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The Dynamics of Coordination Regimes: Implications for Organization Design

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Abstract

This paper examines the dynamics of coordination, looking at the evolution of coordination by rules, norms or standards (which we term ?structured coordination?) and by direct interaction (mutual observation and explicit co-adaptation ad hoc which we term ?unstructured coordination?). Our model of how coordination costs change over time posits that as organizations build up competence in unstructured coordination, they also obtain knowledge of task at hand, facilitating better modes of structured coordination. We obtain several implications for organizational design, showing e.g. that (especially early) reliance on structured coordination mechanisms dynamically suppresses the build-up of coordination competence, or that total costs of coordination can be higher in a structured coordination regime, and that our choice of coordination regime is affected by the inter-temporal discount rate.

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Abstract

This paper examines the dynamics of coordination, looking at the evolution of coordination by rules, norms or standards (which we term "structured coordination") and by direct interaction (mutual observation and explicit co-adaptation ad hoc which we term "unstructured coordination"). Our model of how coordination costs change over time posits that as organizations build up competence in unstructured coordination, they also obtain knowledge of task at hand, facilitating better modes of structured coordination. We obtain several implications for organizational design, showing e.g. that (especially early) reliance on structured coordination mechanisms dynamically suppresses the build-up of coordination competence, or that total costs of coordination can be higher in a structured coordination regime, and that our choice of coordination regime is affected by the inter-temporal discount rate.

The idea that coordination – the alignment of actions among interdependent actors (Camerer & Knez, 1996; Heath & Staudenmayer, 2000) - can occur under two distinctive regimes either emphasizing ongoing communication and mutual adjustment or predefined plans and standards is a well established one. For instance, March and Simon noted that "*We may label coordination based on pre-established schedules coordination by plan, and coordination that involves transmission of new information coordination by feedback.* (March & Simon, 1958: 182)". In this paper, we use the term ***structured coordination*** to describe a regime in which the actions of the agents in a system are primarily coordinated without the need for their directly attempting to coordinate with each other- in principle without even being aware of the existence of the other agents. Coordination mechanisms such as plans (March and Simon, 1958), schedules and rules (Galbraith, 1973), norms (Schelling, 1960) and indeed prices in perfectly competitive markets (Arrow, 1974) dominate structured coordination regimes. The hallmark of a structured coordination regime is that the system itself is well coordinated even though no agent in the system faces a coordination problem. In contrast, we use the term ***unstructured coordination*** to refer to a regime in which the actions of the agents in a system are primarily coordinated through their active efforts at coordinating with each other – through mechanisms such as communication, mutual observation and reasoning about each other. The mechanisms that dominate unstructured coordination regimes have been discussed by several scholars under names such as feedback (March and Simon, 1958), integrated problem solving (von Hippel, 1998), technical dialog (Monteverde, 1995) and qualitative coordination (Langlois, 2001).

An important set of questions, that have gained prominence under several different rubrics over the last few years, considers how activities are coordinated either within the boundaries of an organization (or organizational unit), or across organizational boundaries (e.g., Baldwin, 2008). In this paper, our interest is not to align different modes of coordination with organizational boundaries, the subject of intense interest and even speculation (Eccles & White, 1989; Williamson, 1985; Kogut & Zander, 1996; Baldwin & Clark, 2000; Jacobides & Winter, 2005; Jacobides, 2006). Rather, we acknowledge that either between or within organizations (and their divisions), both modes of coordination occur, so that coordination is characterized by a different mix of each of the two mechanisms we described above, with one "regime" being the near-total reliance on structured coordination, another "regime" being the near-total reliance on unstructured coordination, and with possibilities of relying on both these mechanisms existing as well. Our interest is in capturing some of the *dynamics* that provide a stylized model on how these different modes of coordination (should) evolve over time. We consider how architectural knowledge (that enables organizations to build structured coordination mechanisms) changes over time, and how this affects the effectiveness of structured coordination; but contrast this to the reduction the cost of unstructured coordination that also happens as time proceeds.

This simple conundrum allows us to provide some general propositions, based on simple analytical priors, which may explain regularities observed in practice. We look at the implications of adopting one regime over another; and how this compares to the use of a mix between the two, starting with a stationary environment where organizations gradually improve their understanding of the world through trial and error- and the resulting learning curves. We also consider how environmental turbulence enters the picture, changing the need for and cost of coordinating, and how this re-shapes the appropriate balance between different modes of organizations, and we end our analytical exercise with indication on "results-in-progress" on the optimal mix between these distinct mechanisms, and on the relationship between the number of units that need to coordinate and modes of coordination.

These analytical findings yield implications for organizational design. Our emphasis on dynamics, for instance, makes it clear that the discount rate of the future, and the time in which the assessment is made, is a key part of deciding on what modes to rely; and that design choices should explicitly consider how far down the "learning cycle" organizations are before opining on appropriate design modes. We find that these fairly straightforward dynamic issues provide a potentially useful complement to the extant literature.

