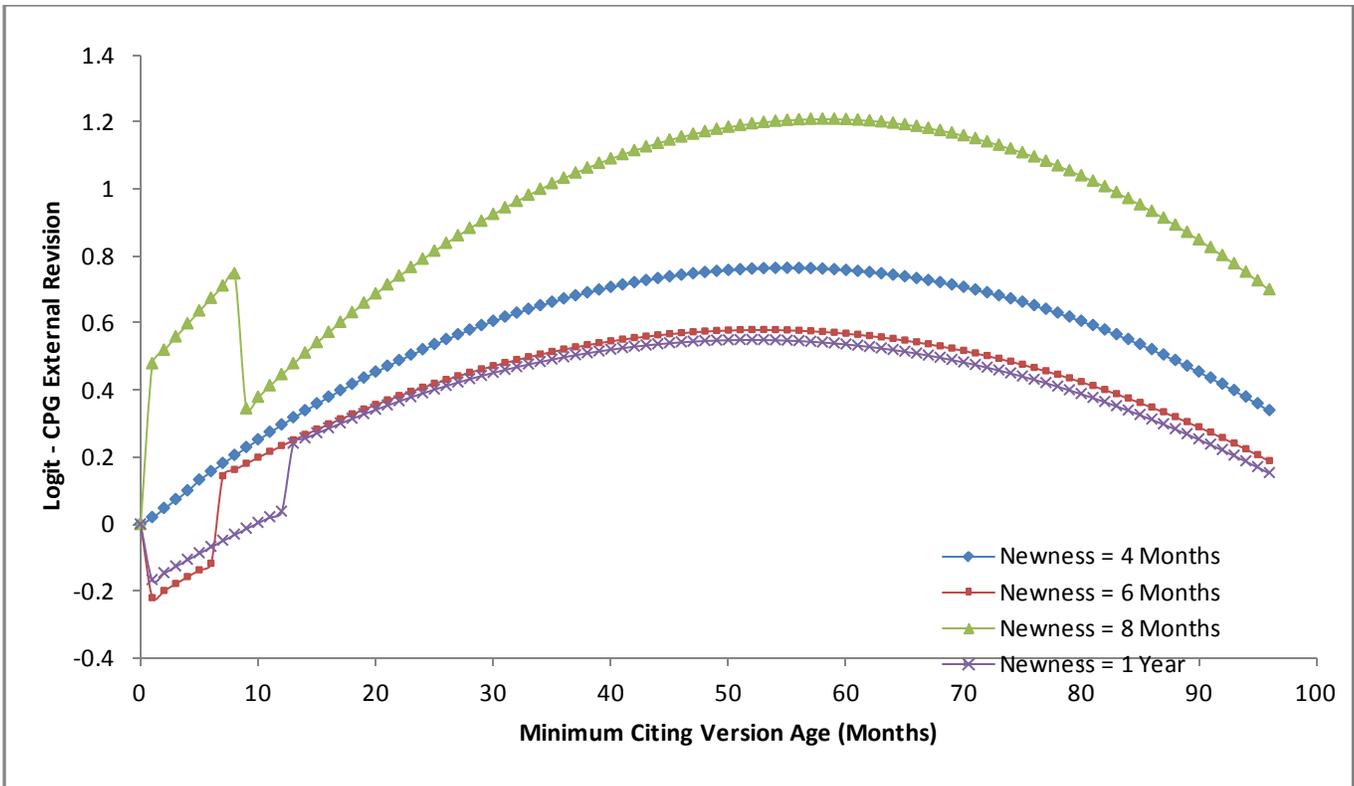


Figure 19: Combined Effects of Citing Version Newness and Citing Version Age on Rate of External Revision

These results partially supported Hypothesis 5. When a citing guideline is revised, the new citing version exposes the focal CPG to newness, which can intensify rule strain and increases the rate of revision of the focal guideline. When examining the two sub-types of guideline revision, I found that citing version newness had consistent and positive effects on internal revisions, but not on external revisions. The pattern is the same as what I found for tie newness. Overall, it seems that network change events have newness effects mainly on focal CPGs' rate of internal revision, and less on the rate of external revision.

The long-term effects of citing guideline revisions (i.e., citing version aging) and new tie arrival (i.e., tie aging) show different curvatures. Version aging appears to have a U-shaped effect on guideline revisions (Figure 17), while tie aging appears to have an inverted U-shape (or even

linear) effect (Figure 14). I think this is related to the differences in the degree of newness that these two types of network change events expose a focal guideline to. While a new tie exposes a focal guideline to a brand-new context, a new version of a citing guideline only introduces some newness into a context that the focal guideline has already been exposed to. The previous experience of the focal guideline with the citing guideline (and its context) reduces its risk of being revised as a result of learning and adaptation of the focal guideline (through prior revisions). After the newness period following a citing guideline revision, the effect of focal CPG's previous experience with the citing guideline is stronger than that of the rule strain brought about by the new citing version; the focal CPG's rate of revision thus declines. However, as time passes by, the latter becomes increasingly stronger and finally exceeds the former; as a result, the focal CPG's rate revision increases afterwards. Therefore, a U-shaped relationship between minimum citing version age and the rate of revision can be observed.

6.5 Summary of Results

Table 13 summarizes the results of hypotheses testing. Clearly, Hypothesis 1 is supported. When a CPG is cited by other guidelines, its baseline rate of revision increases, and the baseline revision rates of the two sub-types of revision are also elevated. Hypothesis 2 is not supported. Increasing the size of a guideline's inbound network does not affect its rates of revision. It seems that the mere presence of an inbound network is sufficient to elevate rates of guideline revision; the size of the inbound network is not a key factor. Hypothesis 3 is partially supported. When a guideline's inbound network becomes sparser, it is exposed to increasingly nonredundant context, which intensify only its rate of external revision, but not the rate of internal revision. Hypotheses

4 and 5 are also partially supported. Change events in a guideline's inbound network can immediately trigger its internal revisions for a limited time period, but not its external revisions.

Table 13: Summary of Results

	Overall Revisions	Internal Revisions	External Revisions
H1: Having an Inbound Network	✓(+)	✓(+)	✓(+)
H2: Inbound Network Size	✗	✗	✗
H3: Inbound Network Density	✗	✗	✓(-)
H4: New Tie Arrivals	✓(+)	✓(+)	✗
H5: Revisions of Citing Rules	✓(+)	✓(+)	✗

In sum, there are four main results of my empirical analysis. First, inbound networks have strong and consistent effects on guideline revisions, while outbound networks do not. Second, when inbound networks grow sparser, guideline revisions intensify. Third, network change events immediately boost the rate of guideline revision for only a limited time period (newness period). Fourth, internal and external guideline revisions are (at least to some degree) driven by different shifts in inbound networks.

