Coordinating Changes in M-form and U-form Organizations

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Abstract

We introduce a method of modelling coordination inside an organization as a process of "attribute matching." Using this method, we compare organizational forms (U-form and M-form) in coordinating changes. In our model, organizational forms affect the information structure of an organization and thus the way to coordinate changes. Compared to the U-form, the M-form organization achieves better coordination but suffers from higher costs due to a lack of scale economies or a lack of what we call "attribute compatibility." The M-form has a distinctive advantage in carrying out experimentation which gives the organization more flexibility leading to more innovation and reform. We apply our theory to business firms, transition economies, and the organization of government (especially federalism). In the case of transition economies, our theory relates the initial conditions of organizational differences with reform strategies, especially the "big-bang" approach in Eastern Europe and the "experimental" approach in China.

Keywords: organization, M-form and U-form, innovation, transition, organization of government, experimentation

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Non-Technical Summary

We introduce a method of modeling coordination inside an organization as a process of "attribute matching." Using this method, we compare organizational forms (U-form and M-form) in coordinating changes. In our model, organizational forms affect the information structure of an organization and thus the way to coordinate changes. Compared to the U-form, the M-form organization achieves better coordination but suffers from higher costs due to a lack of scale economies or a lack of what we call "attribute compatibility." The M-form has a distinctive advantage in carrying out experimentation which gives the organization more flexibility leading to more innovation and reform. We apply our theory to business firms, transition economies, and the organization of government (especially federalism). In the case of transition economies, our theory relates the initial conditions of organizational differences with reform strategies, especially the "big-bang" approach in Eastern Europe and the "experimental" approach in China.

I. Introduction

Understanding how economic activity is coordinated inside organizations has always been one of the most fascinating questions in economics. Introducing changes in an organization, such as innovations in a corporation and reforms in a centrally planned economy or any country, involves sophisticated coordination in order to succeed. Inspired by Milgrom and Roberts' concept of "design attributes" (1992), we introduce a method of modelling coordination inside an organization with the concept of "attribute matching." With this method, we analyze how differences in organizational forms affect coordination and the ability to make changes inside an organization.

An implementation of change can be viewed as assembling complementary parts, such as the assembling of subroutines for a software package; synchronizing travel plans and accommodating logistics for a conference; structuring enterprise restructuring and social safety-net programs for reform, etc. Each complementary part is characterized by its attributes: time, location, technical specifications (such as size, weight, and bits), legal and administrative terms, etc. A product or a service is completed successfully only if the characteristics of each attribute of the various parts are matched. To take a simple example, the diameter of a screw must match that of a bolt so that they both meet certain standards of material resistance. They must be transported to a given location at a given time. Most products and services require a much more sophisticated assembling of parts, each part having numerous attributes which are relevant in this matching process. Failure in the matching of attributes often implies a breakdown. For example, the engine of a Rolls Royce car cannot fit in the body of a mini-Morris; a conference can be a disaster if room allocation conflicts with other academic programs.

Having a blueprint that correctly specifies all attributes is necessary for solving the coordination problem, but not sufficient. In practice, the attributes of parts often depart from their original blueprint because of exogenous disturbances which we call "attribute shocks." When there is a shock affecting an attribute in one task, the attributes in other tasks must be adjusted to achieve matching. Our coordination concept expresses the idea that a need for coordination arises in response to shocks to pre-set plans in the blueprint. The quality of the adjustment of attributes depends itself on the quality of communication inside an organization, which in turn depends on the organizational form. Following Hayek (1945), we assume that only local managers are able to observe local information accurately.[1] Communication is necessary for others to use that information, but it is imperfect because transmitted messages can go wrong. In order to focus on the coordination problem, we assume away the incentive problem and take the team theoretical approach.[2]

In our model, we define an M-form organization as one that is decomposed into self-contained units where complementary tasks (such as producing a given screw and the associated bolt) are grouped together. In contrast, a U-form organization is decomposed into specialized units where similar tasks (such as production and sales in a corporation or steel and textiles in a centrally planned economy) are grouped together. These units are not self-contained in terms of final output.

We obtain three main results in comparing the M-form and U-form organizations in coordinating changes. First, there is a trade-off between better local coordination and lack of scale economies in the M-form compared to the U-form. Indeed, as the M-form is organized in self-contained units, attribute matching can be established by local managers who have better information, whereas in the U-form the attribute matching is established by top managers who rely on imperfect information transmitted from local managers. On the other hand, having self-contained units in the M-form involves higher setup costs for implementing changes since similar tasks are organized in different units. Such costs can be reduced in the U-form where similar tasks are grouped together in specialized units. When both the communication quality and setup costs (and thus economies of scale) are high, the U-form dominates the M-form; otherwise the M-form dominates the U-form.

Second, the M-form is more flexible, which has two effects. Firstly, it gives the *option of local experimentation* with innovation programs having uncertain outcomes. Indeed, the structure of self-contained units makes it possible to first experiment with a new program locally. This reduces the cost of learning about the quality of the program since one can economize on setup costs in other units. In

[2] Maskin, Qian, and Xu (1997) provide an analysis of incentive problems in M-form and U-form organizations. Theoretical studies of organization in the team theoretical tradition include, among others, Marschak and Radner (1972) on the economic theory of teams, Weitzman (1974) on coordination using price and quantity, Crémer (1980) on the optimal partition of workshops inside an organization, Aoki (1986) on the comparison between organization inside the Japanese and the American firm, and Bolton and Dewatripont (1994) on the firm as a communication

other words, experimentation gives the option of waiting to learn about the quality of the innovation program before implementing it in the entire organization. In particular, it reduces the costs associated with bad programs that are only discovered *ex post*. In contrast, in the U-form, these benefits from experimentation cannot be reaped because of the complications in coordinating partial experiments across units which are not self-contained. When uncertainty about the quality of the program or the setup cost of innovation are high, the M-form will benefit from the flexibility of local experimentation whereas the U-form will not. Secondly, the M-form allows for parallel experimentation, yielding faster success in innovation. In particular, this option dominates when setup costs are sufficiently low. Overall, the flexibility of the M-form allows it to dominate the U-form both when the setup costs are high and when they are low. The flexibility of the M-form can lead to a higher propensity to innovate, an important dynamic advantage compared to the U-form.

Finally, we introduce another dimension of the coordination problem, that of "attribute compatibility." Attribute compatibility is a characteristic related to similar tasks and products. Whereas attribute matching refers to complementary products such as screws and bolts, compatibility refers to different types of screws. The latter will have attribute compatibility if for example two different types of screws can be made to fit a same type of bolt, or if they can be readjusted with the same kind of machine. When coordination for attribute compatibility between similar tasks is also needed in addition to coordination for attribute matching, the M-form may suffer from coordination problems due to imperfect communication between the local managers and the top manager, since in the M-form similar tasks are performed in different units. Then the comparison between M-form and U-form is focused on the tradeoff between two types of coordination: that of attribute compatibility and that of attribute matching. When standardization in markets is more prepared to solve most of the compatibility problems, the M-form will have more advantages than the U-form.

Our paper is, to our knowledge, the first formal attempt at studying how the M-form and U-form

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network.

organizations affect communication channels and thus the efficiency of coordination within an organization.[3] Our study has applications to three areas: business firms, transition economies, and the organization of government.

Chandler (1962, 1977) studied how the M-form (multi-divisional form) corporation emerged and how it replaced the U-form (unitary form) to become the prevailing corporate form of large businesses in U.S. business history. Williamson (1975, 1985) theorized Chandler's works with two major focuses: the holdup problem and the overload problem of corporate headquarters. The holdup problem concerns how organizational forms affect incentives and contractual relationships within an organization. A large literature has been generated after Williamson, such as Grossman and Hart (1986) and Hart and Moore (1990). With respect to the coordination problem, Williamson emphasized that M-form firms were more efficient than U-form firms because daily operations were decentralized to divisions, which reduced work overload at the corporate headquarters and freed its time for strategic planning. Aghion and Tirole (1995) analyzed how M-form and U-form organizations generate and solve the overload problem. However, if overload is the only problem, putting more staff and resources in the headquarters and functional departments should reduce the problem without reorganizing a corporation. Chandler's studies (1962, 1977) demonstrated that this is not the case. Our theory can interpret these failures in a consistent way and in our view, the general coordination problem and the way of defining communication channels within an organization have fundamental effects on the evolution of organizational forms.