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Background and Literature Review

The distinction between structured and unstructured coordination regimes is central to understanding many facets of organization. Organizational boundaries often *divide* activities that are integrated through structured coordination mechanisms, but *enclose* activities that require unstructured coordination (Thompson, 1967; Coase, 1937; Williamson, 1976; 1985). Much of the early discussion on the "knowledge-based view of the firm", for instance, noted that firms are distinguished by different types of coordinating mechanisms (Kogut & Zander, 1996; Langlois & Robertson, 1995; Langlois, 2001), whereas sociological research emphasized the role of different mechanisms in distinguishing between different structural alternatives (Eccles & White, 1986), pointing out that we must look at empirical evidence.

In a related literature, which has had notable impact on our understanding of organizational design, it is proposed that modular technological systems allow different modules to be designed in effectively a structured coordination regime where adherence to interface specifications and common design rules enables the system wide design efforts to be coordinated (Baldwin and Clark, 2000). Going further back in the history of organizational design, we can see that organic structures and mechanistic structures typify the distinction between unstructured and structured coordination regimes (Burns and Stalker, 1961). Self organization in cognitively primitive insect and animal societies offer other instances of structured coordination regimes (Anderson and Franks, 1998), whereas primate social organization- particularly among our close cousins, chimpanzees and bonobos- leans more in the direction of an unstructured coordination regime (Boehm, 1993).[1] Traffic on the streets of London vs. New Delhi highlights the same distinction.

Structured coordination regimes appear to offer obvious advantages in terms of economizing on the coordination efforts of the agents in the system. They are also critical in ensuring that organizational members do not have to go through the organizational, political and inter-personal frictions that often arise as interdependencies need to be addressed (see Nelson & Winter, 1982, chapter 3 & 4 on "routines as truces"). Structured coordination regimes are thus not merely cognitively economizing; they enable organizational life. Yet how do such systems arise? How can they be designed?

We propose that answers to such questions are rooted in the notion of architectural knowledge. Colfer & Baldwin define architectural knowledge as "knowledge about the components of a complex system and how they are related" (2010: 2), a definition that builds on Henderson & Clark's (1990) notion of "knowledge about the ways in which the components are integrated and linked together into a coherent whole" (1990: 2). While in nature structured coordination regimes may arise through natural selection, human

[1] In structured coordination regimes in nature simple rules evolve that are quasi-genetically inscribed in the participants of the social aggregates (e,g. bee workers and queens)- so that each follows simple rules that on the aggregate support remarkably adaptive behaviour. While in organizations the rules themselves are subject to Lamarckian manipulation, as opposed to Darwinian selection, they operate in a broadly similar manner.

organization designers can build such regimes when they possess architectural knowledge. Such knowledge is unlikely for novel and poorly understood task architectures (Adler, 1995; Baldwin & Clark, 2000; von Hippel, 1990), but accumulates with experience in the system. In particular, the gains in experience appear to arise from working in an *unstructured* coordination regime. For instance, experienced system architects instinctively know from prior failures as much as successes how to partition a system and what design rules to use in order to enable product development in a structured coordination regime (von Hippel, 1990); and parties in a bilateral relationship may increase the formalization and codification of the contractual terms of their exchange over time as they learn more about the nature of their interdependencies through their interactions (Argyres & Mayer, 2007; Puranam & Vanneste, 2009; Vanneste & Puranam, 2010).

The focus of our analysis in this paper is this paradoxical property of architectural knowledge- **it is necessary to design a structured coordination regime, but is more likely to arise in an unstructured coordination regime.** Through a simple but very general formalization, we explore the dynamics of how architectural knowledge is created and used. We find that this negative feedback property of the reliance on structured coordination mechanisms undermines several of our conventional intuitions and shows them to be special cases. For instance, coordination competence is lower in a structured coordination regime, and early adoption of highly structured coordination mechanisms increases the extent of unstructured coordination in the system. Further, the total costs of coordination in the system can be higher in a structured coordination regime relative to an unstructured regime. Environmental turbulence (ie, shocks that render the existing solutions to the coordination issue obsolete) always increases the *amount* of total unstructured coordination needed, but, depending on the rate of improvement in the coordination capability, might *reduce* the total coordination costs incurred.

Model

Our model, in its basic form, represents an organization with two organizational sub-units. We will later relax this assumption to consider how the increase in organizational sub-units *changes* the nature of our results. In all cases, we assume that the activities in the units must be coordinated in order to optimize organizational performance. The (initially two) sub-units may be related vertically or horizontally. For instance, these may be design and manufacturing units, or two product development groups working on sub-systems within a complex system, or even two different organizations that are trying to coordinate and need to select between structured and unstructured modes of coordination. In the spirit of team theory (Marshack & Radner, 1972), and of several contemporary models of organization design (Bolton & Dewatripont, 1994), we abstract from imperfect contracting issues, looking instead at the effectiveness of different coordination modes on total value creation (or, strictly put, costs visited to the system).

Coordination, needed for the production task at hand, may be achieved through a) *Structured coordination*- through the design of appropriate interfaces, standards and rules by an organization designer, or b) *Unstructured coordination*- it may be left to the devices of the agents in the sub-units to coordinate their actions with each other through communication and information processing activities. We assume that architectural knowledge about the nature of interdependence between sub-systems is essential for enabling structured coordination between the units. Designers will of course differ in their architectural knowledge (Baldwin and Clark, 2000; Henderson & Clark, 1990; von Hippel, 1990). Often the nature of interactions between sub-systems and indeed of the location of boundaries between sub-systems may be unknown to an organization designer. Yet over time, as the personnel in the two units interact, architectural knowledge may build up as they begin to understand the true nature of interdependence between activities in the two units.