Chapter 7

Discussion and Conclusion

In this chapter, I first discuss the main findings of this study and then address their theoretical as well as practical implications. I close with a discussion on the limitations of this study and directions for future research arising from this dissertation.

7.1 Rule Networks as a Driver of Rule Revisions

Rule networks are a new and underexplored topic. Although prior work has explored the interrelationships between (sub-)populations of rules (e.g., March, et al., 2000), the effects of direct ties between rules have so far not been studied. This study is the first attempt to explore whether and how rule networks affect rule change. The findings of this study provide strong support for the proposition that rule networks matter for rule change. I found that guideline revision rates were significantly intensified when guidelines become referenced by other guidelines. I also found that shifts in inbound networks led to significant variation in guideline revisions. I found significant network effects for overall guideline revisions, as well as for the two subtypes of guideline revisions, i.e., internal and external revisions.

Although not all of my hypotheses are supported, the findings are overall consistent with my model of rule strain (though they also add nuance to it). In my model, rule strain arises from the inbound networks of rules. The inbound network of a rule shapes its exposure to sources of rule strain. Embeddedness of a focal rule in a network and exposure to shifts in the network can

create rule strain and lead to rule changes. The findings support this model. The guidelines in my study clearly respond to their inbound networks; their rates of revisions vary significantly when they become embedded in an inbound network, and when their inbound networks shift.

Given the findings of this study, it seems hard to reject the general claim that rule change is network dependent. Network dependence of rule change is not only a new finding (and the main contribution of this study), it also offers a new perspective on the evolution of rule systems. Rules change in ways that reflect the characteristics of their ego networks and the shifts in those characteristics. Rules located in different parts of a rule system are embedded in rule networks with different patterns of rule interconnections and therefore evolve in different ways. That produces an uneven pace of rule elaboration in different parts of the rule system. As a result, rule systems as well as organizational and social structures that rest on them evolve in ways that reflect the underlying relationships between different rules.

The network dependence of rule change arises from the exposure of rules to other rules (with different application contexts) and this can produce rule strain and induce rule change. I distinguished four dimensions of network exposure in this study and explored how they lead to rule strain and rule revisions. My empirical exploration of these four dimensions of exposure can help to understand how network dependence arises and how it is shaped by features of the inbound networks of rules. In the following subsections, I will discuss my findings in more detail.

7.1.1 Inbound vs. Outbound Rule Networks

Rule citation networks are directed and consist of inbound and outbound networks. I explored the effects of both types of rule networks. I found that outbound networks had no significant effects on rule revisions, whereas inbound networks had significant effects. Specifically, baseline rates of rule revision are consistently elevated when rules shift from being isolated to being cited, and characteristics (and their shifts) of rules' inbound networks have significant effects on their revision rates. The strong contrast between the effects of inbound and outbound networks is striking. It confirms my argument that inbound citation ties can create higher levels of uncertainties for the focal rule than outbound ties do. Outbound ties connect the focal rule to others that it cites. The decision of citing others usually arises from the local context of the focal rule (e.g., because it requests support or coordination from other rules and rule contexts). Therefore, outbound ties are not likely to create uncertainties or unintended outcomes for the focal rule. In contrast, inbound ties connect the focal rule to others that cite it. The decision of being cited is made in the context of other citing rules that impose demands on the focal rule; it is not made in the local context of the focal rule. This can create surprises, ambiguities, and unintended outcomes for the focal rule. It can produce rule strain, create learning opportunities (Schulz, 2001), intensify information-processing (Galbraith, 1973), and trigger the search for new knowledge that can be incorporated into the focal rule in order to reduce ambiguities and uncertainties. In that sense, inbound networks are more consequential and can induce stronger change impulses for rules than outbound networks.

It is conceivable that outbound networks might have effects on focal rules (i.e., citing rules) under certain circumstances. When outbound ties dissolve as a result of suspension of cited rules,

citing rules reference non-entities, and the subtasks assigned to cited (but now suspended) rules are left without guidance. Such changes in outbound networks could create change impulses for citing rules and can lead to their revisions (e.g., replacing the citation link to the suspended cited rule with a link to another rule, or include additional provisions to guide the subtasks that were stipulated by the suspended cited rule). The effect would be consistent with my assumption that the locus of decision making is relevant for the impact of network characteristics. For outbound networks, the decision of suspending a cited rule arises from the cited rule's context – it is an externally imposed shift that can have surprising implications for the citing rule. Unfortunately, I cannot explore this idea empirically in this study as I observe too few suspensions of cited rules. However, the underlying proposition that non-local shifts in (inbound and outbound) rule networks have stronger impact on the change of focal rules than local shifts is definitely worth being explored empirically in future research.

7.1.2 Becoming Embedded: Exposure to an Inbound Network

I found that becoming embedded in an inbound network had consistently significant positive effects on rates of guideline revisions, and both subtypes of revisions. This means that inbound networks stimulate guidelines revisions. Guidelines change faster when they are referenced by other guidelines. It is consistent with my interpretation that rules encounter more rule strain when they become embedded in an inbound network. The effect represents the increase in the baseline of guideline revision rates that ensues when a guideline shifts from a state of “isolated” to “embedded”. When guidelines are cited by others, they are drawn into the application contexts of citing guidelines, and this reveals differences and tensions. It increases rule strain and stimulates guidelines revisions. My hypothesis 1 is supported.

The finding might appear counter-intuitive. Rules that are cited by others could be considered as more important, fundamental, and legitimate (e.g., following an institutional line of argument). In that perspective, inbound ties would reconfirm cited rules, thus stabilizing them, just as laws and regulations can be seen as reconfirming and stabilizing constitutions that they cite. This might be true for rule systems with a hierarchical structure, such as legal systems, in which constitutions are created for the purpose of providing foundations for the making of other laws³¹. However, this is not the case for the rule system in this study. Each guideline in the CPG collection of this healthcare organization has been created to guide healthcare practitioners to perform a certain task. Most of the guidelines operate on the same level (they guide decision making in diverse healthcare situations in clinical practice). A priori, none is more fundamental than the others. When a guideline is cited, it guides the performance of tasks (or subtasks) related to the citing guideline. It can be seen as serving as a “subroutine” of the citing guideline. In this sense, the cited guidelines in my study do not act as foundations that give legitimacy to the citing guidelines, nor are they reconfirmed by being cited. Instead, this structure is more similar to a computer program, in which subroutines call other subroutines in the course of performing related tasks. It is a structure in which rules perform related tasks for each other.

