TRANSFORMATIONAL SUPPLY CHAINS AND THE "WICKED PROBLEM" OF SUSTAINABILITY: ALIGNING KNOWLEDGE, INNOVATION, ENTREPRENEURSHIP, AND LEADERSHIP

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Supply chains are increasing asked by consumers, policy makers, and other stakeholders to deliver product attributes that range far beyond the experience and search attributes of classical consumer demand. One name given these attributes is credence attributes. They are challenging to deliver in that they can not be immediately examined in the product nor directly experienced in the product's use. Rather they come from some form of value about how the product is produced, processed, distributed, etc. Organic or locally-grown are both examples of credence attributes. Sustainability is an interesting emerging case. A business decision-maker's immediate inclination is to think of it as just another credence attribute. But such thinking belies the highly complex nature of sustainability. As will be argued, sustainability is an example of what is called a "wicked problem" (Rittel and Webber; Conklin)[1]. Wicked problems are characterized by several features: No definitive formulation of the problem exits; its solution is not true or false, but rather better or worse; stakeholders have radically different frames of reference concerning the problem; constraints and resources for solution change over time; and, the problem is never solved. However messy something like sustainability may be as a wicked problem, it seems highly desired by certain consumers today, and it has recently crept into product advertizing campaigns. Sustainability's lack of tractability raises the interesting question as to how anyone produces a thing that is beyond conventional notions of definition and structure.

Suppose that there are other such wicked problems lurking in the wings for supply chains and networks to respond to with products and services. How are such problems recognized? Are they in any sense manageable? How? Under what circumstances? This paper explores wicked problems and suggests how supply chains/networks might manage them. (Note use of the word "manage" rather then "solve.") A framework for managing wicked problems is developed using the concepts of knowledge, innovation, entrepreneurship, and leadership. It draws from information management theory, supply chain management, and institutional economics. Once the framework is laid out and justified, it will be applied to the wicked problem of sustainability, including several emerging empirical structures being used to manage it. This paper is a conceptual outing. It is exploratory. The problem is worth our attention given that value has

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mostly been extracted from the low hanging fruit of simply product attributes (search and experience). Future economic value is more likely to demand delivery of more and more complex attributes that will take businesses increasingly into the realm of wicked problems.

Supply Chain Performance

Supply chain performance has already been conceived as having many position dimensions (citation examples). For this purpose, presume that all such dimensions can be represented by just two. One dimension is responsiveness—the ability to deliver product or service benefits of value to targeted final consumers. The other dimension is efficiency—the ability to deliver any given set of benefits at the best possible price or cost. Together these two performance dimensions represent the fundamental elements of consumer value—perceived product benefit (marginal utility) compared to product price.

Part of responding to wicked problems is a realization that a subset of a product's targeted final consumer base may be actors who do not actually consume the product in any traditional sense. These stakeholders in the product process may include NGOs that advocate definitions of the problem and its solution, governmental bodies that may have a say in regulation, and third-party certifiers that may act as arbiters in the delivery process. Knowledge organizations (e.g. universities) may also play a role in developing information essential to product development and delivery. The key takeaway is that responsiveness and efficiency vis-a-vis wicked problems hinge on inputs from stakeholders well beyond the traditional notion of the supply chain's final consumers and the constituent firms in the supply chain.

If performance on either dimension of responsiveness or efficiency is less than desirable, the supply chain and/or its participant firms must create or alter strategies in order to improve performance. This is a rather obvious statement, but it sets up the next consideration—what is the relevant input(s) into the strategy formation process.

Knowledge as a Critical Input for Performance Improvement

The formulation of strategy has many inputs and a long history of academic inquiry. For addressing wicked problems, the role of knowledge as an input to strategy is argued to be especially critical. More generally, it seems straightforward to argue that enhancing either dimension of supply chain performance (responsiveness or efficiency) requires knowledge. As taken and adapted from the knowledge management literature (citation), several types of knowledge are relevant to the strategy process.