Our theory is also applied to transition economies. There is a striking difference between the organization of Soviet planning administration on one hand, and the organization of the Chinese planning administration, on the other hand (Qian and Xu, 1993). The Soviet economy was organized into many

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[3] Related to our work is the management science literature which distinguishes between product-focused and process-focused corporations, and treats them as the result of minimization of coordination costs in varying unstable environments (Henderson and Clark, 1990, Hayes, Wheelwright, Clark, 1988, Stinchcombe, 1990, Athey and Schmutzler, 1994). Also related are comparative studies of firms, for example, Aoki (1986) has noted that in Japanese firms, decision-making is more decentralized to workers who are less specialized and better able to make frequent adjustments and use on-site information than their American counterparts. These models, however, are not based on the notion of coordination as attribute matching.

specialized or functional ministries (e.g., mining, machinery, textile, etc.), each controlling some gigantic factories. This corresponds to a U-form organization (also known as a "branch organization"). In contrast, the Chinese economy has been organized mainly on a geographical principle (provinces, prefectures, counties, townships and villages). This corresponds to an M-form organization (also known as a "regional organization"). The M-form structure can provide flexibility and allow for regional experiments without interfering with the rest of the economy, and thus can optimally induce an experimental approach. The U-form cannot exploit this strategy because of difficulties in coordination. In the latter, reforms must be more comprehensive in order to avoid coordination failure and must be coordinated from the top. Therefore, our theory accounts for the contrast between the observed "big-bang" approach in Eastern Europe and the former Soviet Union and the "experimental" approach in China (McMillan and Naughton, 1992; Sachs and Woo, 1997).

Finally, we apply our theory to the organization of government, specifically, the comparison between the unitary and federal states. The unitary state can be viewed as a U-form organization and federalism as an M-form. The organization of the French and Japanese governments are examples of the former and that of the United States is the prominent example of the latter. The French and Japanese government organizations are much more centralized in Paris and Tokyo respectively, with specialized ministries having large powers and regional governments having little. Major changes in government programs, such as education and banking reforms, require initialization by the responsible ministries and coordination by the central government. In contrast, the American federalism is famous for being a "laboratory of the states," where many changes are initiated and experimented with by some states and are the successful results imitated by others. The contrast between the unitary and federal states fits well our theoretical analysis of organizational form, which can be viewed as the beginning of developing a theoretical foundation of federalism.

The rest of the paper is organized as follows. Section II introduces the modelling of coordination as "attribute matching." Section III explores the basic features and the tradeoffs between the U-form and the M-form organizations in terms of coordinating changes. Section IV extends the model to include the possibility of parallel experimentation when more than one blueprint is available at a given time. Section V incorporates coordination on attribute compatibility. Section VI discusses applications of our analysis to business firms, transition economies, and the organization of government. Section VII concludes. The Appendix contains the proofs of the propositions.

II. Modelling Coordination

We consider an economy with two products (or regions), "A" and "B," and two processes (or functions), "1" and "2." The technology of the economy can be fully described by four tasks: 1A, 2A, 1B, and 2B, where task ir involves process i for product r.[4] This setup allows us to focus on the effects of the organizational form in grouping tasks for given technologies.

Each of the four tasks has many attributes in the dimensions of, say, time, location, technical specifications, institutional arrangements, etc. An innovation program is thus characterized by new attributes of the tasks. We suppose that an innovation program is designed so that all attributes are matched perfectly *ex ante* in the blueprints. However, in implementing a program, there are always "attribute shocks" which are unexpected contingencies not taken care of in the blueprints. At the implementation stage of an innovation program, attributes of parts must be mutually adjusted to observed attribute shocks. We assume that attributes between tasks 1r and 2r (r = A, B) must be matched in order to implement an innovation program successfully. We assume in sections III and IV that no attribute matching is needed between the tasks across products and in section V, we extend the model by incorporating the requirement for attribute compatibility across products.

We consider an infinite horizon with discount factor ä. We first assume that one and only one blueprint for change is available in each period. Later we allow the possibility of two independent blueprints in each period. With probability p the blueprint is a good one and with probability 1-p it is a

[4] With this specification, we implicitly assume that products (regions) are symmetric in the sense that each product

bad one. Blueprints available over time are stochastically independent. We assume that if a blueprint is known to be good, then it will be good in the same unit (region) in the future, or it can be good in another unit (region). In contrast, good coordination (i.e., attribute matching) in one unit (region) cannot be "copied" in another unit (region), because of differences in local conditions. Therefore, if a blueprint tried in one unit (region) is found to be good and coordination has been successful, then the same blueprint can be used successfully elsewhere, but coordination is still necessary in order to adjust to local conditions before a successful outcome can be achieved.

In each period, if needed, a manager collects information about the attribute shocks and, if required, sends a message to another manager. Each message contains information about all the attributes in one task. We assume that information transmission between any two managers is imperfect so that the probability of each message being correct is ë with $0 \leq$ ë ≤ 1. We assume that noises in information transmission are independent across tasks as well as over time. Based on the information received, the manager carries out his main job: attribute matching.

Consider the payoffs for unit A (payoffs for unit B are defined symmetrically). Let the status quo (without change) payoff in tasks 1A and 2A be 1/2. The benefits from change are defined as follows. Suppose the program is good, then (i) with change in task 1A but not in task 2A (or change in task 2A but not in task 1A), the payoff is (A+1)/4 if the attributes between 1A and 2A are matched, otherwise 0; and (ii) with change in both tasks 1A and 2A, the payoff is A/2 if the attributes between 1A and 2A are matched, otherwise 0. If the program is bad, then the payoff is always 0 when change is implemented.

<u>Assumption 1.</u> $pA > 1$: the expected per period benefit from change is larger than the status quo.

We assume that all blueprints are made available for free, but for each manager there is a setup

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has two processes.

cost C associated with coordinating changes. This cost can be interpreted as a training cost, that is, to implement a program for change the managers need to be trained on how to match attributes of the program. Because blueprints are free and the setup costs for coordination are not, when a failure occurs in the previous period (either due to a bad program or bad coordination), the organization always prefers to use a new blueprint in the next period rather than to retry the old one.

Assumption 2. A/2(1-ä) - C > 1/2(1-ä), that is, the net benefit from change is better than the status quo for p = 1.

We can now define U-form and M-form organizations. A U-form organization is set up along "functional lines." Two middle managers i (i = 1, 2) are responsible for collecting information about shocks in tasks iA and iB. Because the two tasks that need attribute matching are not assigned to the same middle manager, the two middle managers have to report the information to the top manager, who, after receiving information from the two managers, matches attributes between tasks 1r and 2r (r = A, B). This type of organization can be represented by Figure 1:

Figure 1: A U-Form Organization

Top Manager

Manager 1 Manager 2

Task 1A Task 1B Task 2A Task 2B

An M-form organization is set up along "product lines." The middle manager r (r = A, B) is responsible for collecting information about shocks in tasks 1r and 2r. Because the two tasks which require attribute matching are assigned to the same manager, the middle managers can match attributes between tasks 1r and 2r locally by themselves. The top manager provides a blueprint for change (and in section V, the top manager also coordinates attribute compatibility). This type of organization can be represented by Figure 2:

Figure 2: An M-Form Organization

Top Manager

Manager A Manager B

Task 1A Task 2A Task 1B Task 2B

Under the M-form, setup costs must be incurred in each unit since attribute matching is done separately in each product unit. This leads to higher setup costs. For example, both managers need to be trained to coordinate the changes. In contrast, under the U-form, only the top manager matches attributes in a centralized way. Therefore, the setup cost is correspondingly smaller.[5] For simplicity, we will assume that only one setup cost is required when only one manager coordinates.

We provide two examples below to illustrate our concept of coordination inside an organization as attribute matching.

[5] We note that in this framework, the M-form has an option to "mimic" the U-form by requiring regional managers to send messages to the top for coordination, but the U-form cannot "mimic" the M-form. However, when coordination on compatibility is added into the model in section V, the two organizational forms will look

Example 1. Coordinating innovations: manufacturing trucks

Suppose there are two functions, machine building and bearings to produce trucks. Function 1 consists in supplying many types of bearings to the truck industry, and function 2 consists in manufacturing trucks. Because of differences in local road conditions, each region has its idiosyncratic preference for truck models (call them model A and model B trucks respectively). Task 1r is to produce bearings for a model r truck, and task 2r is to produce model r trucks for region r, where r = A and B.

The attributes of bearings and truck models should be matched to each other in order to produce quality trucks. For example, bearings should match the transmission equipment of the truck. If some attributes between the bearings and the truck are not matched, the truck cannot work. Coordination consists in finding a solution to match bearings with parts of trucks. A technological innovation in transmission may make a truck more efficient, but it will change the technical requirements for bearings.

Suppose there is an innovation in the transmission system and the innovation outcome is uncertain. In the case where a new transmission system is good and every set of bearings is matched with every part of a truck, the new truck will be better than the old one. However, if one of the bearings does not fit with the corresponding part of the truck, the new truck will not work.

The firm can be organized into specialized units, a machine-building unit and a unit for producing bearings with centralized matching of the attributes between bearings and trucks (U-form). It can also be organized along product lines, where each product unit is responsible for producing one model of truck (the M-form).

Example 2. Coordinating reforms: enterprise restructuring and creation of a social safety net

Suppose an economic reform consists of two components: enterprise restructuring (laying off excess workers) and creation of a social safety net. Task 1r is layoffs in region r and task 2r is paying unemployment benefits through the social safety net in region r, where r = A and B.