It is possible that in other contexts citation ties might have an overall stabilizing effect on cited rules. When inbound ties confer legitimacy, they can stabilize a focal rule. Legitimacy might suppress recognition and articulation of rule strain. The absence of such legitimization mechanisms could thus be seen as a boundary condition for my theory of rule strain. However in many contexts (including the one of this study), inbound networks of rules are not fixed; they are

³¹ Even though they are fundamental, individual cases can trigger the reinterpretation of constitutional rules (or their amendments). After all, constitutions reflect myopic learning (of the legislature of a country) by actors which by nature are not perfect.

dynamic. Inbound ties might confer legitimacy to a cited rule, but if the citing rules and inbound networks are dynamic and heterogeneous, they can nevertheless produce rule strain and destabilize rules. Therefore, dynamic inbound network present a natural source of rule strain and change impulses for rules.

7.1.3 Ego Inbound Network Density: Exposure Nonredundancy

Do rules change faster when they are cited by diverse other rules? I explored this question by analyzing the effect of inbound network density on rates of guideline revision. Inbound density is inversely related to exposure nonredundancy. When inbound network density decreases, cited guidelines are exposed to more nonredundancy and are likely to encounter more intensive rule strain. My model predicts negative effects of network density on guideline revisions.

I did find negative effects of network density, but only on external rule revisions. An increase in inbound network density of guidelines hinders external revisions but has no systematic effect on internal revisions. As the inbound networks of guidelines grow denser, they impede revisions that incorporate external knowledge (i.e., knowledge derived from the healthcare literature), while they do not affect revisions that incorporate internal knowledge. The finding provides only partial support for my hypothesis 3. Why is there no effect of inbound network density on internal revisions? It seems that dense inbound networks produce an effect that is similar to “groupthink” (Janis, 1972). Embedded in a dense network, a group of guidelines might grow into a tight-knit citation network that embraces and enforces a particular approach to practice in a healthcare domain; and that shields its members (i.e., constituent guidelines) from external influence and thereby inhibits integrating external knowledge into these guidelines. Even though

a dense network impedes adoption of knowledge “not invented here” (NIH, Katz & Allen, 1982), it has no impact on adoption of internal knowledge. New internal knowledge, such as incremental improvements of the current practice, can still arise from the experiences of individual guidelines made in their own or others’ contexts, independent of the density of the networks they are embedded in.

Conversely, a sparse network can escape such “groupthink” effects. Instead, the differences between the citing guidelines create nonredundant exposure and higher levels of rule strain for cited guidelines. When unconnected guidelines join the inbound network of a guideline, it (the cited guideline) becomes exposed to nonredundant streams of experiences from its application in dissimilar contexts of citing guidelines. The increase in nonredundancy produces forms of rule strain (e.g., complex issues, problems that involve inter-disciplinary differences) that require comprehensive reviews and intensify revisions that draw on externally validated knowledge.

Network density is a structural characteristic of the inbound networks of rules. At the same time, it is a dynamic characteristic because ties between citing rules can change, and rules can join and exit an inbound network. Inbound networks are dynamic, and their shifts have implications for the cited rule. My study demonstrates this in the case of CPGs. The significant effect of inbound network density indicates that guidelines evolve on paths that are shaped by their unfolding inbound ego networks. It means that guidelines (and perhaps rules in general) are shaped by the shifting structures of their inbound networks.

7.1.4 Network Change Events: Exposure Newness

Exposure newness is brought about by network change events. Network change events can expose the focal rule to new and changed application contexts of citing rules. They can cause shocks and induce changes in cited rules. Since newness is transient, its effect on rule revision is also short-lived.

I explored the effects of newness caused by two kinds of network change events: additions of new ties, and revisions of citing guidelines. The first captures newness related to network growth, and the second newness related to network content change. I found that revision rates were significantly elevated for a limited time period after the occurrence of a network change event. I found newness effects for internal revisions but not for external revisions. My findings indicate that exposure to newness causes intense but short-lived rule strain, which increases the likelihood of internal guideline revisions. The short-lived nature of the newness effects suggests that urgency might play a role; that is, unintended outcomes or a sudden performance drop that result from a network change event create a sense of urgency that leads guideline developers to seek quick fixes and stimulate internal revisions. I did not find any newness effects on external revisions. One likely reason is that external revisions (even if they are triggered by newness) involve comprehensive reviews that are too time-consuming to fit into a limited newness window. However, my finding on the tie aging effect indicates that new ties produce newness that might stimulate external revisions, but their effect is long delayed (and instead produces an aging effect; see below).

In addition to these short-term newness effects of network change events, I also found indication of long-term effects of shifts in inbound networks. In general, as a new tie ages, and as a new citing version ages, rates of cited guideline revision increase, consistent with the interpretation that rule strain accumulates over time and grows increasingly intense, which increases the rate of revision of the focal rule. However, this effect varies in terms of statistical significance for the two sub-types of guideline revisions. New tie aging significantly intensifies external revisions (and has much weaker effects on internal revisions), while new citing version aging significantly intensifies internal revisions (and has much weaker effects on external revisions). This result likely reflects the different degrees of newness that the two types of network change events expose a focal guideline to. New ties expose a focal guideline to contexts that it has never been exposed to, and this provides more opportunities for exploratory learning and stimulates external revisions. In contrast, revisions of citing guidelines expose the cited guideline to less newness (and smaller shifts) which is more conducive to exploitation learning and produce signals that stimulate internal revisions.

The result is even more striking when newness effects and aging effects are considered together. New ties have strong effects on cited rules; they lead to an initial spike of internal revisions, followed by a gradual increase of external revisions. Unlike new ties, revisions of citing rules only stimulate incremental change. They produce an initial spike of internal revisions, followed by a relatively long period of stability, and a late-stage increase of internal revisions. I think the pattern can be explained by differences between the two types of network change events. New ties present larger differences (compared to the contexts that the focal rule has been exposed to in the past) than revisions of citing rules, and therefore stimulate both internal revisions in the short

term and external revisions in the long term. In contrast, revisions of citing rules present relative small differences to cited rules, and they only stimulate internal revisions, in both the short and long term.

From a whole-network perspective, this pattern reflects a cascade of rule revisions in a rule system composed of interdependent rules. Addition of new ties and revisions of citing rules stimulate immediate internal revisions of cited rules. This can trigger more immediate internal revisions of other rules (i.e., rules that the cited rules cite), and thereby can produce waves of internal revisions that spread among connected rules. Internal revisions spread faster through the network, while external revisions take more time to unfold and they spread much slower because they involve non-local search and exploration of external knowledge.

7.1.5 Network Size: Exposure Intensity

In chapter 4, I connected exposure intensity to network size. I argued that larger inbound networks would expose cited rules to more rule contexts and produce more salient rule strain. I predicted (in H2) that the rates of guideline revision would increase with ego network size. My findings, however, did not support my hypothesis, which is somewhat surprising. Given an inbound network, its size does not matter. My empirical explorations show that the number of citing guidelines does not have any systematic effect on any type of guideline revision.