The hallmark of unstructured coordination is that it is effective even when architectural knowledge is imperfect or non-existent. Thus, the individuals in the two sub-units of our organization may be able to coordinate their activities through a process of joint discovery - trial-and-error learning - even in the absence of detailed knowledge about how their actions are interdependent. This joint discovery process of collective trial-and-error learning (Lounamaa & March, 1987), with or without communication, is what we refer to as unstructured coordination.

While unstructured coordination can take place even in the absence of architectural knowledge, it is also a basis for building architectural knowledge. Indeed such knowledge is more likely to be gathered through unstructured coordination efforts than through highly structured information exchange; understanding the full ramifications of changes in one sub-system to another subsystem is more likely if communication between them is not constrained by predefined topics and channels of information (Argyres & Mayer, 2007; Jacobides & Winter, 2005). We therefore assume that architectural knowledge is an increasing function of cumulative experience at unstructured coordination V_t.

While architectural knowledge about the nature of interdependence is being accumulated through unstructured coordination, over time the organization also becomes more adept at unstructured coordination itself. Repeated interactions give rise to trust, interpersonal routines, and common language, which together enhance the efficacy of mutual adjustment between them (Puranam & Vanneste, 2009); and the very task of coordinating exhibits economies of learning and duplication as "routines on how to coordinate" develop (Vanneste & Puranam, 2010). Therefore, over time, an organization's competence at unstructured coordination improves. Consistent with standard learning curve formulations (Argote & Epple, 1990), we therefore assume that there is a reduction in c_t (ie, the costs of unstructured coordination per unit) as a function of cumulative experience at unstructured coordination V_t.

Finally, we assume that the extent of unstructured coordination U_t necessary to manage inter-unit interdependence at any point of time decreases with architectural knowledge. As the individuals in the two sub-units build architectural knowledge and gain a better understanding of how their actions are interdependent, they are able to rely to a greater extent on structured coordination- interfaces, standards, rules and procedures, instead of relying on unstructured coordination. As an empirical example of this process, consider the case of mortgage banking, discussed by Jacobides (2005), whereby units over time both developed architectural knowledge on the nature of the loan making process, shifting from unstructured to structured coordination (first, within organizational boundaries, and then, across organizational boundaries). As time passed and architectural knowledge grew, the need for unstructured coordination decreased, and so did the communication and coordination through this mechanism.

We therefore assume that the extent of unstructured coordination required between the units to manage interdependence reduces as a function of architectural knowledge. Further, we allow for a distinction between the existence of architectural knowledge and its utilization to create structured coordination mechanisms (e.g. through the specification and use of interfaces, the creation of rules, etc.) The parameter $\phi \in (0,1)$ captures the degree of reliance on structured coordination mechanisms for a given level of architectural knowledge. (Low) High values of ϕ represent a (un) structured coordination regime. We will first consider how different choices in terms of organizational design in setting the ϕ affect coordination costs, under varying deterministic and then stochastic conditions; and we will later consider the endogenous (optimal) setting of ϕ as a choice variable that the organization can be allowed to vary over time.

Using very general functional forms, the relevant functions can be written as:

$$c_t = g(V_t(\phi)) > 0 \qquad (1)$$

$$U_t = h(\phi.V_t(\phi)) > 0 \qquad (2)$$

To complete the specification of our model, we also state two identities. The first equation simply specifies the accumulation function for unstructured coordination experience

$$V_t = \int_{t0}^{t} U_t dt \qquad (3)$$

The second states that the total coordination costs C_t are equal to the volume of unstructured coordination multiplied by the cost per unit of unstructured coordination.

$$C_t = U_t.c_t \qquad (4)$$

The total cost of coordination C_t is the key dependent variable in our analysis, and can be seen as the obverse of organizational efficiency.

From these basic and quite general functional forms, we obtain propositions, proved in the Appendix.

Proposition 1: *The total costs of coordination strictly decrease over time in both structured and unstructured coordination regimes.*

The intuition is straightforward: in unstructured coordination regimes, the effect arises primarily because of improved coordination competence (lower c_t) whereas in structured coordination regimes, the effect arises from a combination of improved coordination competence as well as a reduction in the need for unstructured coordination.

Proposition 2: *Coordination competence is lower in a structured coordination regime.*

In structured coordination regimes, the reduction in the need for unstructured coordination in any period also means that the cumulative experience at unstructured coordination is lower in such a regime relative to an unstructured coordination regime. Therefore, the unit costs of coordination are lower in an unstructured coordination regime.

Proposition 3: *Early adoption of highly structured coordination mechanisms increases the extent of unstructured coordination in the system.*

The extent of unstructured coordination decreases with both the reliance on structured coordination mechanisms as well as the architectural knowledge accumulated with experience of unstructured coordination (2). However, because reliance on structured coordination mechanisms will reduce the accumulated architectural knowledge at any point, the net effect of increasing reliance on such mechanisms on the extent of unstructured coordination may be positive. Specifically, if there is very little history of unstructured coordination and structured coordination mechanisms strongly suppress the accumulation of architectural knowledge, then increasing reliance on structured coordination mechanisms may actually increase the extent of unstructured coordination in the system.