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symmetric.

The attributes of enterprise restructuring are the number and individual characteristics of the laid off workers such as age, seniority, family composition, length of residence, sex, type of contract, current wage, history of employment, etc. The attributes of compensation from the social safety net are rules of eligibility such as length of employment, special circumstances (veteran or not), status of enterprises, rules of benefits such as size and length, types of benefits (monetary or not), technical support of computers, administration, budget, etc. If some attributes of the two tasks are not matched, some laid off workers may not be compensated appropriately.

If the reform is organized by specialized ministries (or committees), then each ministry is responsible for either enterprise restructuring or the social safety net, and the national government is responsible for matching the attributes between enterprise restructuring and the social safety net (the U-form). It is possible that there will be bad coordination between layoff policies and the creation of the social safety net, leading to riots. For example, the rules for eligibility set at the national level may be completely inappropriate in some important regions which are concentrated with older workers, if the national rule for pension eligibility does not make workers close to pension age eligible for any benefits.

If the reform is organized by the regions, each regional government is responsible for matching the attributes between enterprise restructuring and the social safety net in its own region (the M-form). Under this type of organization, layoff policies and the institution of social safety nets can be better coordinated within each region so that riots can be prevented.

III. Coordination, Experimentation, and Organizational Flexibility

In this section, we compare the M-form and the U-form assuming that only one blueprint is available in each time period. Under both organizational forms, the payoff from the status quo (i.e., no reform) is 1 for each period, and thus the status quo discounted payoff is 1/(1-ä).

Consider first the situation in which an organization starts a reform in both of its units and continues in that way afterwards. Under the M-form, every unit manager will be responsible for matching the attributes of the two tasks within his unit. With perfect local information, attribute matching under the M-form will be performed perfectly. If a program is good, which happens with probability p, the total payoff from the two units is A/(1-ä). If a program is bad, which happens with probability 1-p, the current payoff is zero, and a new program will be tried in the next period. Therefore, the expected payoff of continued reform in an M-form is

$$ð_{m2} = pA/(1-ä) + (1-p)äð_{m2},$$

from which we obtain

$$ð_{m2} = pA/\{(1-ä)[1-(1-p)ä]\}.$$

On the cost side, in period 1, 2C is paid because two managers are involved in coordination. With probability p, the reform program is good so no more costs need to be paid afterwards. But with a probability 1-p the program is bad, which is discovered after one period of change. Then a new program is tried in the next period. Because the managers need to be retrained for matching attributes, an additional cost of 2C is paid in the next period, and so on. Therefore, we should have

$$c_{m2} = 2C + ä(1-p)c_{m2},$$

from which we derive

$$c_{m2} = 2C/[1-(1-p)ä].$$

Under the U-form, the top manager is responsible for coordinating the four tasks. He thus receives four messages through noisy communication, each corresponding to one of the four tasks. When the program is bad (with probability 1-p), the reform fails, and a new program will be tried in the next period. If the program is good (with probability p), there are three possibilities: (i) With probability $ë^4$, coordination is successful for both products A and B. (ii) With probability $(1-ë^2)^2$, coordination fails in both A and B. This will give the same outcome as a bad program. (iii) With probability $2ë^2(1-ë^2)$, coordination for one of the two products is successful. In this case, knowing that the program is good, the top manager will use the same program for the product for which the coordination failed and solve only the attribute matching problem in the next period. Hence, the payoff of reform under the U-form is

$$ð_{u2} = p\{ë^4A/(1-ä) + 2ë^2(1-ë^2)[A/[2(1-ä)] + äð] + (1-ë^2)^2äð_{u2}\} + (1-p)äð_{u2},$$

where ð is the expected payoff of change for one product for a good program:

$$ð = ë^2A/[2(1-ä)] + (1-ë^2)äð,$$

which implies that

$$ð = ë^2A/\{2(1-ä)[1-(1-ë^2)ä]\}.$$

Using the above recursive formula of ð, we obtain

$$ð_{u2} = p\{2ë^2[ë^2A/2(1-ä) + (1-ë^2)A/2(1-ä) + (1-ë^2)äð + (1-ë^2)äð - (1-ë^2)äð]/\{1-ä[p(1-ë^2)^2+(1-p)]\}$$

$$= 2p[ë^2A/2(1-ä) + ë^2(1-ë^2)äð + (1-ë^2)äð - (1-ë^2)äð]/\{1-ä[p(1-ë^2)^2+(1-p)]\}$$

$$= 2pð[1 - (1-ë^2)^2ä]/\{1-ä[p(1-ë^2)^2+(1-p)]\}$$

$$= ë^2pA[1-(1-ë^2)^2ä]/\{(1-ä)[1-(1-ë^2)ä][1-ä[p(1-ë^2)^2+(1-p)]]\}.$$

On the cost side, when an innovation is introduced in period 1, only a setup cost C is paid (instead of 2C in the M-form) because only the top manager makes attribute matching. With probability 1-p the program is bad, which is discovered after one period. With probability $p(1-ë^2)^2$ the program is good but coordination fails for both products. In both cases, a new program is tried in the next period. When the program is good and coordination is successful for at least one of the two products, the program will be known to be good. In such a case, no new setup cost needs to be paid in the next period. Indeed, the top manager has already been trained for that program and he has been able to successfully coordinate attribute matching for one product. Under this assumption, we have:

$$c_{u2} = C + ä[p(1-ë^2)^2 + (1-p)]c_{u2},$$

from which we obtain

$$c_{u2} = C/\{1-[p(1-ë^2)^2+1-p]ä\}.$$

<u>Lemma 1:</u> (1) $ð_{u2} \leq ð_{m2}$, and $ð_{u2}$ increases in ë and reaches $ð_{m2}$ at ë = 1.

(2) c_{u2} decreases in ë, and $c_{u2} < c_{m2}$ if and only if $ä(1-p+2p(1-ë^2)^2) < 1$.

When communication between the middle managers and the top manager is perfect, the two organizational forms are equivalent in the expected payoffs. However, when communication is not perfect and because there is no communication problem under the M-form, M_2 always has higher expected benefit than U_2. Under U_2, costs decrease with ë because better communication decreases the probability of failure with change, thereby lowering the probability of drawing new experiments and incurring repeated set-up costs. The trade-off between costs under M_2 and U_2 is also related to the quality of communication under U_2. The latter avoids the costs of duplication but bad communication leads to a higher failure rate, possibly leading to higher total costs because of the need to draw more experiments before achieving success.

We define the expected net payoff under the M-form and U-form, respectively,

$$M_2 = ð_{m2} - c_{m2},$$

and

$$U_2 = ð_{u2} - c_{u2}.$$

To compare the M-form with the U-form, we have:

<u>Proposition 1:</u> Comparing M_2 and U_2:

(1) M_2 has a higher expected net benefit than U_2 if ë is low enough: for p and C given, there exists ë $\in$ (0,1) for which $M_2 > U_2$ if and only if ë < ë.

(2) U_2 has a higher expected net benefit than M_2 if C is high enough: when $c_{u2} < c_{m2}$ and for p and ë given, there exists C > 0 such that $U_2 > M_2$ and if only if C > C.

Proposition 1 demonstrates the basic tradeoff between coordination and scale economies in implementing changes under the M-form and the U-form. The U-form has an advantage in scale economies because the top manager is responsible for coordination in the entire organization. The organization thus saves on setup costs but the U-form has disadvantages in coordination because local information is communicated imperfectly from the local managers to the top manager. In contrast, the M-form has better coordination because managers can make better use of local information for coordination purposes, but it suffers from disadvantages in scale economies: it pays twice the setup costs because two local managers are responsible for attribute matching instead of one top manager.[6] In view of this trade-off, the M-form will be more efficient than the U-form when communication quality is relatively low, or when the setup cost is relatively small.

We next introduce the possibility that an organization starts a reform in one of its two units and later extends it to another unit, conditional on successful implementation in the first unit. In other words, we look at the possibility of experimentation in implementing reforms.