Why does the shift into an inbound network intensify revisions, while changing network size does not affect rule revisions? There might be several explanations. First, the transition from an isolated rule to a “social” (i.e., connected) rule has stronger impact than the transition from N to

N+1 citing rules, because it fundamentally transforms the attention structures (March & Olsen, 1975; Ocasio, 1997) of the decision making processes leading to rule revisions. A citation tie marks an official recognition of interdependency between two rules. The first inbound citation tie received by a focal rule establishes its relevance to the citing rule and thereby embeds it into a rule network. This triggers a shift in the focus of attention from the focal rule *per se* to the “organizational role” that the focal rule plays. The shift can attract extra attention and new participants (e.g., rule makers and users of the citing rules), intensify monitoring and review, reveal new types of problems, and produce more opportunities for decision making about the focal rule. When rules become embedded, they are exposed to a more intense dynamics of change. From the perspective of the Garbage Can Model (GCM) of decision making (M. D. Cohen, March, & Olsen, 1972), the presence of an inbound network alters all four elements of the underlying decision making processes. Being relevant to others (citing rules) gives rise to new types of problems, solutions, participants, and choice opportunities, and this elevates baseline rates of revision.

Second, in light of the effect of exposure nonredundancy, the non-significant effect of network size might be explained by a problem pooling mechanism. Even though a large inbound network exposes a focal rule to more rule contexts and to more problems, these problems can be similar or related. If that is the case, multiple problems might be pooled together and resolved by a single rule revision. Hence, the relationship between network size and rates of rule revision is attenuated. My finding of the significant density effects supports this interpretation. It means that differences between citing rules matter more for changes of cited rules than the number of citing rules. It suggests that the size of a network is less important for the creation of rule strain than the

presence of differences in the network. Large differences in the inbound network can create rule strain that intensifies revisions. Moreover, they can create nonredundant problems which induce stronger rule strain that intensifies external revisions.

Third, the effects of network size might be confounded by tie age effects. Guideline revision rates clearly vary with the age of the most recent tie (e.g., as shown in Figure 14). There are newness and aging effects. This suggests that a tie contributes different levels of rule strain at different times in its life. During initial time periods, it exposes a cited rule to newness and shifts its revision rate up. As the initial newness of the new tie fades, rule strain drops to lower levels producing trickles of problems that slowly accumulate and produce a gradual increase in the revision rate. This means that we have to consider the effect of network size in context. Network size matters, but it is not its level. Rather, what matters is the dynamics of ties arriving and aging. It is not the number of inbound ties that drives revisions, but rather the stage that each of the ties is at in its life cycle (i.e., new tie, mid-aged tie, old tie). Network size is too crude to capture the effects of this intricate network dynamics, while the analysis of tie age effects reveals the underlying relationships.

7.1.6 Internal vs. External Rule Revisions

I distinguished two sub-types of guideline revisions in my empirical analyses. Internal revisions incorporate knowledge that is generated within the local organizational context (e.g., the clinics in which a particular guideline is used), whereas external revisions incorporate knowledge that is externally generated (and published in healthcare research). The two sub-types connect to the learning types of exploitation and exploration (March, 1991). Internal revisions are relatively

incremental and incorporate local knowledge arising from exploitation-type learning. External rule revisions introduce often radical changes and incorporate knowledge from external sources, comparable to exploratory learning.

I found that rule networks can intensify both forms of guideline revisions, but via different mechanisms. It confirms my conjecture that rules respond to different change signals with different types of revision (see section 4.5). When exposed to nonredundant contexts, guidelines integrate more external knowledge; whereas when exposed to newness, guidelines react mostly (especially initially) with internal revisions. It appears that nonredundant exposure produces rule strain that demands external knowledge to resolve underlying problems. In contrast, challenges arising from exposure to newness can be resolved by incorporating local knowledge into guidelines. These findings indicate that different types of rule revision are triggered by different signals from the inbound network. From the perspective of exploration and exploitation, it seems that exposing rules to nonredundant contexts can stimulate exploratory learning, while exposing them to newness stimulates exploitation.

7.1.7 Driving Force for Embedded Rule Change – Exposure to Differences

When I developed the hypothesis on the effect of network size (H2, in section 4.4.1), I assumed that networks would contribute to rule change in a cumulative fashion. I reasoned that rule strain would increase with network size as each citing rule would provide additional exposure to other rule contexts. My results do not support the assumption of cumulative exposure leading to H2. Network size has no effect. Instead, rule strain seems to be more related to exposure to others,

nonredundancy, and newness. Taken together, these results indicate that rule change is driven less by cumulative exposure than by exposure to differences.

Exposure to differences is inherent in the three dimensions of exposure that find support in my study. First, network exposure introduces an external point of reference into the focal rule's revision process. When rules become cited, they play a role for others in contexts that are different from their own. This creates rule strain and signals about the need for their revision. Second, exposure nonredundancy arises when citing rules are different from each other (reflected by the lack of connections among citing rules). Differences among citing rules create rule strain that triggers rule changes (in particular, exploratory types of rule changes). Third, exposure newness, which results from network change events, causes shocks that can create experiences of "differences" in the contexts that the focal rule is exposed to, thereby elevating their rate of rule revision during limited time periods. These three dimensions of exposure capture the differences that individual rules are exposed to when their networks shift. In contrast, network size does not impact revisions (although new ties create exposure to differences and intensify rule change during a limited newness time period). Network size – by itself – has little effect because it does not create additional exposure to differences.

These findings support the notion that exposure to differences drives rule change. Embedded rules react to differences that their networks expose them to. Embedded rule change reflects the level of exposure to differences, not exposure to multiples. I am aware that this represents a post-hoc interpretation of my results and hope that future research will explore this assumption in further detail.

7.1.8 Human Actors vs. Networks as Drivers of Rule Change

The results of my study suggest that changes of rules are driven by the rule networks in which the rules are embedded; human actors do not play a direct role in my model. This might appear a little surprising to readers who intuitively assume that rules and rule change are driven by human actors. It is less surprising to readers who are familiar with multilevel thinking and macro sociological conceptualizations. One of the grand sociologists, Emile Durkheim, already underscored the important role of laws and rules as social facts – “social phenomena sui generis” – that would exist on supra-individual level, relatively independent from individual actors.

Rules appear as “facts” to most actors, and thereby powerfully shape their action. More recent approaches recognize the emergent qualities of rules and see them as socially constructed (e.g., Berger & Luckmann, 1966), for example, through processes of mutual typification and institutionalization. In these approaches, social processes are the drivers of rule change, while human actors – though clearly necessary for producing lines of action shaped by rules – play a subordinate role for the emergence and transformation of rules and the evolution of social structures. In my study, rules (and the rule system) – clinical practice guidelines – remain in the organization and shape the action of actors (i.e., healthcare practitioners) who enter and exit the organization over time. The rules are sporadically changed by assigned actors, but the actors come and go, while the rules stay behind.