Proposition 4: *Total costs of coordination in the system will be higher in a structured coordination regime relative to an unstructured regime if the "suppression of coordination competence" effect dominates the "economizing in unstructured coordination" effect.*

This proposition captures the balance of three key forces in this simple model. As the reliance on more structured coordination mechanisms increases a) this will reduce coordination competence (increase unit costs of coordination-Proposition 2) b) will suppress the accumulation of architectural knowledge and c) will directly reduce the extent of unstructured coordination for a given level of architectural knowledge. The third effect is time invariant, and always reduces total coordination costs. Therefore the net effect of increasing reliance on structured coordination mechanisms at any point in time depends on the balance of the first two effects.

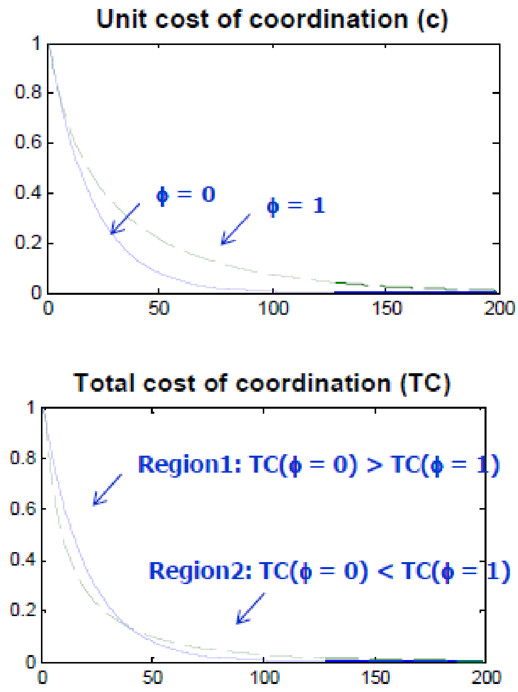
Implications and Interpretation

To aid our intuition we illustrate results graphically for some specific functional forms that satisfy equations (1-4). We assume architectural knowledge at any point in time is given by $A_t = 1 - e^{-\theta Vt}$ (5). The unit cost of coordination at any point in time is given by $c_t = e^{-\alpha Vt}$ (6). Finally the extent of unstructured coordination at any point in time is given by $U_t = e^{-\phi At}$ (7).

We rely on exponential forms for all three equations to maintain comparability. Unless specified all variables and parameters have the same interpretations as in the general functional forms. The parameters in these functions affect the second derivatives in meaningful ways. In particular parameters θ and α have meaningful interpretations as "investments in building architectural knowledge and coordination competence", respectively. Increasing these parameters increases the rate at which unstructured coordination experience is converted into architectural knowledge and coordination competence respectively. These functional forms allow us to not only illustrate, but also qualify / extend the broad propositions we proved above. In particular, we observe the following:

1. *Reliance on structured coordination mechanisms dynamically suppresses the build-up of coordination competence. The merit of a structured coordination regime depends on the discount rate of the future*

The figures below show the *unit* cost of coordination (the figure above) and the *total* cost of coordination (in the figure below), over time (which depicted in the x-axis).



As we can see in the top panel, in the case of unstructured coordination mechanisms (φ=0, solid line), the unit cost of coordination declines more quickly over time as agents engage in more coordination, making coordinating more effective through learning (as proved in P1 & P2). However, to consider the *total* cost of coordination (shown in the bottom panel), we have to multiply this by the coordination required, which is higher in the unstructured coordination regime. As a result, the total cost in a structured coordination regime (φ=1, dotted line) is *lower* in the early parts of the period (see Region 1), and *higher* further out in the future, as the benefits of learning to coordinate are foregone, and the "cost of rigidity" of structured mechanisms becomes important.

An important corollary to this result is that our choice of the appropriate mechanism (structured vs unstructured) can trivially be shown to depend on our discounting rate of the future, since the unstructured regime has greater upfront benefits, but loses out on the learning upside, even in a stationary environment such as the one we consider here. The question "which design should I adopt?" cannot be answered without a sense of how much future benefits are weighed against current shortcomings.

2. *Environmental turbulence may either increase or decrease total coordination costs, depending on the efficiency of building unstructured coordination capability over time*