Under the M-form, suppose at first that a reform program is introduced in unit A whereas status quo is maintained in unit B. If the program is a good one, the first period payoff is (A+1)/2. In the second period, the same program is then used in unit B. From then on, the payoff is always A per period. However, if the program is bad, the experimenting unit A will get 0 payoff and the non-experimenting unit B will get 1/2. In this case, a new experiment in unit A will take place again in the next period. Therefore, the expected payoff of the M-form with experimentation is given by

$$ð_{m1} = p\{A/2(1-ä) + 1/2 + äA/2(1-ä)\} + (1-p)\{1/2 + äð_{m1}\},$$

that is,

$$ð_{m1} = p[A+(1-ä)+äA]/2(1-ä) + (1-p)\{1/2+äð_{m1}\}.$$

Therefore, we obtain

$$ð_{m1} = [pA(1+ä)+(1-ä)]/\{2(1-ä)[1-(1-p)ä]\}.$$

The setup cost in the first period is C because only unit A's manager does attribute matching. If the program is good, unit B will use the same program in period 2 and another cost C will be paid in period 2 because unit B's manager needs to match attributes according to local conditions. Unit B thus

[6] In Bolton and Farrell (1990) it is coordination failure that creates duplication costs. In our model, there is no causality between coordination failure and the duplication of setup costs. This is because coordination here is defined as attribute matching inside an organization while the duplication of setup costs is related to the lack of scale

imitates unit A's success, but does not copy it, since local coordination is still required to introduce the successful blueprint. With probability 1-p, the program is bad and a new blueprint must be tried. We are then back to the situation of period 1. Hence we get,

$$c_{m1} = C + \text{ä}[pC + (1\text{-}p)c_{m1}],$$

which implies that

$$c_{m1} = (1\text{+}p\text{ä})C/[1\text{-}(1\text{-}p)\text{ä}].$$

We define the net expected payoff under the M-form with experimentation as

$$M_1 = \text{ð}_{m1} - c_{m1}.$$

Because of Assumption 1, pA > 1, we have:

<u>Lemma 2:</u> (1) $\text{ð}_{m1} < \text{ð}_{m2}$, and $c_{m1} < c_{m2}$.

(2) $dM_2/dp > dM_1/dp > 0$.

Both M_1 and M_2 monotonically increase with p. By Lemma 2, we can define p_{m2}* as the probability such that M_2 = 1/(1-ä) and p_{m1}* as the probability such that M_1 = 1/(1-ä), where 1/(1-ä) is the status quo payoff. Then, for all p > p_{m1}*, M_1 has higher expected net payment than the status quo; and for all p > p_{m2}*, M_2 has higher expected net payment than the status quo. Let be the probability such that $M_1 = M_2$. The following proposition compares two reform strategies in the M-form: the experimentation strategy M_1 and the strategy M_2 of "big bang" where innovation is introduced in both units simultaneously.

<u>Proposition 2:</u> The difference in the expected net benefits between M_1 and M_2 is

$$M_1 - M_2 = \{C(1\text{-}p\text{ä})\text{-}(pA\text{-}1)/2\}/[1\text{-}\text{ä}(1\text{-}p)].$$

(1) p_{m1}* < p_{m2}* < < 1. Therefore, M_1 has a higher expected net benefit than M_2 if and only if p < , and

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economies or specialization (on the latter point, see also Becker and Murphy (1992)).

M_1 is better than the status quo while M_2 is not for p å (p_{m1}*, p_{m2}*).

(2) M_1 has a higher expected net benefit than M_2 if and only if C > C = (pA-1)/2(1-pä).

Proposition 2 demonstrates the following tradeoff between experimentation (M_1) and no experimentation (M_2). M_1 provides an option value of waiting to learn about the quality of the blueprint before implementing full reform, but it comes at the cost of delay of a successful full reform. The first term C(1-pä) in the numerator of M_1 - M_2 indicates the option value of waiting to learn about p before sinking C in an additional unit. This option value of waiting increases as p decreases, i.e. when there is greater uncertainty about the value of the blueprint. Therefore, experimentation can saves on setup costs because of the option value of early reversal of a bad blueprint (Dewatripont and Roland, 1995). The second term in the numerator (pA-1)/2 (which is positive by Assumption 1) shows the cost of delaying experimentation in one unit under M_1. This cost increases with p. Clearly, when p = 1, M_2 > M_1 since the numerator becomes C(1-ä)-(A-1)/2, which is smaller than zero by Assumption 2. M_2 continues to dominate M_1 until p falls below . In particular, when p further falls into the region of [p_{m1}*, p_{m2}*], M_1 is greater than the status quo but M_2 is not.

We now analyze the possibility of experimentation under the U-form. Without loss of generality, we assume that at first a blueprint is implemented in unit 1 whereas unit 2 maintains the status quo. In line with our assumptions, the top manager does the attribute matching for products A and B.

We assume that the quality of the program (good or bad) can be discovered even when the reform is implemented for only one task. We further assume that to match attributes of two tasks, whenever there is a change in at least one task, information (and thus communication) about the attributes of both tasks is needed. This is because even if a change is introduced in one task, attribute matching always involves another task. Therefore, under U-form with reform in only one unit, all messages corresponding to the four tasks must be communicated by the two middle managers to the top manager.

After one period of experimentation in one unit, if a program is bad, the innovation fails, and in the next period a new program will be tried. If a program is good, there are three possible outcomes: (i) With probability $ë^4$ attribute matching is achieved for both products A and B. Then in the next period, the same program is used in both units and the final payoff will only depend on the outcome of attribute matching. (ii) With probability $(1-ë^2)^2$, coordination is bad for both A and B. This will give the same outcome as a bad program and a new program will be tried in the next period. (iii) With probability $2ë^2(1-ë^2)$, coordination for A or B is successful which will reveal that the program is good. In the next period, the two units will use the same program and the payoff for the earlier failed product depends on the outcome of attribute matching. Hence, the expected payoff of the U-form with experimentation is

$$ð_{u1} = p\{ë^4[(A+1)/2 + ä2ð] + 2ë^2(1-ë^2)[(A+1)/4 + ä2ð] + (1-ë^2)^2 äð_{u1}\} + (1-p)äð_{u1},$$

where $ð$ is, as above, the expected payoff of reform in one region when the program is good, as defined above. Hence, we obtain

$$ð_{u1} = p\{ë^4[(A+1)/2 + ä2ð] + 2ë^2(1-ë^2)[(A+1)/4 + ä2ð]\}/\{1-ä[p(1-ë^2)^2+(1-p)]\}.$$

Under the U-form, the setup cost is the same as reform without experimentation. This is because coordination is done at the top and always requires four messages to be sent to the top manager who must be trained to do the appropriate coordination. We also assume that the setup cost C enables the manager to implement both partial and full change.[7] Therefore,

$$c_{u1} = c_{u2} = C/\{1-[p(1-ë^2)^2+1-p]ä\}.$$

We define the net expected payoff under the U-form with experimentation as

$$U_1 = ð_{u1} - c_{u1}.$$

Proposition 3: Comparing U_1 and U_2:

$$ð_{u1} < ð_{u2},\ c_{u1} = c_{u2}, \text{ and } U_1 < U_2.$$

[7] It would be reasonable to assume that the setup cost should be incurred twice, a first time when partial innovation is tried and a second time when the full innovation is implemented since the nature of the coordination is different in both cases. This assumption would however only reinforce the result of proposition 3.

The U-form organization does not benefit from experimentation due to the complications involved in coordinating activities. While the setup cost is not lower as with full change, there is no additional benefit in coordination and there are only costs in delaying expected benefits.

Since partial innovation in the U-form never occurs in equilibrium, it is useful to give an example. Think of changes in computer software where task 1 represents change in the operating system and task 2 change in a word processor. Gradual change (i.e., U_1) in this case means for example first changing the operating system (from DOS to windows 95), and then changing the word processor (from WordPerfect 5.1 to WordPerfect 8). In this example, partial innovation involves first matching the attributes of the old word processor with the new operating system (via a solution like the "DOS prompt") and then matching the attributes of the new operating system with the new word processor. In terms of difficulty of coordination, one gains nothing from this partial innovation and one might just as well directly introduce both changes. This is the message of proposition 3.

We can now compare M_1, M_2, and U_2. The flexibility of the M-form is an advantage over the U-form.

<u>Proposition 4:</u> Comparing M_1, M_2, and U_2:

(1) U_2 has higher expected net benefits than M_1 and M_2 if ë is close enough to 1.

(2) M_1 has higher expected net benefits than M_2 and U_2 if ë is small enough and either p < or C > C = (pA-1)/2(1-pä).

When communication quality is high, the U-form will dominate because of its advantages in scale economies. The more interesting results are those on the flexibility of the M-form. From Propositions 2 and 3 we know that when the probability of success is low or the setup cost is high, the M-form has the option of experimentation while experimentation has no value to the U-form. In such a case, the M-form can do better than the U-form, provided communication quality is low.

IV. Coordination and Parallel Experimentation

In this section, we assume that two independent blueprints are available at a given time. This introduces a possibility that both blueprints are tried simultaneously in the two units in the M-form (call it M_{11}). If there is one successful experiment in one unit, it can be copied costlessly in the other unit, as in the previous section. In this strategy:

$$ð_{m11} = p^2A/(1-ä) + 2(1-p)p\{A/2(1-ä) + äA/2(1-ä)\} + (1-p)^2äð_{m11},$$

from which we obtain:

$$ð_{m11} = \{A(p^2+p(1-p)(1+ä))\}/(1-ä)[1-ä(1-p)^2].$$

Similarly for the cost:

$$c_{m11} = 2C + 2(1-p)päC + (1-p)^2äc_{m11},$$

from which we obtain:

$$c_{m11} = 2C[1+äp(1-p)]/[1-ä(1-p)^2].$$

We first compare M_{11} with M_2, the latter has only one blueprint (or, two perfectly correlated experiments) used in the two units of the M-form.