The definitions for knowledge and types of knowledge are taken from the classic knowledge management work by Takeuchi and Nonaka (T&N). Knowledge as used here is about beliefs and commitments; it is about action toward some end; and, it is about meaning that is context-specific and relational (T&N, p.141). Knowledge is in this sense justified true belief (not truth in some objective disembodied sense). Existing knowledge is divided into two types: (1) ***tacit knowledge*** which is context-specific and informal arising from experience and practice, and (2) ***explicit knowledge*** which is codified, rational, separable from context and thus transmittable by

formal means, e.g. information systems, manuals.

For T&N, ***new knowledge*** is created by various forms of "conversion" between tacit and explicit knowledge. Tacit knowledge becomes explicit through the process of externalization, i.e. taking what is known from practice and experience and making it formal and accessible to others. The scientific induction is a form of externalization. Tacit knowledge is converted into more tacit knowledge through the process of socialization, i.e. sharing experiences and practice with others. Apprenticeship is an excellent example of socialization. Explicit knowledge becomes tacit trough a process of internalization, i.e. taking explicit knowledge (from others) and applying it in one's own practice. Finally, explicit knowledge is converted to more explicit knowledge through combination, i.e. combining or synthesizing different bodies of explicit knowledge. Formal education is an archetype of this knowledge conversion. Scientific deduction also fits here.

T&N argue that organizations can use the two types of knowledge and the four conversion processes as the foundation for creating a spiral of organizational knowledge creation. To complete their model, a final dimension is added to the analysis called the knowledge level that moves from the individual being the knowledge holder through intra-organizational groups to the organization itself and ending with inter-organizational holders, this latter category being of particular interest in the context of supply chains. As various forms of conversion between explicit and tacit knowledge occur across the various organizational levels, new knowledge is created, shared and acted upon.

Suppose the T&N spiral can be uncoiled to examine the strategic value of the three types of knowledge being considered—explicit, tacit, and new. Strategic value equates to the economic rents earned from knowledge used to create competitive advantage (and associated enhancements of performance in responsiveness or efficiency). The resource based view of the firm posits that resources such as knowledge have value if they are scare, imperfectly mobile, and protected from imitation or neutralization by isolating mechanisms (citation, ES p. 429). If strategic value is the comparative dimension for knowledge, then the three types of knowledge form a continuum from explicit (low strategic value) through tacit (moderate strategic value) to new (high strategic value). Table 1 presents this continuum and its component dimensions.

Explicit knowledge has low strategic value because it is easy to access given it codified form and thus easy to transfer and then internalize for tacit knowledge purposes. In this sense, explicit knowledge is neither scare nor immobile. As a foundation for innovation, explicit knowledge's accessibility and transferability would help assure that all significant economic rent opportunities would be wrung out of it. However, technical innovation arising from combination might still be available but likely represent relatively simple application or transfer to new settings (i.e. some form of imitation). Explicit knowledge may have great tactical value in doing management and business tasks effectively and efficiently but it has little strategic value as a source of competitive advantage. The one caveat to this analysis arises from the existence of isolating mechanisms, e.g. patents, trade secrets, that keep accessibility low even if the knowledge is explicit. However, patents expire and trade secrets are subject to exposure (e.g. a key employee shifts employers). On the whole, the resource based theory of the firm would say that as a resource explicit knowledge has limited strategic value. It is commodity knowledge.

Tacit knowledge has moderate strategic value lying between explicit and new. It is only moderately accessible (less than perfect mobility) in that socialization requires willing partners to share in the context in which the knowledge is relevant. As a source of innovation, tacit knowledge likely has more potential than explicit knowledge to spur innovation. Adaptations and enhancements to the tacit knowledge as it is externalized into explicit knowledge or as it is shared with other holders of distinct tactic knowledge would likely provide some fertile ground for valuable if constrained innovation (likely some scarcity effect). The lack of documentation for such knowledge becomes a part of its defense against imitation. The isolating mechanism of causal ambiguity (citation) directly reflects the strategic value of tactic knowledge. Tacit knowledge is differentiated knowledge embedded in specific context, and thus it has more strategic value than explicit knowledge.