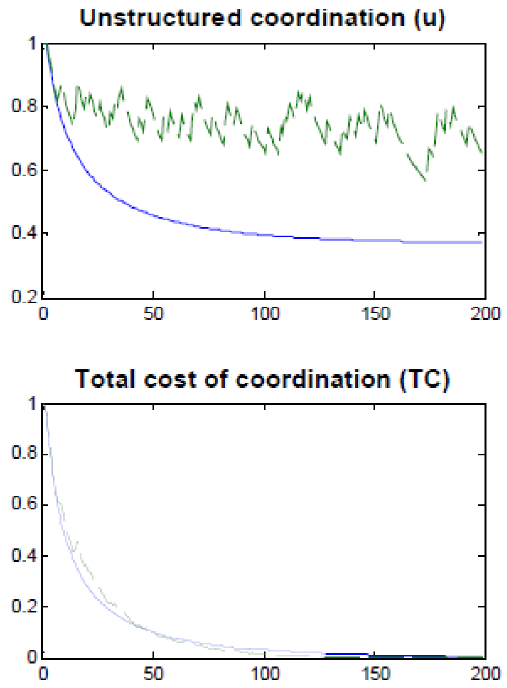
The previous result also showed us that *a structured coordination regime may have higher total coordination costs,* even disregarding any costs for setting up the structured coordination, in a stationary environment. Yet things become more interesting once we introduce environmental turbulence. Changes in the environment change the underlying patterns of interdependencies, and this, in turn, renders architectural knowledge ineffective; as the world changes, the rules, procedures and the assumptions that underlie them become less effective, and there is a great need for *ad hoc* solutions to problems that the existing division of labour and existing sets of rules are unable to deal with appropriately. This leads to an increase in unstructured coordination- a familiar pattern in organizations finding themselves needing to re-think or circumnavigate their processes by ad hoc interaction. But just *how* do such disturbances alter the merits of different coordination mechanisms?

Our analysis suggests that what happens to the total cost of coordination depends on the balance between two forces: The increase in the *extent* of unstructured coordination on the one hand (as a result of the changes in the environment); and the reduction in the per unit coordination costs which happens as a result of getting greater cumulative experience with unstructured coordination. When the second effect is strong, then shocks that destroy architectural knowledge may actually improve the performance of the system in terms of total coordination costs, when compared to a stationary baseline, beyond the first few periods!

To illustrate this, we present results which include a loss of architectural knowledge (in equation 5) ranging from 10% to 30% drawn from a uniform distribution, so that at each period, a firm finds itself with a mean of 20% loss in terms of its understanding of the environment. We then compare this with the "base-case" of the same setup with no architectural loss (ie, the stationary environment we considered previously). We do so by considering two illustrative cases: One with low, and one with high rates of coordination competence formation, which turns out to be an important variable. We have provided results with intermediate levels of ϕ, as this does not critically affect our analysis.

The top panel in the figure below shows the evolution of unstructured coordination U needed over time with disturbances (green line) and without (blue line), given a *low* rate of coordination competence formation. The bottom panel, “total costs of coordination” presents the total costs of coordination TC which occur for the case without disturbances (solid line, corresponding to the blue line above) and with disturbances (dotted line, corresponding to the green line above).

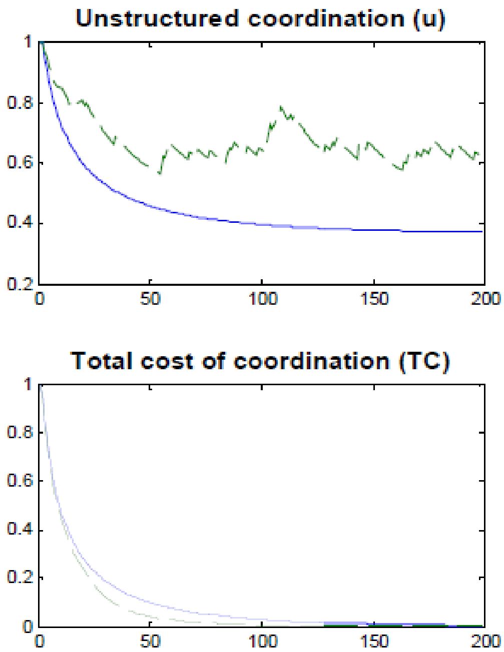
Coordination Needs and Costs with Low Rate of Competence Formation



As we can see, with low rate of competence formation, we see that disturbances lead to a substantially higher need for unstructured coordination, and also to a higher total cost of coordination.

The next set of panels provides us with the exact same information on the extent of coordination needed, and its total costs, under high rates of competence formation.

Coordination Needs and Costs with Low Rate of Competence Formation



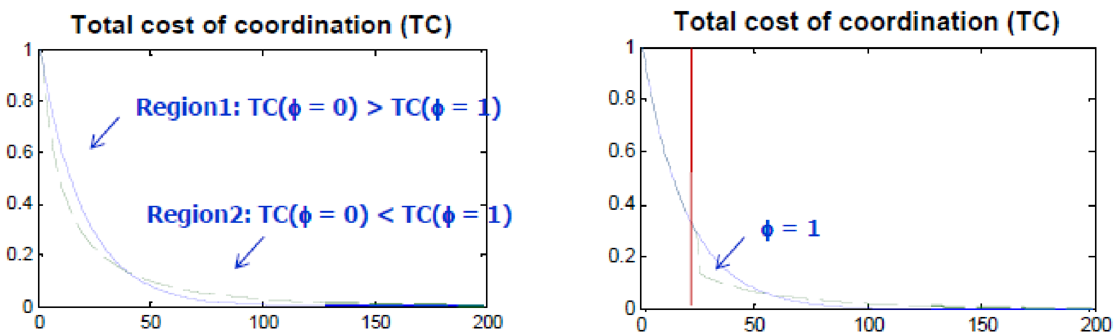
As we can see, whereas in this case there still is a higher need of unstructured coordination, the total costs of coordination are *lower,* as the disturbances have a substantial beneficial impact on the efficiency to the response to environmental perturbation (through competence building), which more than offsets the "nuisance" of the environment being turbulent. So, our basic mechanisms suffice to show how environmental turbulence, under given capability formation conditions, can dynamically improve organizational efficiency. Interestingly, these results are shown to hold over all values $\varphi < 1$.