<u>Proposition 5:</u> Comparing M_{11} and M_2, M_{11} always has higher expected benefits and lower expected costs than M_2:

$$ð_{m11} > ð_{m2} \text{ and } c_{m11} < c_{m2}.$$

If two independent blueprints are available, then it is always better to try one in each unit rather than one in both units. Why do two independent experiments always give higher expected benefits than two perfectly correlated experiments? In the first period, the two will give the same expected outcome but since two independent experiments have a higher probability of at least one success, success will tend to be implemented earlier with independent experiments. Similarly, the reason for the lower costs with two independent experiments is that under the latter, the probability that no further cost will be paid next period is $1-(1-p)^2$ whereas it is only 1-p under two perfectly correlated experiments.

We now compare M_{11} with M_1.

Proposition 6: Comparing M_{11} and M_1:

(1) M_{11} has both higher expected benefits and expected costs than M_1:

$$ð_{m11} > ð_{m1} \text{ and } c_{m11} > c_{m1}.$$

(2) $M_{11} > M_1$ if and only if

$$C < C^1 = pA(1+ä(1-p)^2)/2[1-ä+äp(1-p)(1-ä(1-p))]+(1-ä(1-p)^2).$$

The higher benefit of M_{11} compared to M_1 is due to two reasons. First, the former has a higher first period expected benefit (pA > pA/2 + 1/2 because pA > 1 (by Assumption 1). Second, M_{11} has a higher probability (i.e., $1-(1-p)^2$) than M_1 (i.e., 1-p) to have a known good blueprint from the second period onward.

The reason why M_{11} has higher costs than M_1 is that under the former at least 2C always have to be paid out up front. Note that both c_{m11} and c_{m1} decline with p. The former declines faster than the latter as under M_{11} learning about a success is faster. Nevertheless, when p approaches 1, c_{m11} approaches 2C while c_{m1} approaches C(1+ä), which still remains smaller.

Looking at the difference M_{11} - M_1, we have:

$d(M_{11} - M_1)/dp = A(1+ä(1-p)^2)-2pAä(1-p)-2C[ä(1-2p)(1-ä(1-p))+ä^2p(1-p)]-2ä(1-p)$

$= A(1+ä(1-p)(1-3p))-2Cä[1-2p-ä(1-p)(1-3p)]-2ä(1-p)$

$= ä(1-p)(1-3p)(A+2Cä)+A-2Cä(1-2p)-2ä(1-p).$

There is thus a non-linear relationship between p and M_{11} - M_1. Comparing the net benefits in M_{11} and M_1 is therefore complicated. But one sees intuitively that the lower C relative to A, the higher the advantage of M_{11} over M_1, and vice versa.

We can now summarize the comparison between various organizational forms in the following proposition:

<u>Proposition 7:</u> Comparing M_{11}, M_1, M_2, and U_2:

(1) U_2 has higher expected net benefits than all other organizational forms if ë = 1 and either p = 1 or C > C^2 = pAä(1-p)^2/[1-ä(1-p)^2(1+2äp)].

(2) M_1 has higher expected net benefits than all other organizational forms if ë is low enough and C > C^1.

(3) M_{11} has higher expected net benefits than all other organizational forms if either ë = 1 but C < C_1 or if ë is low enough, p >   or C < C^1.

The U-form dominates when communication quality is high and either setup costs are high or there is no uncertainty about the experiment. M_1 dominates when communication quality is low and setup costs are high and M_{11} dominates either when costs are low enough (in which case it dominates U_2) or when communication quality is low enough but setup costs are sufficiently low and the probability of success sufficiently high (in which case it dominates M_1). A major difference between Propositions 4 and 7 is as follows. When parallel experimentation is not available, the flexibility advantage of the M-form can be achieved when setup costs are high and the probability of success is low whereas when parallel experimentation is available, an additional flexibility advantage of the M-form can be achieved when setup costs are low and the probability of success is high.

V. Coordination on Attribute Compatibility

In this section we extend our coordination concept to incorporate attribute compatibility between tasks iA and iB (i = 1, 2). We will focus on the trade-off between better matching under the M-form and better compatibility under the U-form. Therefore, we abstract from setup costs and assume C = 0 to make this trade-off clear. We assume that the dimension of attributes for which compatibility between tasks iA and iB is required is of order k. We assume that $k \leq 1$, which represents the idea that the attributes to be made compatible typically have a lower dimension than the attributes to be matched. Indeed, remember that compatibility concerns attributes of similar tasks which in general are not matched together but rather act as substitutes for one another. Whereas matching is the rule for complementary parts, substitution is not necessarily the rule for similar parts.

Under the U-form, unit managers coordinate compatibility between tasks iA and iB within each unit. Because they do not need to communicate with other managers, compatibility will be achieved perfectly inside each unit of the U-form. Under the M-form, unit managers must send messages about shocks concerning attribute compatibility to the top manager who is responsible for attribute compatibility. The probability of a message being correctly received by the top manager is ë^{k}.

In the example of innovation in truck manufacturing, bearing for model A truck should be compatible with bearing for model B truck, and similarly for the transmission systems for the two models. Otherwise, even if the two trucks can run well, the lack of service (or higher costs of inventories) due to the incompatibility of the two models will lower the value of the new truck. In the example of enterprise restructuring and the social safety net, if the layoff policies in the two regions are not compatible, inefficient close-downs may occur. Similarly, if the rules of eligibility for compensations in the social safety net are not compatible across regions, sub-optimal labor mobility may result.

We assume the following payoff structure when compatibility is required in addition to attribute matching. Again, let the status quo payoff be 1/2. Consider the payoffs for product A under reform (payoffs for B are defined symmetrically). Suppose the blueprint is good, then (i) with change in task 1A but not in task 2A (or change in task 2A but not in task 1A), the payoff is (A+1)/4 if the attributes between 1A and 2A are matched and the attributes between 1A and 1B and those between 2A and 2B are compatible, otherwise 0; and (ii) with reform in both tasks 1A and 2A, the payoff is A/2 if the attributes between 1A and 2A are matched and the attributes between 1A and 1B and those between 2A and 2B are compatible, otherwise 0. If the program is bad, then the payoff is always 0.[8]

Under the U-form, because coordination on compatibility is perfect, the expected payoff is the same as in the case without attribute compatibility analyzed in section III. But, the expected payoffs of the M-form will be different. Local managers continue to make perfect attribute matching in both units. In the M-form without experimentation, the top manager now receives four messages from the two local managers about compatibility shocks. Therefore, we can write down the expected payoff under M-form as

$$ð_{m2} = p\{ë^{4k}A/(1-ä) + ä(1-ë^{4k})ð_{m2}\} + (1-p)äð_{m2},$$

from which we obtain:

$$ð_{m2} = pAë^{4k}/\{(1-ä)[1-ä[p(1-ë^{4k})+(1-p)]]\}.$$

Now consider the experimentation approach in the M-form. Suppose a blueprint is tried in unit A, and unit B remains unchanged. With probability 1-p, the program is bad. Therefore, the payoff in A is 0. However, with probability $ë^{4k}$, compatibility is achieved and the unreformed unit B produces payoff 1/2. With probability $1-ë^{4k}$, the payoff in B is 0 due to compatibility failure. In period 2, we are back to the situation of period 1. With probability p, the program is good. In this case, with probability $ë^{4k}$, compatibility is achieved, and the total payoff is (A+1)/2. In the next period, the same reform program is used in B. However, the managers in the two regions still need to communicate with the top manager for the purpose of coordination on compatibility between tasks iA and iB. Thus, there is a probability of $1-ë^{4k}$ that the coordination on compatibility will fail: in such a case, the payoff will be 0 and we will be back to the situation of period 1. Therefore, we have,

$$ð_{m1} = p\{ë^{4k}[(A+1)/2 + äð_k] + (1-ë^{4k})äð_{m1}\} + (1-p)[ë^{4k}/2 + äð_{m1}],$$

[8] The assumption here that the payoff is zero when attributes between tasks iA and iB are not compatible is made for simplicity. It makes the disadvantage of the M-form in coordinating compatibility the highest. In addition, the assumption that compatibility is not achieved if any one message is wrong also simplifies the analysis. Relaxing

where $ð_k$ is the expected payoff from two regions when four messages need to be reported to the top manager for coordination on compatibility:

$$ð_k = ë^{4k}A/(1-ä) + (1-ë^{4k})äð_k,$$

which gives:

$$ð_k = ë^{4k}A/\{(1-ä)[1-(1-ë^{4k})ä]\}.$$

Therefore, we obtain:

$$ð_{m1} = \{pë^{4k}[(A+1)/2+äð_k]+(1-p)ë^{4k}/2\}/\{1-ä[p(1-ë^{4k})+1-p]\}.$$

Because of Assumption 1, $pA > 1$, then we have:

<u>Proposition 8:</u> M_2 always has higher expected net benefits than M_1: $ð_{m2} > ð_{m1}$.