New knowledge has high strategic value. It is difficult to access in that it must be created before it can be used. No doubt it can arise from explicit and tacit knowledge but as previously argued such new knowledge would have at best moderate strategic value. Therefore, it is necessary to understand why T&N's spiral can be uncoiled. There must be another source of new knowledge beyond what can be explained by the conversion of explicit and tacit knowledge. Knowledge was defined as justified true belief. New knowledge that could fuel breakthrough or new-to-the-world innovation must come from outside the existing base of justified true belief. Paradigm shifts or other radical changes in prevailing mental models must be the source of high value new knowledge. It cannot simple come from explicit and tacit knowledge alone although they may play some part in generating the paradigm shift. New knowledge creates the opportunity for first mover advantage. New knowledge is scare, immobile (at least early in its life after discovery), and has its own isolating mechanism if properly managed as a first mover. New knowledge means the definition of a strategically valuable resource.

Two other dimensions to the knowledge continuum are also critical to understand. Knowledge was defined as actionable—it must be in a form that is applicable to taking action. The risk associated with knowledge application to action need not be alike across the continuum. Explicit knowledge has relative certainty and high predictability in its application. Tacit knowledge loses some certainty and predictability given the potentially vague nature of socialization as a conversion process or the potential to be found not generalizeable as it is externalized. New knowledge represents the greatest risk of applicability. New knowledge may even be beyond risk assessment as it may be uncertain and unpredictable until the new paradigm or other mental model shift that spawned it, is itself proven useful.

Finally, the three types of knowledge are linked dynamically. As new knowledge is created it needs to be converted into some level of tacit knowledge (through internalization) or explicit knowledge (through externalization) to be fully useable. Valuable tacit knowledge ultimately needs to be converted into explicit knowledge to make it fully accessible. The hypothesis here is that all knowledge decays with time to explicit knowledge. The strategic value of new knowledge is ultimately wrung out as it is applied and as others seek to copy it upon seeing its value in use. The rate of decay can be managed. A business that holds valuable knowledge will seek to protect the knowledge from decay (isolating mechanisms are all about doing this). A competitor business that does not hold the knowledge will seek to have that value decay quite quickly through imitation or substitute design. Academics actually want their new knowledge to

decay immediately based on journal publication (scientific externalization to explicit form). Another reason that knowledge decays to explicit is the incentive (even for its owner) to reap the great tactical value of explicit knowledge. Explicit knowledge allows for generational transfers from senior to junior employees. It allows knowledge institutions to train new employees at society's cost to support the infrastructure of the economy, and it allows operational efficiencies to emerge as the learning curve is descended. The learning curve itself is a function of the decay of new knowledge through tacit to explicit.

Again, Table 1 summarizes all the dimensions of the knowledge continuum. Now the analysis must move to further explore how knowledge gets harnessed in a supply chain setting to help respond to performance issues, most especially wicked problems.

Table 1: The Knowledge Continuum Based on Strategic Value

Dimensions	Explicit Knowledge	Tacit Knowledge	New Knowledge
Accessibility	Easy (codified; internalization; unless isolating mechanism, e.g. patent)	Moderate (socialization)	Difficult (creation precedes access)
Relevance to innovation	Low-level or *technical* innovation (application to new settings)	Moderate-level or *adaptive* innovation (adoption with enhancements in new settings)	High-level or *transformative* innovation (breakthrough or new-to-the-world)
Application Risk	Relatively certain, highly predictable	Moderately certain, predictable	Uncertain, unpredictable
Dynamics	All knowledge "decays" to explicit or becomes obsolete	Becomes explicit through externalization (theory/science)	Becomes tacit through practice or explicit through theory/science
Strategic Value	Low/limited (unless isolating mechanism) "Commodity"	Moderate (causal ambiguity) "Differentiated"	High (first mover advantage) "Unique"