In the same spirit, it is trivial to demonstrate that if shocks occur more infrequently, then it generally pays off to have *mild disturbances* that reduce the value of architectural knowledge, as organizations will build the capability to engage in unstructured coordination. This ability will come in handy when the environment changes abruptly, so that the small direct cost outlay for adapting to the needs of a changing environment through unstructured coordination will be more than compensated by the ability to engage in unstructured coordination. This is consistent with the view that organizations would benefit by engaging from some permutation in environments with sudden and unpredictable shifts (March, Sproull & Tamuz, 1991), and our stylized model suggests that the extent to which organizations can build coordination competencies from experience is a critical mediating variable.

3. Timing a transition to a structured coordination regime, and additional analyses.

In our analysis so far, we have considered the comparison between different regimes (in the sense of the overall reliance on structured vs. unstructured coordination mechanisms), and have implicitly assumed that these choices, represented by φ are stable in time. Yet this is but an initial simplifying assumption. In the extended paper we expect to present in DRUID, several additional related analyses (in the process of being run) will be presented. Specifically, we consider the issues of the inter-temporal choice of φ. We start with the base-line of an optimal choice of φ under full information conditions. We show how optimal φ* changes over time, as the forces of increasing efficiency of unstructured communication and increasing architectural knowledge (and ability to specify the right interfaces) juxtapose. We then consider how environmental turbulence, whose mean is known ex ante, affects this optimal choice.

For the purposes of this paper, let us provide a basic result that hints to the intuition of inter-temporal choices, by illustrating the effects of delaying the introduction of the "structured coordination regime". In the figure below, we first replicate, in the LHS, the panel which shows the total costs of coordination (TC) for both regimes (φ=0 and φ=1). Next to this panel, on the RHS, we provide a panel where we delay the introduction of structure for 20 periods (till after some architectural knowledge has been built).



As we can see, the delay in the RHS confers substantial total coordination advances. The intuition is straightforward: Time allows both for the creation of a better sense of the interdependencies and links that allow us to specify more appropriate interfaces and rules, and helps in terms of reducing the per unit cost of coordination in the future. Or, otherwise put, an early specification of structured coordination still leaves many issues to be "ironed out" by the organization, even as it suppresses the need for coordination in the short term. Our intention is to present the results we are working on now, in terms of the optimal timing and φ^*, under perfect or imperfect information conditions, and how that relates to uncertainty at greater length in the conference.

Discussion and Conclusions

Our goal in this paper was not to provide a comprehensive model of organizational coordination mechanism evolution. Rather, we considered how some very simple analytical primitives create an interesting composite picture, which is both consistent with stylized facts, and yields some counter-intuitive results. First, we provided a stylized rendition of coordination costs (which are the dependent variable in our analysis, and can be seen as the obverse of organizational efficiency), looking at their evolution over time. We found that reliance on structured coordination mechanisms dynamically suppresses the build-up of coordination competence, and that the merit of a structured coordination regime depends on the discount rate of the future- a very important consideration for prescription. We also saw that the delay of structured coordination is beneficial, and have provided a platform for considering the appropriate timing of "regime change" in terms of formalization.

Second, we considered how environmental perturbations that change the appropriateness of existing structures and rules, by rendering them inefficient or obsolete, alters our results. We found that environmental turbulence may either increase or decrease total coordination costs, depending on the efficiency of building unstructured coordination capability over time. We considered the dynamic implications of such turbulence, as it relates to the ability of organizations to cope with their environment, and looked at the cost implications (as well as the timing choices) organizations face as they consider whether they should coordinate through structured or unstructured means.

Whether we consider structured coordination in the context of an organization (e.g., via the creation of autonomous sub-units linked through fairly rigid interfaces and modular design, with few demands for explicit *ad hoc* coordination), or in the context of inter-organizational relations (e.g., via the institution of high autonomy, "black-boxing" and limited reliance in collaborative but ad hoc means of addressing coordination challenges), our analysis provides a starting benchmark to consider the potential merits of structure. It also helps shed some light to its shortcomings, and in particular the *dynamic* shortcomings associated with foregone opportunities to learn or simply reduce the cost of future *ad hoc* unstructured coordination, a set of trade-offs which tend to be neglected in the literature on organization design.

What clearly emerges from our analysis, then, is that any pronouncement in terms of organizational design must be made in terms of its *position in the life cycle,* and that *comparing rates of improvement or learning* that exist in our organizational design are a critical and generally neglected aspect. Thus, our analysis parts with much contemporary organizational design which is rather a-historical, looking at the static interactions between the elements. We would argue that while much useful progress has already been made in this regard (see Balwdin & Clark, 2000), the attention to coordination *dynamics* may be called for.