Not only are rules supra-individual “facts”, their inbound networks are even more so. Inbound citation networks of rules are the unintended outcomes of the decisions made outside of the local contexts of the cited rules (i.e., decisions are made at the local contexts of citing rules). Their

configurations and structures are not planned nor centrally controlled (e.g., by healthcare practitioners). Inbound networks of rules arise and change as a result of local decision making around citing rules. Inbound networks produce surprises and rule strain for cited rules – because they expose cited rules to non-local impulses and differences. In that light, inbound networks represent a relatively autonomous source for rule change – one that arises from the exposure to differences when rules are embedded. As an unintended product of decision making at earlier times and different places, inbound network of rules represents a sui-generis phenomenon. In my study, I observed the inbound networks of CPGs and I found that they play a significant role for guideline revisions. Inbound citation networks of rules are supra-individual ‘facts’, and they matter to rule change.

Human actors do play a role in my study. Human actors receive signals about rules (e.g., signals about rule strain) from rules’ inbound networks. Rule networks expose rules and human decision makers to signals and shape their exposure over time. Once receiving signals, human actors then make decisions about them. Their decisions, in turn, shape rules’ inbound networks and can produce surprising outcomes. The decision of referencing another rule can have unintended implications for the cited rule at a later time, producing signals and impulses for change. Human actors are thus in my model; but their actions are structured by rules and their impact on rules is shaped rule networks.

7.2 Theoretical Implications

Starting out with the observation that rules are often interdependent, I take the Dynamic of Rules approach, combine the literatures of organizational rules, organizational learning and networks

and seek to understand how rules evolve over time as they become embedded in networks of interconnected rules. I have developed a new theory of rule networks and rule change, which finds empirical support in my quantitative analysis. The implications of this study might be relevant to research in other related domains. In this section, I first discuss the contributions of this study to the understandings of rule dynamics. Then I discuss implications of my study for four related and important theoretical domains: (1) rule-based learning, (2) knowledge evolution, (3) innovation, and (4) complex adaptive system.

7.2.1 Contributions to Understanding of Rule Dynamics

This study makes several contributions to deepening the understandings of rule dynamics. First, I found strong empirical evidence that rule networks affect individual rules' revisions. In prior research on dynamics of rules, researchers have recognized that rules are interdependent and have found that the interrelatedness among subpopulations of rules has deep implications for rule change (e.g., March, et al., 2000; Schulz, 1998a). In this study, I take the notion of rule interdependence a step forward. I adopt an ego network approach to directly capture and measure the characteristics of interdependencies between individual rules. This approach allows me to examine directly whether and how rule interdependence (manifested by citation ties that form rule networks) affects rule revisions. This ego network approach helps to shift the focus to individual rules and explain the paths which individual rules follow as they evolve over time. I argue that when individual rules are cited by other rules, they are exposed to the application contexts of citing rules, and this can produce experience streams that might be misaligned with those in their local contexts. The experience misalignment can cause rule strain on the focal rules,

thereby provide learning opportunities and intensify their revisions. The findings of this study are highly consistent with my rule strain model.

Second, building on the assumption that rule networks affect rule revisions, I further developed and empirically explored my model to explain how dynamic network characteristics affect rule changes. My theoretical model connects inbound ego network characteristics (and shifts in them over time) to rule strain. I argued that when ego networks of individual rules grow larger, less dense, and undergo changes, the levels of rule strain would increase, and thereby intensify the rates of revision. Although network size in itself showed no significant effects, I did find significant effects of network density and network change events that were consistent with my hypotheses. My findings suggest that rule networks shape the exposure of individual rules to other rules (and their contexts), and thereby can affect the levels of rule strain the focal rules experience. The results of my study indicate that rules adapt to each other in a rule system when they reference each other. Rules receive change impulses not only from their own operating contexts, but also from the contexts of citing rules.

Third, this is the first study on organizational rules that examines the network dependence of different types of rule revisions separately. Revisions can transform rules in different ways and can shift rule content into different directions. In the context of this study, external revisions align guidelines with extant healthcare research, while internal revisions align them to local experiences arising from the clinical practice of the healthcare organization. External revisions often reflect more radical changes, while internal revisions usually reflect incremental changes. The findings demonstrate that different types of rule revision can be triggered by different

change signals arising from rules' inbound networks. Particularly, rules are more likely to undergo external revisions when their inbound networks provide nonredundant exposure, and they are more likely to undergo internal revisions when their inbound networks expose them to newness. This means that the inbound network of rules affects not only the speed of change of cited rules, but also the direction of their (content) change.

Lastly, my study extends the research on rule dynamics into a new setting – healthcare. This is the first quantitative study that examines how rules change in a healthcare organization. My study extends the “Dynamics of Rules” studies into healthcare and shows that healthcare rules are driven by organizational mechanisms. I approach CPGs from the perspective of organization theories (about rules, networks, learning, change, etc) and analyze guideline change with methodologies and approaches developed in prior research on organizational rule change in various contexts (such as banks, universities, and governments). CPG change in my study displays patterns that are consistent with prior research on rule change (reflected by the effects of the control variables that are consistent with prior findings on rule revisions), suggesting that healthcare guidelines change in ways that are similar to other rules in other organizations. Apart from reconfirming existent theories of rule change, more importantly, my study shows that CPG revisions are shaped by their networks. The organizational embeddedness of the guidelines matters for their change. Organization theories, in particular rule-based learning theories, extend to healthcare rules. My study thereby contributes to the generalizability of organizational learning theories and dynamic models of rule change.

7.2.2 Implications for Organizational Learning: Interdependent Learning

This study builds on organizational learning theories and follows the Dynamics of Rules approach (March, et al., 2000) that is heavily built on organizational learning theories. In organizational learning theories, rules are viewed as repositories of organizational knowledge (Levitt & March, 1988). From that perspective, rule change reflects organizational knowledge change, driven by organizational learning around rules. As rules interact with organizational practice contexts (i.e., are used) over time, experience is accumulated, from which lessons and knowledge are extracted and encoded back into rules. In that sense, rules are locales of learning in organizations and they can “learn” from experience.

Seen from the rule-based learning perspective, this study reveals that learning in organizations does not occur independently, but rather interdependently. The process of interdependent learning is different from that of knowledge transfer, which has been greatly explored and investigated in prior research (e.g., Argote & Ingram, 2000; Darr, Argote, & Epple, 1995; Hansen, 1999; Reagans & McEvily, 2003). Knowledge transfer occurs when a focal unit (i.e., individuals, teams, departments, rules, routines, organizations, etc.) learns from others’ experience (Argote, 2012) or adopts (or imitates) others’ practice and technologies (with or without modification), while interdependent learning is triggered when a focal unit receives learning impulses from the network of interconnected units in which it is embedded.