Harnessing Knowledge across the Supply Chain

Presume that decision makers within a supply chain are faced with a performance problem with regard to responsiveness, efficiency or both. *The hypothesis is that a critical first assessment toward solving the problem is determining which type of knowledge (explicit, tacit, or new) will dominate in finding and implementing a solution.* If much relevant explicit knowledge exists and is applicable, then explicit knowledge is the key. If solving the problem appears to hinge on context-rich, experiential knowledge, then tacit knowledge is the key. If little or no existing knowledge appears relevant to the solution, then new knowledge becomes critical. The

assessment of what knowledge is needed is neither a trivial task nor a precise one. Some means of analyzing the underlying cause of the performance concern would be required, and then a scan of the situation and potential options for solution would suggest what knowledge is required and available. An initial assessment process would be highly likely as the assessment moves from initial stages to fully understanding and problem solving.

After the initial assessment of which knowledge is needed, the next assessment is who holds the existing knowledge or who is best positioned to create the new knowledge. This assessment is based on T&N's dimension of knowledge level (also referred to as the ontological dimension) ranging from individually held to intra-organizational group held to organizationally held to inter-organizationally (or multi-organizationally) held. Although knowledge held within a single organization may be of substantial interest in its own right, any supply chain performance problem that can be solved within the confines of a single supply chain participant is the issue of interest here. In T&N's sense, the focus is on knowledge that needs to be shared inter-organizationally in order to solve a supply chain's performance problem. This need for inter-organizational sharing of knowledge is a necessary condition to the remainder of the decision framework's development. Intuitively, if a supply chain performance problem can be traced, say to a single participant's inefficiency (unrelated to other participants' behavior) then this is not a supply chain problem at all, and supply chain governance is not a significant issue beyond some likely market based discipline to get the one participant to enhance performance. The more interesting situation is when problems involve multiple supply chain participants and their respective knowledge sets, establishing the need for sharing and some form of collective action.

The third assessment in the problem solving process has two parts: what barriers exist to knowledge sharing or co-creation across the supply chain, and what incentives are essential to overcome the barriers. Given its relatively low strategic value and easy, low risk application, the sharing of explicit knowledge held by various supply chain participants would not appear to present many barriers. If isolating mechanisms such as patents exist, contracts for use are routinely negotiated and would not per se offer a particular barrier. In general, explicit knowledge would allow typical exchange or market based rules and powerful economic incentives to govern its sharing in the problem solving process.

The sharing of tacit knowledge provides a more challenging situation. Tacit knowledge has moderate strategic value to its holder and socialization opportunities need to be created to convert it for supply chain use. The holder may behave opportunistically attempting to extract rents from other participants or fail to fully disclose the knowledge. Incentives for sharing and opportunities for socialization need to be created and enforced if the knowledge flow is to occur. A learning environment must be created to facilitate the conversion of tacit knowledge (through T&N's socialization and internalization) leading to a solution for the performance problem.

The co-creation and sharing of new knowledge becomes the most challenging situation of the three. New knowledge has high strategic value, and who creates what share of the knowledge becomes a substantial potential source of barriers to achieving the needed knowledge creation. Again, potential opportunism by individual participants would be expected. The incentives may not be clear and the uncertainty of application may muddle the entire process. Market-like exchange rules will not suffice, and socialization however strong will also likely not suffice. Yet

another regime of coordination and incentives would need to be created—one with even stronger characteristics of managed coordination.

These distinctions among the types of knowledge in regard to sharing, opportunism (e.g. rent seeking), coordination, and incentives are all the stuff of transaction cost economics, most especially Williamson's work. The supply chain's governance structure will thus have a major influence on whether the transaction costs can be minimized and the knowledge flow needed for performance enhancement occurs. The three types of knowledge suggest three types of supply chain governance—exchange governance, learning governance, and transformational governance. If the incorrect governance structure is in place, underinvestment in tacit and new knowledge would be predicted, and solving performance problems requiring tacit and new knowledge would be unlikely to occur.