Of course, as in any model, we only offer a stylized rendition, and shed light to the dynamics we are interested in, leaving other matters outside the scope of our analysis. Some, such as the potential setup costs for engaging in structured coordination, have been left out as their implications are fairly straightforward. Others are directions we are pursuing, and will hopefully report by the conference. Yet more are additional analyses which we have not undertaken here, to preserve focus. For instance, a straightforward extension to our model consists of explicitly looking at the role of the number of units that need to coordinate. The basic intuition is simple; unstructured coordination between units grows by an increasing function of size (if we assume all pair-wise combinations of n, by $n!$), and as such structured coordination is preferred as size grows. What is interesting is how this is compensated not only by the increase in capability of unstructured coordination, but also by environmental uncertainty. Our dynamic graphs can consider such interactions in setting an optimal φ. Another important extension, which requires more elaboration, is the identification of heuristic rules for setting φ, since an optimal φ requires fairly heroic assumptions about the knowledge of the environment. We would consider, though, that such agent- or rule-based modelling would best be left for subsequent research.

Limitations and extensions notwithstanding, we hope that this simple model encapsulates some interesting fragments of reality on how structured and unstructured mechanisms of coordination evolve, and how we should choose between them. Thus, we hope that this research complements the existing literature by providing a simple rendition of the underlying dynamic processes, deterministic and stochastic alike.

REFERENCES

Adler, P. S. 1995. Interdepartmental Interdependence and Coordination: The Case of the Design/Manufacturing Interface. ***Organization Science***, 6(2): 147-167.

Arrow, K.J. 1974. ***The Limits of Organization.*** New York: WW Norton & Company.

Argote, L & D Epple. 1990. Learning Curves in Manufacturing, ***Science,*** 247 (4945): 920-924

Argyres, N. & K. Mayer. 2007. Contract Design as a Firm Capability: An Integration of Learning and Transaction Cost Perspectives. *Academy of Management Review* **32** 1060-1077.

Aumann, R. & Brandenburger, A. 1995. Epistemic Conditions for Nash Equilibrium. ***Econometrica,*** 63(5): 1161-80

Baldwin, C. Y., & Clark, K. B. 2000. ***Design Rules***. Cambridge, MA: The MIT Press.

Bolton P. & M. Dewatripont 1994, The Firm as a Communication Network. ***Quarterly Journal of Economics*** 109: 809-839

Burns, T., & Stalker, G. M. 1961. ***The Management of Innovation***. London: Tavistock.

Burton, R. M., & Obel, B. 1998. with contributions by S.D. Hunter III., M. Sondergaard, and D. Dojbak. ***Strategic Organizational Diagnosis and Design: Developing Theory for Application*** (2nd ed.). Boston/Dordrecht/London: Kluwer Academic Publishers.

Burton, R. M., & Obel, B. 1984. ***Designing Efficient Organizations: Modelling and Experimentation***. Amsterdam: North-Holland.

Camerer, C. 2003. ***Behavioural Game Theory: Experiments in Strategic Interaction***. Princeton: Princeton University Press.

Camerer, C. & Knez, M. 1996. Coordination, Organizational Boundaries and Fads in Business Practices. ***Industrial and Corporate Change,*** 5(1): 89-112.

Colfer, L. & Baldwin, C.Y. 2010. ***The Mirroring Hypothesis: Theory, Evidence and Exceptions***. Working Paper No. 10-058, Harvard Business School, Cambridge, MA.

Eccles, R.G. & H.C. White. 1986. Firm and Market Interfaces of Profit Center Control. In: S. Lindenberg, J.S. Coleman & S. Nowak, eds., ***Approaches to Social Theory***. New York: Russell Sage, pp. 203-220.

Galbraith, J. R. 1977. ***Organizational Design***. Reading, MA: Addison-Wesley.

Galbraith, J. R. 1973. ***Designing Complex Organizations***. Reading, MA: Addison-Wesley.

Heath, C., & Staudenmayer, N. 2000. Coordination Neglect: How Lay theories of organizing complicate coordination in organizations. ***Research in Organizational Behavior,***, 22:

153-191.

Henderson, R. M., & Clark, K. B. 1990. Architectural innovation: The reconfiguration of existing product technologies and the failure of established firms. ***Administrative Science Quarterly,***, 35(9-30.).

Jacobides, M.G. 2005. Industry change through vertical disintegration: How and why markets emerged in mortgage banking. ***Academy of Management Journal***. 48 (3) 465-98.

Jacobides, M. G. 2006. The architecture and design of organizational capabilities. ***Industrial & Corporate Change*** 15(1): 151–169

Jacobides, M.G. & S.G. Winter. 2005. The co-evolution of capabilities and transaction costs: Explaining the institutional structure of production. *S**trategic Management Journal***. 26(5): 395-413.

Langlois, R. N. 2001. Modularity in Technology and Organization. ***Journal of Economic Behavior and Organization.***

Langlois, R.N. & P.L. Robertson, 1995. ***Firms, Markets, and Economic Change: A Dynamic Theory of Business Institutions***. London: Routledge

Kogut, B. & U. Zander, 1996. What Firms Do? Coordination, Identity, and Learning, ***Organization Science***. 7 (5): 502-518

Lawrence, P. R., & Lorsch, J. W. 1967. ***Organization and Environment: Managing Differentiation and Integration***. Boston, MA: Harvard Graduate School of Business Administration.

Lounamaa P.H. & J.G. March, 1987.Adaptive coordination of a learning team, ***Management Science*** 33: 107–122

March, J. G., & Simon, H. A. 1958. ***Organizations***. Cambridge, MA: Wiley.