This study shows that learning is interdependent in two senses. First, learning is embedded in networks of interconnected learning units. Embeddedness of learning means that learning of individuals, teams, departments, rules, routines, etc. is interconnected within organizations. In

order to enhance organizational effectiveness these learning units have to learn to coordinate and work together, which is usually not straightforward and fraught with problems. Learning is network dependent as the experience that one learning unit makes is inevitably shaped by other units. In that sense, individual learning units' experience is shaped by the network in which it is embedded. Learning grows interdependent because experience streams become connected. As a critical input for learning and knowledge creation, experience plays a vital role in organizational learning (e.g., Argote & Epple, 1990; Argote & Miron-Spektor, 2011; March, 2010; Schulz, 2002). Prior research has shown that various types of experience (e.g., direct vs. indirect, success vs. failure, novelty, heterogeneity, etc.) have different implications for learning (see Argote, 2012 for a review). In the same vein, networks affect learning by shaping the experiences of the embedded nodes (i.e., learning units). They can expose some units to more problem-laden experiences; and the intensity of problems in their experience streams depends on the structural characteristics and dynamics of the networks in which the focal units are embedded. Networks give rise to problems that can trigger and intensify learning, and the type and intensity of the problems affect the speed and direction of learning.

Second, learning is interdependent also in the sense that learning at one locale in an organization impinges on learning at other locales. One of the processes of interdependent learning is learning substitution, in which "different learning locales or mechanisms are substitutes for each other" (Levinthal & March, 1993, p. 99). Alternatively, learning can positively affect learning at other locales. Learning in one locale can trigger learning in other locales within organizations. When one learning unit is engaged in learning (and therefore undergoing change), it can disturb the status quo of the network in which it is embedded. This can potentially create impulses (i.e.,

problems, newness) that force other interconnected units to react by searching for alternatives, and thereby produce a cascade of learning and change within the network.

7.2.3 Implications for Knowledge Evolution

Organizational rules are often seen as repositories of organizational knowledge. In my study, the CPGs contain clinical knowledge and are critical for the regional healthcare organization to function properly. Therefore, the processes of rule change that I explore in this study can shed light on the processes of organizational knowledge evolution. An organizational knowledge base is usually considered as a set of repositories that contain the content of what an organization knows (e.g., Ahuja & Katila, 2001; Fleming, 2001). Prior research has explored several forms of knowledge evolution in knowledge base, such as change in the size of an organization's knowledge base (e.g., Ahuja & Katila, 2001; Fleming, 2001), or its effect on organizational performance (e.g., Epple, Argote, & Devadas, 1991; Haunschild & Sullivan, 2002). This view to a large extent ignores the fact that knowledge nodes are often interconnected within a knowledge base, thus forming a network structure (Yayavaram & Ahuja, 2008).

The network characteristics of knowledge base has so far received only limited attention, even though it is implied that the interconnections between individual pieces of knowledge are to some extent relevant to organizational learning and growth. For example, Cohen and Levinthal (1990) pointed out that an organization's innovation capabilities relied on its ability to recognize, evaluate and assimilate external knowledge, namely absorptive capacity. From this perspective, knowledge grows in a way of establishing connections between internal knowledge and external knowledge. Likewise, Kogut and Zander (1992) argued that a firm learned new skills by

combining existing capabilities. In other words, new knowledge is created by combining existing knowledge. Having recognized the interconnections between knowledge elements, these studies did not put much importance on the network structure of an organization's knowledge base.

The network view of knowledge base has a strong "cognitive flavor" (Schulz, 2002, p. 430), and has been articulated theoretically in some of the earlier works (e.g., Duncan & Weiss, 1979; Sandelands & Stablein, 1987). Empirical studies on organizational knowledge did not adopt this view until only recently. This view entails two aspects of knowledge evolution – change in knowledge nodes and change in the network structure that connects the knowledge nodes. The latter has been explored in a recent study which showed that the decomposability of a firm's knowledge base had an inverted U-shaped relationship with its further change of the network structure (Yayavaram & Ahuja, 2008). However, knowledge evolution driven by the change in the content of knowledge nodes has received little attention.

My study combines both aspects of knowledge evolution. Taking a dynamic network view of knowledge, my study suggests that organizational knowledge evolves as knowledge nodes change in response to shifts in their networks (i.e., shifts in the structure of the knowledge base). The findings of my study indicate that connections to diverse and nonredundant others stimulate changes of knowledge nodes. Furthermore, changes of nodes can also trigger change in related knowledge nodes, thus creating waves of change within the knowledge base.

7.2.4 Implications for Innovation

Rule change can be seen as a form of organizational innovation, even though rules are often intuitively seen as an impediment of innovation. At the core of innovation is “doing things differently” (Anderson, Potočnik, & Zhou, 2014; Crossan & Apaydin, 2010). Organizational rules define the ways in which organizational members “do things”, and their changes thus can be seen as innovation. In my study, CPGs define the ways in which healthcare professionals treat patients. Change of CPGs can be seen as innovation in healthcare practice.

Seeing rule change as innovation, my study offers a somewhat unusual perspective on innovation. From my perspective, innovation is an emergent process. Innovation in organizational practice (in the form of rule changes) can naturally arise from the dynamics in the networks in which organizational rules are interconnected. The network model that I have developed and explored in this study contributes to understanding such emergent innovation processes. The findings of my study indicate that innovation is embedded in rule networks, and its speed and magnitude depend on the dynamics in rule networks. Specifically, radical innovation occurs when rules become cited by other rules that are operating in diverse contexts (and thereby produce more nonredundant signals), and incremental innovation ensues after change events occur in the network and expose rules to newness.

This process of innovation operates at the rule network level. It is supra-individual and essentially independent of any particular individual’s volition. Innovation is an embedded process in my model. Even though managers and innovators might play a role in the processes of innovation, their attention and activities related to innovation are shaped by the dynamic

structure of rule networks. Rule networks act as powerful *decision premises* (Simon, 1957) for managers and innovators. Although my model does not build on strong assumptions about individual actors (e.g., managers or innovators, etc.), it does not completely exclude them. My model implicitly includes them and their activities as a mediator between dynamic rule networks and innovation outcomes.

7.2.5 Implications for Complexity Theory

Taking a perspective of complexity theory, a rule system might be viewed as a complex adaptive system (CAS). A CAS is a system that contains interacting agents that adapt to signals from both their local environment and from other interacting agents; orderly patterns of behavior at the system-level emerge as a result of the seemingly chaotic interaction at the agent-level (e.g., Drazin & Sandelands, 1992; Holland, 1995; Nan, 2011). A CAS is emergent and self-organizing, rather than designed. Orders and structures emerge from the interaction of agents that act locally by following their “schemata”. My study shows that a rule system, similar to a CAS, contains individual rules that interact and adapt to each other. The rule system evolves not according to any central power’s will, but in ways that reflect underlying patterns of interaction among individual rules.