Specifically, the various concepts of the paper can be brought together into a framework presented in Figure 1. The two performance dimensions of responsiveness and efficiency become the axes of the framework. Explicit, tacit and new knowledge are arrayed along the axes according to their strategic value (low to high) and thus related to the means of enhancing supply chain performance. The hypothesized three forms of supply chain governance are then presented in the areas related to their respective knowledge foundation. If a performance problem requires explicit knowledge to solve, then exchange governance should be applied. If a performance problem requires tacit knowledge, then learning governance should be applied. If a performance problem requires new knowledge, then transformational governance should be applied.

The framework of Figure 1 has little content without a clearer notion of what underlying processes lead to the effectiveness of each governance type. Table 2 presents a first cut at articulating the underlying processes for each. The knowledge foundation and incentive structure are present based on analysis already covered. The other three processes are necessary to complete the governance profile. Each governance structure would have a logically consistent means of:

1. Generating innovation consistent with its knowledge foundation;
2. Assuring entrepreneurial behavior within and across supply chain participants to commercialize generated innovation;
3. Assigning supply chain leadership that appropriately coordinates the supply chain's governance and makes it effective.

In the presence of the appropriate knowledge, incentives, innovation process, entrepreneurship and leadership, a supply chain has the necessary and sufficient conditions to solve and implement strategies for supply chain performance enhancement. Consider the comparative governance features presented in Table 2.