March, J. G., L. S. Sproull & M. Tamuz. 1991. Learning from events of one or fewer. ***Organization Science*** 2(1) 1–13.

Mayer K & Argyres N.S. 2004 Learning to Contract: Evidence from the Personal Computer Industry. ***Organization Science*** 15(4): 394-410

Milgrom, P. & J. Roberts 1990. The economics of modern manufacturing: Technology, strategy, and organization." ***American Economic Review*** 80(3): 511-28.

Mintzberg, H. 1979. ***The Structuring of Organizations***. Englewood Cliffs, NJ: Prentice Hall.

Monteverde, K. 1995. Technical dialog as an incentive for vertical integration in the semiconductor industry. M***anagement Science***, 41(10): 1624-1638.

Nadler, D. A., & Tushman, M. L. 1997. ***Competing by Design: The Power of Organizational Structure***. Oxford, UK: Oxford University Press.

Nelson, R.R. & Winter, S.G. 1982. ***An Evolutionary Theory of Economic Change***. Cambridge, MA: Belknapp Press.

Puranam, P & B Vanneste. 2009. Trust and governance: Untangling a tangled web. ***Academy of Management Review***, 34(1): 11–31

Schelling, T. 1960. ***The Strategy of Conflict***. Cambridge, MA: Harvard University Press.

Simon, H. A. 1945. ***Administrative Behavior***. New York: Macmillan Press.

Simon, H. A. 1981. ***The Sciences of the Artificial*** (2nd ed.), Cambridge, MA: MIT Press.

Thompson, J. D. 1967. ***Organizations in Action***. New York: McGraw-Hill.

Tushman, M. L., & Nadler, D. A. 1978. Information Processing as an Integrating Concept in Organizational Design. ***Academy of Management Review***, 3(3): 613-624.

Vanneste, B. & P. Puranam, 2010. Repeated interactions and contractual detail: Identifying the learning effect. ***Organization Science***. 21(1): 186-201

Van de Ven, A., Delbeq, A., & Koenig Jr., R. 1976. Determinants of Coordination Modes within Organizations. ***American Sociological Review***, 41(2): 322-338.

Von Hippel, E. 1990. Task Partitioning: An Innovation Process Variable. ***Research Policy***, 19: 407-418.

Von Hippel, E. 1998. Economics of product development by users: The impact of `sticky' local information. ***Management Science***, 44(5): 629.

Williamson, O. E. 1975. ***Markets and hierarchies: Analysis and antitrust implications.*** New York: Free Press.

Appendix: Proofs of Propositions

Proof of Proposition 1:

$$\frac{\partial C_t}{\partial t} = c_t . \frac{\partial U_t}{\partial t} + U_t \frac{\partial c_t}{\partial t}$$

$U_t > 0, c_t > 0$ (1,2)

$U_t > 0 \Rightarrow V_{t+1} > V_t \Rightarrow c_{t+1} < c_t \Rightarrow \frac{\partial c_t}{\partial t} < 0$ (3,1)

Case I: $\phi = 0 \Rightarrow \frac{\partial U_t}{\partial t} = 0$.

$\therefore \frac{\partial C_t}{\partial t} < 0$

Case II: $1 \geq \phi > 0 \Rightarrow \frac{\partial U_t}{\partial t} \neq 0$

$$\frac{\partial U_t}{\partial t} = \phi . \frac{\partial V_t(\phi)}{\partial t} . \frac{\partial U_t}{\partial(\phi . V_t(\phi))} < 0$$

$\therefore \frac{\partial C_t}{\partial t} < 0$

Proof of Proposition 2:

$$\frac{\partial c_t}{\partial \phi} = \frac{\partial g}{\partial V_t} \frac{\partial V_t}{\partial \phi} > 0 \quad (3)$$

Proof of Proposition 3:

If $1 \geq \phi > 0$

$$\frac{\partial U_t}{\partial \phi} = [V_t(\phi) + \phi . \frac{\partial V_t}{\partial \phi}] . \frac{\partial U_t}{\partial(\phi . V_t(\phi))}$$

If $| V_t(\phi) | < | \phi . \frac{\partial V_t}{\partial \phi} |$ then $\frac{\partial U_t}{\partial \phi} > 0$

Proof of Proposition 4:

$$\frac{\partial C_t}{\partial \phi} = c_t . \frac{\partial U_t}{\partial \phi} + U_t \frac{\partial c_t}{\partial \phi}$$

$U_t > 0, c_t > 0$ (1,2), and $\frac{\partial c_t}{\partial \phi} > 0$ (Proposition 3)

$$\frac{\partial U_t}{\partial \phi} = [V_t(\phi) + \phi.\frac{\partial V_t}{\partial \phi}].\frac{\partial U_t}{\partial (\phi.V_t(\phi))}$$

If $|V_t(\phi)| > |\phi.\frac{\partial V_t}{\partial \phi}|$ then $\frac{\partial U_t}{\partial \phi} < 0$

Then $\frac{\partial C_t}{\partial \phi} < 0$ if $|c_t.\frac{\partial U_t}{\partial \phi}| > U_t \frac{\partial c_t}{\partial \phi}$, else $\frac{\partial C_t}{\partial \phi} > 0$