One of the fundamental concepts in complexity theory is the edge of chaos. An edge of chaos is a state that is far from equilibrium (Kauffman, 1995). It is “a natural state between order and chaos, a grand compromise between structure and surprise” (Kauffman, 1995, p. 15). It is argued that self-organization occurs and structure emerges when a system is at the edge of chaos in order to relieve adaptive tension (McKelvey, 1999). In organizational contexts, it is important to

keep an organization at the edge of chaos as this is critical for its learning and adaptation. Yet, it is difficult to do so, as this far-from-equilibrium state requires energy to maintain. Organizations easily slip from the edge of chaos into a state of too-much-order or too-much-disorder (Brown & Eisenhardt, 1998). My study suggests that one way to keep organizations at the edge of chaos is to loosely interconnect rules. When rules are connected, experiences flow from one rule to another, thereby creating rule strain. Rule strain introduces chaos into the otherwise orderly structure, thereby keeping rule systems as well as organizations at the edge of chaos. However, when rules are tightly interconnected to each other, the rule system can be trapped in chaos, because change in any rule would disturb the other rules in the system.

One contribution of my study to complexity theory is that it describes how a complex adaptive system – a rule system – evolves over time with the analysis of empirical data. Most of the current literature on CAS is either theoretical or based on computer simulation. Introducing a network angle, my study suggests that experiences flow along network ties within the rule system and thereby can produce rule strain and stimulate change in individual rules. In that view, rule networks give rise to a new form of self-organization. Because rules are embedded in networks of other rules, rule systems self-organize by shaping the streams of experiences between rules, thereby make rule change network dependent.

7.3 Practical Implications

This study bears practical implications for both healthcare sector and general management. In the healthcare sector, CPGs are important repositories of clinical knowledge that guide healthcare providers' daily work. Given the rapid development in healthcare research and change in local

organizational contexts, it is vital to keep CPGs up to date in order to assure that patients receive the most appropriate, effective and efficient care. In this framework, each CPG revision can be considered as an instance of knowledge uptake; the updated CPG version incorporates new knowledge from healthcare research or new knowledge developed in local contexts. In that sense, examining rates of CPG revision is highly relevant and meaningful, as it can help healthcare professionals better understand what factors can impede or facilitate CPG updating and knowledge uptake.

Updating CPGs requires considerable effort (“systematic reviews” can easily absorb hundreds of thousands of dollars, see Culleton, 2009; Shiffman, 2009, etc.) and they (like other rules) can grow persistent over time due to infusion of value (Selznick, 1957) or entanglement with other parts of the system (March, et al., 2000; Schulz, 2003). Guideline change is thus not easy, as guidelines might resist change efforts and grow obsolete. As a result, guideline updating can be delayed or impeded, and this can have undesirable outcomes in practice, such as delivery of inferior healthcare. How to break the inertia? My study provides a natural “solution” from a rule network perspective – connect (interdependent) CPGs with citation ties. When a guideline becomes cited by others, it is exposed to other guidelines’ contexts; this can route attention and experience to the focal guideline, reveal its problems and raise awareness of knowledge obsolescence (i.e., rule strain), thus intensifying the revisions of the focal guideline that incorporate new knowledge.

This study specifically suggests a way of managing CPGs’ ego networks in order to facilitate their role of translating research-based knowledge into clinical practice – to reduce the degree of

redundancy in CPGs' inbound networks. Redundancy causes groupthink and staleness, while nonredundancy fosters debate and learning. Reducing network redundancy can be achieved by adding new citing guidelines that are different from the ones currently in the focal guidelines' networks (e.g., in terms of clinic units of origin, disciplines, etc.). As network nonredundancy increases, CPGs' ego networks will provide more diverse impulses, which cause stronger rule strain on the focal guidelines. This can present more opportunities that trigger CPG developers to search beyond the organizational boundaries, thereby leading to guideline revisions that integrate new knowledge generated in the healthcare research.

In other types of organizations, where the implications of rule change are often ambiguous, this study helps managers to be aware that rules are often interdependent, and that the interconnections among rules, as well as their characteristics and dynamics, have deep implications for rule change. It can provide a general guidance for managers to understand and monitor rule change (and thus structural change) in organizations, and allocate limited organization resources accordingly. Managers might want to pay extra attention and send more resources to those isolated rules that likely lack enough changes and grow obsolete over time. On the other hand, they might also want to route enough resources to the parts that are elaborating fast in order to facilitate the rule change in those parts of the organization.

Rules are tools of organizational learning and important repositories of organizational knowledge. Rule change thus indicates learning of organization. Organizations can involve in exploratory and exploitative learning. It has been suggested that the balance between the two types of learning can contribute greatly to organizational performance (Gupta, Smith, & Shalley, 2006;

March, 1991). However, due to the high risk associated with exploration, many organizations are facing the problem of insufficient exploratory learning (Rosenkopf & Nerkar, 2001). My study suggests that exploratory learning (that triggers external rule revisions) might arise when rules are exposed to nonredundant contexts (e.g., cited by nonredundant rules). These rules tend to experience strong rule strain that can only be alleviated by searching and integrating nonlocal knowledge. To promote exploration, managers should allocate enough resources to such rules, which can likely become the locales of exploratory learning.

Rules are behavioral guidelines in organizations. Change in rules indicates different ways of doing things, and therefore can be viewed as innovation. Considering rule change as a form of innovation, managers can gain a unique insight from this study that innovation, as an emergent process, can arise from interdependencies of organizational rules and routines, without the initiatives of leaders or managers. From this perspective, innovation can arise from dynamic rule networks, especially when rules are connected to increasingly nonredundant others and when change events are introduced in rule networks. Managers can monitor the rule-based innovation processes and facilitate innovation by allocating necessary resources to those parts where innovation is likely to occur.

7.4 Limitations and Future Research

My study is the first one that explores the relationship between rule networks and rule change. My exploration is necessarily limited. In the following, I first discuss two limitations of my study – limited generalizability and measurement issues. This is followed by a discussion on directions for future research that can be inspired by my study.

7.4.1 Limited Generalizability

Since my study is the first that examines the effects of dynamic rule networks on individual rule revisions, the generalizability of my findings is open to further investigation in future work.

Several factors can potentially limit the generalizability of my findings, including the focus of the study on a specific type of rule network (i.e., rule citation network), a specific structure of the rule system (i.e., non-hierarchical structure) and a specific empirical context (i.e., healthcare).

I used citation ties between guidelines over time to reconstruct each guideline's ego network. Citation ties are only one type of manifestation of interdependence between rules (though probably a prevalent form of interdependence). In organizations, rule interdependence can also be reflected in other ways. For example, rules might be connected by being paired and applied simultaneously to specific situations while not directly citing each other. Does my theory of rule strain still apply? Do the findings of this study still hold if rules are interconnected by different types of ties? How can my theory accommodate multiplex ties between rules? To answer these questions, one would need to observe and analyze different types of rule interdependence (and rule networks) and compare their effects with those of citation networks.