Without the setup costs, there is no benefit from waiting as long as a blueprint is attractive (in expected terms) on a per-period basis. In this case, experimentation cannot be a good strategy.

<u>Proposition 9:</u> Comparing M_2 and U_2:

(1) $ð_{m2} = ð_{u2}$ for $ë = 1$. For $ë < 1$, there exists $k^*(ë, p) > 0$ such that $ð_{m2} > ð_{u2}$ if and only if $k < k^*(ë, p)$. In particular, for $p = 1$, $k^*(ë, 1) = 1/2$.

(2) There exists $k^*(ë)$, where $0 < k^*(ë) < 1/2$, such that:

(i) for $k < k^*(ë)$, $ð_{m2} > ð_{u2}$ for all p;

(ii) for $k^*(ë) < k < 1/2$, there exists p such that $ð_{m2} > ð_{u2}$ for $p > p$ and $ð_{m2} < ð_{u2}$ otherwise; and

(iii) for $k > 1/2$, $ð_{m2} < ð_{u2}$ for all p.

The first part of Proposition 9 says that the tradeoff between the M-form and the U-form is that between the ability of coordination on attribute matching and that on compatibility. When coordinating

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either of these assumptions will not change our results qualitatively.

compatibility is less demanding (i.e., $k < k^*$), then the M-form has an advantage over the U-form. On the other hand, if coordinating compatibility is very demanding (i.e., $k > k^*$), coordination becomes less of a problem in the U-form than in the M-form, consequently, the U-form will dominate the M-form.

The second part of Proposition 9 says more. When attribute compatibility is not important as compared with attribute matching, then M-form is better than the U-form. When attribute compatibility is moderately important, then M-form is better than the U-form if uncertainty of blueprint is low, but the U-form is better if the uncertainty is high. The reason is that $\eth_{m2}$ increases faster than $\eth_{u2}$ when p increases for moderate values of k. When attribute compatibility is very important, than the U-form is always better.

VI. Applications

In this section we apply our theory to three areas: business firms; transition economies; and the organization of government.

A. Business Firms

We first revisit the three cases documented by Chandler (1962, 1977) on coordination failures between production and sales under a U-form structure when a corresponding firm introduced new products or adopted innovations. Our theory can interpret these failures in a consistent way.

The first case is about du Pont in the late 1910s and the early 1920s. Before 1921, du Pont was organized as a U-form: under the headquarters there were functional units for production and sales respectively. After the World War I du Pont expanded production from explosives to consumer products, such as paints (Chandler, 1962, pp. 78-94). At that time, whenever a new chemical was developed which changed attributes of explosives and paints, the production unit reported the attribute change to the headquarters, which then sent commands to the sales unit. Then the sales unit learned the attributes of the new product and demonstrated them to customers. At the same time, the sales unit learned customers' preferences and translated them into a new set of attributes.

The expansion of product lines caused major coordination troubles in du Pont: there were too many mistakes and inertia in adjusting attributes. Du Pont started to make losses. The problem became most evident in 1919 when almost all the new final products, which required much coordination, made (sometimes heavy) losses. In contrast, in the same year nearly all the traditional du Pont products, which did not require much coordination, made profits (Chandler, 1962, p. 95). Moreover, while du Pont suffered heavy losses for some new products such as paints, most of its competitors who were specialized in paints did not have similar coordination problem like du Pont and "were enjoying one of their most profitable years" (Chandler, 1962, p. 92).

In the early 1920, a subcommittee under the Executive Committee at du Pont investigated and concluded that "the underlying problem was not one of selling, but organization." The subcommittee proposed to change du Pont into a multi-divisional organization. This conclusion was further confirmed when du Pont suffered even bigger losses in 1921 after every effort was made to improve informational channels while keeping the U-form under the President Irénée du Pont (Chandler, 1962, pp. 96-101). Later in 1921, the failure to improve the organization's performance and the persistent losses convinced du Pont to reorganize the firm into an M-form. This solved the problem, and the organizational form has been kept stable since then (Chandler, 1996, pp. 104-113).

The second case is about Sears. Before 1925, Sears, the largest mail-order firm in the U.S., was organized as a U-form. At the headquarters in Chicago, there were departments responsible for specialized functions nationwide, such as the Merchandise Department responsible for procurement, the Catalogue and Advertisement Department responsible for sales, and the Operating Department responsible for distributing commodities from producers to customers (Chandler, 1962, pp. 226-232). The U-form structure worked well when the number of regions covered and the number of stores were not too large.

When Sears expanded to many new territories, acquired a large number of new stores and factories, and involved in new businesses such as retailing, coordination problems became severe. Many idiosyncratic regional issues were hard to manage through separate functional departments. To manage the vast multi-regional mail-order/retail network while keeping the U-form structure, Sears put territorial officers in charge of handling territorial-specific issues by giving them authority on their region's personnel issues (Chandler, 1962, pp. 253-256). However, without the authority to coordinate problems locally, this structure did not work. In fact, on many occasions, instead of reporting to functional departments, local shops often relied on territorial officers to solve their problems (Chandler, 1962, p. 259). In 1939, Sears started a reorganization based on a territorial principle and completed in 1948: under the headquarters there were multi-functional and autonomous territorial divisions, such as the Midwestern Zone, the North-Western Zone, the North Central Zone, etc (Chandler, pp. 268-282).

The third case concerns the Ford Motors Company. Before World War II, with a U-form organization and a focus on the T-model car, Ford was the largest car producer in the U.S. and its engineers were among the most innovative ones. Ford also developed inexpensive tractors and technically excellent airplanes. However, the separated production and sales structure made the introduction of innovation difficult because of the poor coordination between production and sales.

When a new tractor was produced, to answer customers' questions, any consultation about relevant attributes between the sales unit and the production unit went through the headquarters. Misunderstandings between the sales unit and the headquarters and between the latter and the production unit were frequent. When customers preferred different features in a tractor, the sales unit had to send the attribute-change requests to the headquarters. Receiving the attribute-change command from the headquarters, the production unit might find the attributes should be adjusted in a different way, but then it would report to change the plan. After receiving the report from the production unit, the headquarters needed to talk to the sales division for the adjustment of the attributes again. As a consequence of this cumbersome communication, matching production and sales attributes became increasingly difficult. Indeed, Ford failed in producing and selling tractors and air planes although it technically made them well (Chandler, 1962, p. 301, pp. 372-373).

We next look at a case of how an M-form corporation can coordinate well between complementary tasks, thus creating organizational flexibility in introducing innovation, even when attribute compatibility is a relevant issue. We consider the case of IBM reported by Argyres (1995). The Programming Systems Division (PS) and the Personal System Division (PC) of IBM were organized as self-contained units. The headquarters made sure that applications developed in the PS and the PC divisions were compatible.

In the late 1980s, there were different innovations in the two divisions. The PS division was developing a very large-scale software called "the Systems Application Architecture" (SAA) aiming to allow different hardware and operating systems to exchange data; and the PC division was developing PS/2 operation system and related applications to compete with other PC makers. Facing tough outside competition, the PC division was desperate to incorporate "cc:Mail" (a communication software) and "Notes" (a multi-task software from Lotus Development Corporation). The M-form of IBM allowed the PS division and the PC division to implement their innovations separately first. As it was the policy of IBM that all the systems had to be SAA-compliant, attribute compatiibility, i.e. SAA compliance, was made later by the headquarters.

B. Transition Economies

We may regard a centrally planned economy as a huge "firm" with the national government as the headquarters and ministries or subnational governments as sub-units of the firm. In this perspective, Eastern Europe and the former Soviet Union (EEFSU) economies were organized as a gigantic U-form, where each state-owned enterprise was under the control of a single ministry which specialized in administering one type of product. Typically, the degree of industrial concentration was high, so was interdependence across regions. This requires comprehensive administrative coordination at the center.[9]

[9] Before the transition, there was only a single producer in the whole Soviet Union for a large number of consumer

In contrast, the Chinese economy was organized as an M-form, where most state-owned enterprises were under the control of regional governments. Typically, production of each region was relatively self-contained. Correspondingly, the size of Chinese enterprises was much smaller, and industries were much less concentrated than the EEFSU. With regional governments taking major responsibilities of coordination, the central government's role of coordination was greatly reduced compared to that in the EEFSU.[10]

According to our theoretical analysis, the introduction of reforms (be they reforms within the central planning system or market-oriented reforms) in the EEFSU requires a comprehensive approach with coordination from the center. On the other hand, in China, reforms can proceed with local experiments, or even parallel experiments, because coordination is established locally. Indeed, we demonstrate below that, plagued by coordination problems, many previous reform experiments in the EEFSU had not been successful. In contrast, China repeatedly has adopted successfully an experimental approach to reforms.