Figure 1: Linking Supply Chain Performance to Knowledge and Governance

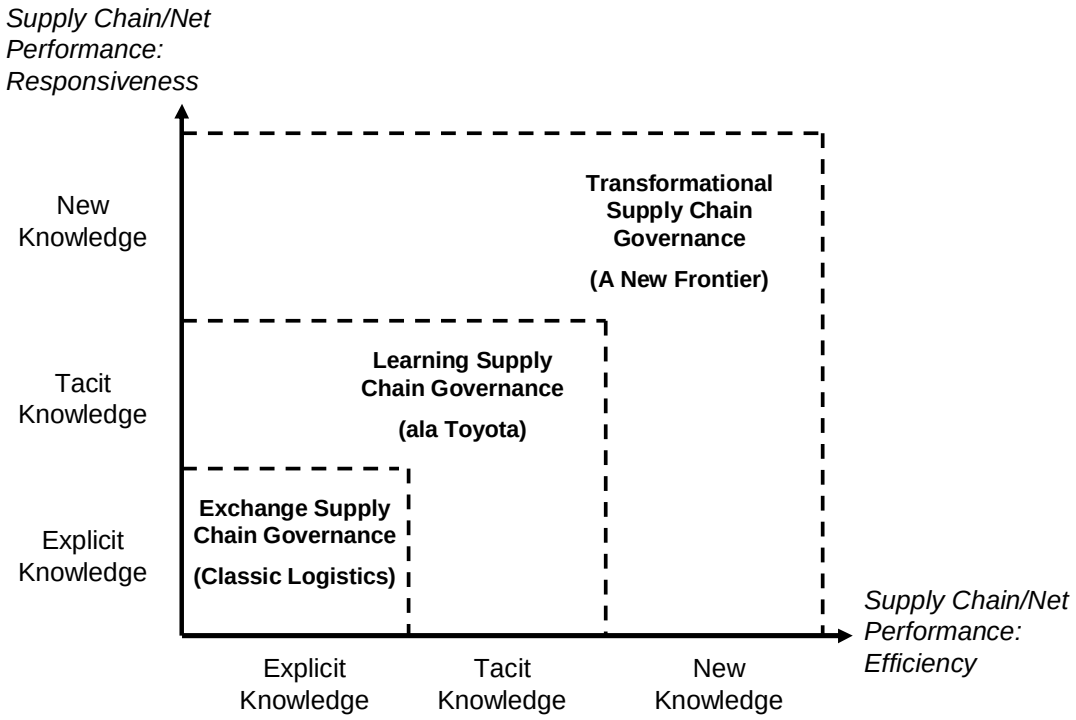

Table 2: Comparative Governance Features

Features	Exchange Supply Chain Governance	Learning Supply Chain Governance	Transformational Supply Chain Governance
Knowledge Foundation	Explicit knowledge	Tacit knowledge	New knowledge
Incentive structure for supply chain collaboration	Exchange based (Market; "buy" knowledge externally)	Relationship based (Alliance; "share" knowledge under mutual agreement)	Co-creation based (Managed; "make" knowledge internally to the collaboration)
Innovation Process	Technical processes and their linkages	Mutual discovery as tacit knowledge is shared	Mutual creation and evolution through experimental design
Entrepreneurship	Individual or intra-firm locus	Individual and collective loci; intra- and inter-firm	Collective within and beyond supply chain
Leadership	Leader-directed, e.g. Supply Chain "Captain"	Leader-facilitated, e.g. supply chain work associations ala Toyota	Shared leadership, e.g. collective engagement

Exchange supply chain governance upon closer examination is simply traditional supply chain management in the form of classic logistics. The sharing of explicit knowledge via interconnected databases and formal sets of standards are well known to any student of supply chains. The sharing converts explicit to explicit knowledge through T&N's process of combination. The incentive structure for sharing is based on exchange or market rules and is equivalent to the traditional notion of buying (rather than making), in this case the purchase is knowledge as it flows through the supply chain. The innovation process focuses on technical processes and their linkages, e.g. upgrading knowledge sharing interfaces along the supply chain. Entrepreneurship is handled by individuals within the firms with appropriate responsibility for internal implementation and coordination with similar individuals within other supply chain participants. Leadership would likely be provided by a supply chain captain or other directive leader in the strongest position to access and arbitrate the various needs for explicit knowledge.

Learning supply chain governance was a term coined and initially described by Peterson (two cites). Its tacit knowledge foundation supports relationship based sharing built on T&N's socialization and internalization processes. Incentives are governed by an alliance process that would develop rules for mutually agreed upon means of and rewards for sharing. Innovation is fueled by mutual discovery as tacit knowledge is shared among the supply chain participants. Entrepreneurship occurs on both an individual basis and a more collective basis as individuals and groups of inter-organizational membership work together to commercialize innovation. Leadership would need to shift from directive to facilitative in order to assure that incentives were properly implemented and socialization was fully participative. The alliance literature concerning supply chains would provide a broader view and description of the processes outlined here whether the literature used the "learning" modifier or not.

Toyota's supply chain governance is a particularly relevant example of what would be expected of a learning supply chain. Dyer and Nobeoka present extensive case evidence that Toyota is a high-performance knowledge-sharing network, i.e., a learning supply chain. Their case is made through a detailed examination of the various governance processes used by Toyota to establish and maintain the character of their supply chain network, most especially its focus on knowledge management. Network-level knowledge management processes include a supplier association, Toyota=s operations management consulting division, voluntary small group learning teams, and inter-firm employee transfers. These are all examples of socialization structures needed for tacit knowledge sharing. Undoubtedly strong integrated IT systems also underlie this network for explicit knowledge transfer, but they are not argued to be the key to high performance. Dyer and Nobeoka also argue that two norms play a key role in knowledge management: (1) intellectual property rights reside at the network level rather than at the firm level and thus valuable knowledge must be shared if a firm is to remain a member of the supply network, and (2) the appropriable returns norm allows the recipient of knowledge from the network to appropriate 100% of the knowledge-created benefits in the short run. In regard to the second norm, only over time must the recipient share a proportion of those benefits with the network. For example, Toyota=s consulting team shares valuable knowledge with suppliers, helps make changes, and allows the value of the benefits to remain with the supplier for some time before Toyota begins sharing them in the form of lower prices for components. These two norms establish the appropriate incentive structure for tacit knowledge sharing. Dyer and Nobeoka contrast Toyota=s practice with General Motors= more exchange oriented governance to show that GM's

alternative norms do not result in the same two-way sharing of knowledge, either in breadth or in depth, that emerges from the Toyota system.