A second factor that might limit the generalizability of my findings stems from the rule collection I used in my analysis. As discussed earlier, the CPG collection in this study does not have a hierarchical structure. Citation ties are not endorsement ties in my study, and cited guidelines do not confer legitimacy to the citing guidelines. Instead, cited guidelines serve as "subroutines" that perform "subtasks" of the citing guidelines. Hence, being cited exposes a guideline to other contexts where it makes experience that can cause rule strain and lead to its

revisions. Does this theory apply in a rule system where individual rules are interconnected across hierarchical levels? In future research, it will be worthwhile to collect data on hierarchical rule systems (perhaps in the legal arena) and investigate to what extent my theory can still apply in that context.

Lastly, my focus on a single empirical context can also contribute to the potential limited generalizability of my study. My data were collected from the CPG archives of a regional healthcare organization in Canada. To what extent can my theory be generalized to other types of organizations in other fields and other countries? I would expect that healthcare organizations in other countries display similar rule network effects. Likewise, I would expect that other rule intensive organizations (e.g., in fields such as insurance, tax, aviation, homeland security) have rule networks that affect rule change in similar ways. I hope my study will inspire future research on rule networks in different types of organizations and in different contexts.

7.4.2 Measurement Issues

My study did not rely on experiments, but rather used organizational archives as the main data source. The archives provide limited information about the underlying processes, and this sets limits for measuring theoretical concepts. For some concepts, the data facilitated accurate measurement. The citation tie dynamics and the revision histories of the guidelines were quite accurately recorded and this allowed me to measure the characteristics of rules, rule networks and their shifts over time. Other concepts, however, are unobserved and operate only on the level of theory in this study. Exposure and rule strain are the central concepts in my rule network theory, but unfortunately, I did not have the data that allowed me to measure them directly.

Future research can collect data on exposure and rule strain, and test their mediating effect between rule networks and rule change. Even though it is generally difficult to collect such data over time (and accurately reconstruct network dynamics and rule revision histories), it is conceivable that more and better data will become available as the trend towards “big data” continues. A growing number of organizations have been developing computer-based knowledge databases to store and manage organizational knowledge, which are likely to include more detailed information about organizational rules and policies and their changes, relevant decision making processes, different types of ties between rules and their change over time, the use of rules (e.g., number of clicks rules receive, especially directed from other interconnected rules), and the concomitant problems (e.g., conflicts, exceptions, blind spots) encountered by organizational members as they use the rules in different situations. With such information, it might be feasible to construct a database of dynamic rule networks with explicit measures of exposure and rule strain.

7.4.3 Inspirations for Future Research

Despite these limitations, this study has provided strong evidence that rule networks have significant impact on individual rule change. It opens a new field to explore the relationship between rule networks and rule change. As a starting point of the new research arena, this study might raise more questions than it answers. In this section, I highlight three questions that might inspire future research.

First, how do indirect networks (i.e., second-degree, third-degree networks) affect individual rule change? This study focused only on the direct networks (i.e., first-degree networks) of individual

rules. I examined the effects of individual rules' ego networks composed by rules that are directly connected with the focal rules. This boundary of ego network is set for the sake of simplicity, as this is the first attempt to explore the effects of rule networks on rule change. Given the established relationship between rule networks and rule change, one can further expand the research agenda to examine the effects of indirect rule networks. Do the rules that are indirectly connected with the focal rules also affect their change? For example, how do citing rules' inbound network size and density affect the focal rules' rate of revision? Exploring these questions might further deepen our understanding of the role that rule networks play for rule change. In that view, it might be worthwhile for future research to explore the effects of rules' indirect inbound networks, and test how shifts in these indirect networks affect revisions of the focal rule.

Second, how do different types of rule revision diffuse in rule systems? I have shown in my study that change in citing rules can trigger change in the cited rules, but I did not distinguish different types of revision of citing rules in this diffusion process. I have also shown that rules respond to different kinds of change impulses with different types of revision. So it is conceivable that the processes in which internal and external revisions diffuse in rule systems are different. Do they diffuse in the same speed? What network characteristics can facilitate internal and external revisions respectively? How and why do different types of rule revisions trigger or hinder each other? Answering these questions can deepen our understanding of how a rule system evolves through the diffusion of different types of rule revision in dynamic rule networks.

Third, how are ties between rules formed and how do they dissolve? Rule networks consist of individual rules and ties between them. Rule network evolution therefore involves change in both individual rules and ties. My study focuses on how individual rules change (as dependent variable), and I do not analyze the dynamics of ties (as dependent variable). My data cannot facilitate the analysis of tie arrival and departure because ties are relatively stable once established in the CPG archives. Future research on this topic can help us to better understand why other rules become relevant for the functioning of a focal rule, and how rule changes can shape tie formation and dissolution. Future research on the tie dynamics in rule networks can help us to gain a full picture of the dynamic and reciprocal relationship between rule networks and rule change.

7.5 Conclusion

Rules play an enormously important role in organizations and society. However, rules do not operate in isolation. Organizational rules are interdependent because they operate in a context of other rules that deals with the same or related issues. Rules often become embedded in rule networks in which interdependent rules cite each other. How does the embeddedness of rules affect their change? Prior research on the dynamics of rules has identified the importance of this question, but empirical studies on this topic are absent so far. This study represents a first effort to close this gap.

I took a network approach to explore how rule interdependence, reflected by rule networks, affects rule change. My first research question is: Do rule networks affect rule change? I argue that rules' ego networks expose them to other rules' operating contexts which can generate rule

strain and thereby trigger change in the focal rules. The results of my empirical, longitudinal and quantitative analysis are consistent with my argument. This is the first contribution of my study. It means that individual rules respond to change impulses that arise from their ego networks. Rule change is (ego-)network dependent.

My second research question is: How do characteristics of rule networks affect individual rule revisions over time? According to my model, rule networks affect rule change by shaping rules' exposure to sources of rule strain. Shifts of rule network size and density, as well as occurrence of change events in the inbound networks, should affect focal rules' revisions. I found a significant negative effect of network density and a significant positive effect of occurrence of network change events, but no systematic effect of network size. The findings suggest that when rules are exposed to nonredundant and new change impulses, their revision rates increase.

This study shows that rule change is not only path-dependent, but also network-dependent. When rules become embedded in rule networks, their change becomes embedded too. Change impulses arise from the inbound networks and are shaped by network-level mechanisms. My network dependence model of rule change is a new model and opens a new research field of rule networks and rule change. As a starting point, I hope this study will inspire more future research on dynamic rule networks and rule change.

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