We first consider the agricultural reform. The organization of the Soviet agriculture is the one of U-form, where tractors were provided centrally by the so-called MTS stations. The tasks of providing inputs to the farmers and managing their operations, storage, processing, transport, and road infrastructure were all allocated to separate agencies (van Atta, 1993a). Warehouses and processing plants were more likely to be located hundreds of miles away from farms. Farming was subordinate to at

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goods and producer goods (e.g. sewing machines, freezers, hydraulic turbines, and 87 percent of all the 5,885 products in machine building industry). In general, for about two thirds of all the products in the Soviet Union there were no more than three producers in 1988 (IMF et al., 1991, Vol. II, pp.39-40). This structure makes central coordination essential: in the late 1970s the *Gosplan* in the Soviet Union was responsible for 48,000 plan "positions" and 12 million products (Nove, 1983).

[10] Compared with the overwhelming responsibilities of the *Gosplan*, the Chinese State Planning Commission was never responsible for more than 1,000 products (Qian and Xu, 1993). Correspondingly, the central statistical agency in the Soviet Union had 41,000 staff (in 1987) while China had only 280 (in 1981) (Huang, 1994). We further note that the different organizational forms between China and the EEFSU is not due to the different sizes of the corresponding economies. In fact, China's central statistical agency was even smaller than that in Hungary, which is about 100 times smaller than China in terms of population. A comparison between Hungary and a small Chinese province, Hainan, may further illustrate the point. Hungarian ministries controlled most of the firms before the transition. However, the control of firms in Hainan is distributed at different levels of hierarchy, although Hainan is

least 8 different ministries (Butterfield, 1990).[11] Local authorities had no control over farming and played mainly a role of expediters, throwing themselves in the search for batteries, belts and harvester blades, undoing complex knots in the supply system (van Atta, 1993b). There were serious coordination problems.

These coordination problems could not be solved within the U-form despite repeated attempts to improve the situation. For example, in the 1980s, a structure called RAPO (*raïonnoe agropromyshlennoe obyedinenie*) was created with the task to coordinate locally activities between the various ministries. Nevertheless, the existing U-form structure was kept in place. This led to a conflict of authority between the functional ministries and the new local coordination structure. The RAPOs did not have the power over resources controlled by the ministries and they were generally ignored by the latter. Other attempts at reforms such as the introduction of an overarching ministry *Gosagroprom*, the introduction of agrofirms at a smaller scale and even the introduction of leasing contracts (*arenda*) also failed to improve coordination (Butterfield, 1990). When the Soviet system collapsed, the U-form organization had left a difficult legacy for potential private Russian farmers: a high average farm size (60 hectares per household compared to 2/3 hectares in China), an important dependence on machinery and supplies, outside transport and storage, high capital requirements, etc.

The lack of development of private farming stands in stark contrast to the success of the Chinese agricultural decollectivization. In China, the well-publicized agricultural household responsibility system was developed through the initiatives of local governments. Local government officials in Fengyang County, Anhui province, took the initiatives and coordinated related tasks, such as land distribution, grain procurement, chemical fertilizer supply, etc. Only later that the central government endorsed and promoted such a practice nationwide.

We next consider the industrial reform. The Soviet government launched several SOE reforms

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smaller than Hungary, in terms of both population and GDP.

[11] There may well be political motives in the design of economic institutions to prevent the reemergence of independent, private farms by making farming completely dependent on the specialized organization of production.

between the 1960s and the 1980s. Most of these reforms started with experiments giving a small number of SOEs increased autonomy and incentives. Usually these experiments gave positive results when the number of SOEs involved was very small. Central authorities then generally made sufficient resources available for the experimenting firms so that coordinating supplies and deliveries, matching attributes of products, etc. would not be a problem. However once the number of involved SOEs became sufficiently large, the task of matching attributes between experimenting SOEs and the experimenting ministries become a formidable coordination nightmare for the *Gosplan*. SOE autonomy was then taken away in order to allow *Gosplan* to regain control over the coordination process (Hewett, 1988, p. 271). Those reforms and their consequences appeared as the so-called decentralization-centralization cycles (Hewett, 1988, p. 243).

For example, the so-called "Liberman reform" attempted to reduce the number of planned indicators, giving enterprise autonomy and replacing output indicators by profit as the main success indicator to determine managerial bonuses. The reform was introduced in 1965 to Bolshevichka and Maiak clothing factories and seemed effective in improving their productivity. However, when the experiment was expanded and generalized, the coordination problem dragged the experiment into chaos (Hewett, 1988, p. 230). Again, in 1983 under Andropov, a small number of SOEs in two ministries were given increased incentives and autonomy. With some preliminary success in 1986 in those SOEs, the experiment was expanded into 5 more ministries. However, the enlarged experiment failed again due to the coordination problems (Hewett, 1988, pp. 260-267). The example of a machine-building SOE, *Iuzdizelmash*, illustrates how the coordination problem under the U-form hinders reform. Given improved incentives, *Iuzdizelmash* developed a new engine. However, replacing the old model by the new model required complicated coordination with all involved SOEs and ministries. Overwhelmed by those coordination problems, *Gosplan* simply refused the replacement (Hewett, 1988, pp. 265-266).

Although the Chinese SOE reform has had serious problems, such as the soft budget constraint problem, it was relatively more successful than that in the EEFSU. In particular, the failures in coordinating changes were not a major problem in China as in the EEFSU. The Chinese M-form structure facilitated local experiments in the SOE reforms.

The Chinese SOE reform began in 1978 when Sichuan province started experimenting to give autonomy to enterprises in a small number of SOEs. The experiment augmented enterprises control rights and awarded them according to their performance (*kuoquan rangli*) by combining their responsibilities, rights, and benefits (*zequanli jiehe*). The reforming SOEs were allowed to keep a proportion of profits as their employees bonus and as their self-investment fund, which were set by regional governments. Moreover, regional governments were still responsible for coordinating supplies for essential inputs of the reforming SOEs. In 1979, the experiment was promoted to 140 SOEs province-wide in Sichuan; in 1980, about 16 percent of SOEs in China participated in this experiment (Liu, 1998, pp. 26-32) while most of the experiments were coordinated by local rather than central governments.

The case of Chongqing Clock and Watch Company (hereafter referred to as the Clock Company) illustrates how coordination under the M-form helped the SOE reforms. The Clock Company is one of the largest watch manufacturers in China and is under the supervision of the Chongqing Municipal government in Sichuan Province. It was a pioneer in several major province-wide (and nationwide) reform experiments (Byrd and Tidrick, 1992, p. 59). In the early 1980s, the Clock Company was given substantial autonomy and incentives. The company's activities and interactions with other SOEs were coordinated through relevant industrial bureaus of the municipal government. With the relative ease of coordinating, the regional government agents were flexible to adjust their planning targets when there were unexpected shocks (Byrd and Tidrick, 1992, p. 94-96). Moreover, the municipal government coordinated the Clock Company to merge with other SOEs, and to form associations or joint ventures with other SOEs within the city. By having access to more resources, the mergers and joint ventures gave the Clock Company even more autonomy and incentives and further simplified coordination problems of the regional government (Byrd and Tidrick, 1992, pp. 68-72).[12] Later, when the reforms experimented in the Clock Company were generalized, similar coordination mechanisms were also provided by the corresponding regional governments.

The later SOE reform of the "contract responsibility system" (*chengbao jingying zhi*) (a contract between a SOE and its supervisory regional government reflecting the regional plan targets for the enterprise), which was started in 1987, was also based on regional experiments. Regional governments coordinated the reforms.

Finally, we consider privatization of state-owned enterprises. After the collapse of the Soviet Union, Russia's mass privatization program was coordinated from the center. Given the industrial structure inherited from the U-form organization, local initiatives to privatize large enterprises could have created problems given both the extreme form of specialization and the geographical dispersion of complementary assets.

In China by contrast, privatization was driven by local government initiatives. Experiments of privatization began in some counties (e.g. Yibin of Sichuan Province, Shunde of Guangdong Province, and Zhucheng of Shandong Province) around 1993. Having controls over most of the related issues, county governments could try out different ways of privatizing according to the local environment. Indeed, in the privatization process county governments took responsibilities to coordinate most of the related activities and policies, such as issues concerning corporate governance, ownership structure, bad debts, taxes, and excess workers, etc. This experimental approach not only makes local privatization smooth, it helps other regions as well. By imitating some of the successful experiments, at the end of 1996, in many provinces about two thirds to one half of small SOEs had been privatized.[13]

Similarly, with respect to state enterprise restructuring, responsibilities for coordinating layoffs, social welfare, and reemployment of the unemployed workers were delegated to provincial and municipal

[12] This is in a sharp contrast with the case of Soviet Union where branch ministries were responsible for coordination and the mergers of SOEs were usually within the ministry.

[13] In a few years about 80,000-90,000 people from other provinces visited Zhucheng to learn their privatization

governments. A few cities and provincies (such as Shanghai and Helongjiang) started this reform and experimented with different approaches to solve their particular problems in the mid-1990s.[14] These experiences and lessons of them were later learned by other cities and provinces, which made restructuring in other regions smoother.

C. The Organization of Government and the Foundations of Federalism

Two organizational forms of government have received much attention: unitary state and federalism. Our analysis starts to provide a theoretical foundation of both, especially federalism.