Transformational supply chain governance is suggested as the new frontier. There may be no current examples although the paper presents a possible candidate in the next section. New knowledge is the knowledge foundation. The supply chain must thus create as well as share knowledge. Incentives must be in place to promote co-creation. These incentives will likely be specific to the situation and thus be uniquely managed. The goal is to make new knowledge internally to the collaboration of the supply chain participants. This process is not one of exchange or adaptive discovery; it is one of mutual creation, articulation and evolution. Entrepreneurship must be a collective enterprise involving all relevant participants in the chain. Leadership needs to go beyond facilitative to co-led through a wide sharing of leadership tasks. Collective engagement better captures the quality of leadership desired (Fear citation).

Because new knowledge arises largely from new paradigms or new mental models, participation in transformational governance would potentially draw in a much broader group of participants than just the supply chain members. Knowledge institutions (e.g. universities and the academy more broadly) become potentially useful. Non-governmental organizations (NGOs) that have insights into novel consumer demands or evolving social or environmental norms may become relevant as well. Governmental actors may also be needed to assure that the broader institutional setting would ultimately cooperative with and sanction new strategies that emerge. In short, transformational governance may require a fully open process (at least among relevant stakeholders) to achieve and implement new knowledge. The broader participation may also be essential to assure needed spreading of risk (given high levels of uncertainty) and buy-in by key stakeholders.

If successful, transformational governance can transform knowledge and supply chain relationships (thus the name transformational). However, the risks are high. Will new knowledge emerge? Will it be accepted by all key stakeholders? What incentives actually motivate the sharing of potential breakthrough, high-value knowledge? Who owns the new knowledge thus created? What happens if somewhere in the transformation process some current participant in the supply chain becomes clearly expendable to the new supply chain that must emerge? What if future supply chain performance hinges on an ever evolving set of knowledge, innovation and entrepreneurship because the problem being addressed is a wicked problem without solution? Would any such governance structure be stable or would its half-life be rather short? Having posited that such a governance structure is needed in a particular setting, this paper will have to leave the answers to all these questions until another time. The question suggest a robust research agenda for future work.

A framework for linking supply chain performance to knowledge and governance is now in place. The fundamental hypothesis taken from the framework is this: As the knowledge needed to enhance supply chain performance moves from explicit to tacit to new, the supply chain governance structure must move:

- From simple incentives to complex ones that motivate sharing and creating of ever more strategically value knowledge;
- From technical innovations through adaptive innovations to breakthrough innovations

- From individualized entrepreneurship to collective entrepreneurship
- From directive leadership to shared leadership

In sum, governance must move from exchange governance to learning governance to transformational governance.

The last task for this paper is laying out an empirical example that motivates the need for the framework, suggests how it could be used, and provides support that transitional supply chain governance is even possible in practice. The example is the wicked problem of sustainability.

Applications to Sustainability

- Needed Performance Improvement (the Problem)
  - Responsiveness: New consumer/stakeholder demand for sustainability
    - Inherently "values" driven, e.g. "corporate social responsibility"
    - Role of external (to supply chain/network) stakeholders makes governance even more complex
  - Efficiency: Minimize supply chain implementation cost
  - Chain/network issue: performance requires all participants in chain/network to react
- Needed Knowledge
  - "Wicked" problem in that new knowledge is needed in both performance dimensions
    - Responsiveness: *New knowledge* required given the "indefinable" nature of sustainability
      - Multiply definitions, strongly held across stakeholders and supply chain participants
      - An ideal that cannot ever knowingly or assuredly be achieved. It is like "happiness."
    - Efficiency: *New knowledge* required given no known management procedures to "produce" sustainability
      - Concern that a sustainability definition will be adopted merely because it is conducive to being technically manageable.
  - Given the need for new knowledge on both performance dimensions, the framework recommends a transformational governance structure for the supply chain/network.
    - TransForum as exemplary structure
    - Other evolving examples:
      - Brazilian sugar cane industry
      - Nestle Sustainable Agriculture Initiative
      - Michigan Sustainable Endowed Project