France, Japan and the U.K., among others, have a unitary state, and their governments are mainly organized along functional lines where specialized ministries concentrate most powers, leaving regional governments with very little authority. Consider the example of higher education in France. There, major decisions (curriculum, hiring, promotion, budgetary allocations) are decided at the central level. This leaves very little scope for local experimentation with reform. For example, attempts to create top level Ph. D. programs in economics require tremendous coordination with the central ministry.

The organizational form of the government in the United States is the primary example of federalism. The fifty states in the American federalism have the constitutional rights and responsibilities for coordinating governemnt activities inside their states, and the federal government cannot intervene.

In the early 20th century, the American Supreme Court Justice, Louis Brandeis, had a famous characterization of American federalism as the "laboratory of the states." Indeed, many changes of legal

approach (*Economic Daily*, March 29, 1996).

[14] Shanghai municipal government funded "reemployment service centers," which served as "trust institutions" for those laid off workers. Backed with the municipal government these centers are responsible to coordinate all the social welfare and reallocation tasks for unemployed workers, such as paying subsistence support, clinic fees, and training workers for new jobs. In Heilongjiang province, featured by abundant uncultivated land but shortage of funding, a different approach of restructuring was experimented. Coordinated by a municipal government, a SOE tried out a layoff-reallocation scheme. In this scheme, 1/3 of the employees was reallocated to new tertiary industries, and 1/3 of the employees was reallocated to agriculture with an exemption on land and agricultural taxes. The provincial government later promoted this practice in other cities and other industries.

rules and government policies were initiated by some states, and these experiments were later imitated by other states. For example, several important propositions were first voted in by the Californian voters, such as ...., they were also later adopted by other states. There was also an experiment on health care reform in Florida and Hawaii.

VII. Concluding Remarks

In this paper we introduced a method of modelling coordination inside an organization as a process of "attribute matching." Using this method, we developed a theoretical analysis of organizational forms in order to understand the performance of the M-form and U-form organizations in coordinating changes. Our theory sheds new lights on business organizations, transition economies, and the organization of government.

Our paper seems to be the first formal attempt to study how the M-form and U-form affect coordination problems within an organization. The paper mainly aims at providing a new conceptual framework, while it also derives some predictions on the superiority of the M-form or the U-form depending on the quality of communication within organizations, the uncertainty of innovations and the costs of introducing innovations. This paves the way for empirical analysis in the comparison of organizations in the future.

The application of our analysis to transition economies opens new perspectives to understand how the differences in organizational forms in the EEFSU and China affected their transition paths. We, for the first time, addressed formally the following questions: Why is China special in using experimental approaches? Why is U-form not suitable in doing experiments locally? The importance of our understanding those questions lies in the fact that in the EEFSU, some experimental reforms were introduced before their transition but failed. On this basis, the regional experimental approach to reform a planned economy has been discredited and abandoned during the later transitions in these economies.

The difference between M-form and U-form is highly relevant in other aspects.

Note first that the consequences of a collapse of power at the center are much smaller in the M-form. For example, during the Cultural Revolution (1966-1976), the Chinese central government lost almost completely its ability of coordination on the economy but the national economy did not collapse: National income dropped in two years (-7.2% in 1967 and -6.5% in 1968) and recovered quickly afterwards without much central government coordination.

In the context of transition and price liberalization, where government coordination is replaced by market forces, the output response is likely to be different in both organizational forms. In a U-form economy with greater induced specialization and more widespread monopolies, price liberalization gives smaller outside options to firms in the domestic economy, in terms of finding new suppliers and/or clients while making disruptions of existing output links more dramatic. In line with the models of the output fall of Blanchard and Kremer (1997) and Roland and Verdier (1999), this leads to a more dramatic output decline. Blanchard and Kremer (1997) have emphasized the role of complexity in technological complementarities between firms in generating disruption. In our framework, complexity is not simply an exogenous technological variable. The choice of technology is affected by the organizational form. Even for a given technology, the M-form reduces the complexity of coordination due to the decentralization of decision-making to self-contained units. In contrast, by centralizing communication on attribute shocks, the U-form makes coordination more complex.

In the U-form economy, the higher degree of monopolization is likely to give single firms more holdup power over the government, possibly leading to more rent-seeking and soft budget constraints whereas in the M-form economy, competitive forces are likely to develop more easily from scratch, with single firms having less holdup power and less leverage via the government. The larger firms left by the U-form economy are likely to require more sophisticated management expertise to operate in the global economy compared to their counterparts in the M-form organization. A lack of fulfillment of requirements in terms of management expertise may lead to more disappointing results of privatization.

Appendix. Mathematical Proofs

Proof of Lemma 1: (1) Because

$$ð_{u2} = 2pð[1 - (1-ë^2)^2ä]/\{1-ä[p(1-ë^2)^2+(1-p)]\},$$

where both $ð = ë^2A/\{2(1-ä)[1-(1-ë^2)ä]\}$ and $[1-(1-ë^2)^2ä]/\{1-ä[p(1-ë^2)^2+(1-p)]\}$ increases in $ë$ (the latter because $[1-xä]/\{1-ä[px+(1-p)]\}$ decreases in x), then $ð_{u2}$ increases in $ë$.

(2) $c_{u2} = C/\{1-[p(1-ë^2)^2+(1-p)]ä\}$ decreases in $ë$.

$c_{u2} < c_{m2}$ if and only if

$1 - ä(1-p) < 2[1-ä(p(1-ë^2)^2+1-p)]$

if and only if

$2äp(1-ë^2)^2 + ä(1-p) < 1,$

which is valid for all $ë$ provided $ä < 1/(1+p)$.■

Proof of Proposition 1: (1) By Lemma 1, at $ë = 1$, $ð_{u2} = ð_{m2}$; but $c_{u2} = C/(1-ä(1-p)) < c_{m2} = 2C/(1-ä(1-p))$, then $U_2 > M_2$. Also by Lemma 1, $ð_{u2}$ increases in $ë$ and c_{u2} decreases in $ë$, then $U_2 = ð_{u2} - c_{u2}$ increases in $ë$. Because M_2 is independent of $ë$ and because U_2 goes to 0 as $ë$ decreases, then for p and C given there exists $ë > 0$ such that $M_2 > U_2$ if and only $ë < ë$.

(2) For any $ë < 1$, $M_2 > U_2$ at $C = 0$. When $c_{u2} < c_{m2}$, c_{m2} also increases faster than c_{u2} as C increases, therefore, for p and $ë$ given, such a C exists. (U_2 could be the same as M_2 if both have the same value as the status quo at C.)

Proof of Lemma 2: (1) Note that $pA(1+ä)/2+(1-ä)/2$ is a weighted sum of pA and 1. Therefore, because $pA > 1$ by Assumption 1, then the sum is less than pA, or $ð_{m1} < ð_{m2}$.

(2) Because $dð_{m1}/dp = [A(1+ä)/2 - ä/2]/[1-(1-p)ä]^2$ and $dc_{m1}/dp = -ä^2C/[1-(1-p)ä]^2$, we have:

$$dM_1/dp = [A(1+ä)/2 - ä/2 + ä^2C]/[1-(1-p)ä]^2 > 0.$$

Also because dð$_{m2}$/dp = A/[1-(1-p)ä]^2 and dc$_{m2}$/dp = - 2Cä/[1-(1-p)ä]^2, then we have

dM$_2$/dp = {A + 2Cä}/[1-(1-p)ä]^2 > 0.

Therefore, by A(1+ä)/2 < A, äC - 1/2 < 2C, we have A(1+ä)/2 - ä/2 + ä^{2}C < A + 2Cä, then, dM$_2$/dp > dM$_1$/dp > 0.■

Proof of Proposition 2:

(1) Because

M$_1$ - M$_2$ = {pA/2(1+ä) + (1-ä)/2 - pA - (1-ä)C(1+pä) + 2C(1-ä)}/(1-ä)[1-ä(1-p)]

= [C(1-pä)-(pA-1)/2]/[1-ä(1-p)],

then M$_1$ > M$_2$ if and only if p < . Furthermore, < 1 if and only if A/2(1-ä) - C > 1/2(1-ä).

From M$_1$ = 1/(1-ä) we obtain:

p$_{m1}$* = (2C+1)(1-ä)/{A(1+ä)-2ä(C(1-ä)+1)},

and from M$_2$ = 1/(1-ä) we obtain:

p$_{m2}$* = (2C+1)(1-ä)/(A-ä).

Then p$_{m1}$* < p$_{m2}$* if and only if A/2(1-ä) - C > 1/2(1-ä).

By Lemma 2, p$_{m1}$* < p$_{m2}$* must imply that p$_{m1}$* < p$_{m2}$* < .

(2) follows directly from the expression for M$_1$-M$_2$. ■

Proof of Proposition 3: We note that

ð$_{u2}$ = p{ë^4[A/(1-ä)] + 2ë^2(1-ë^2)[A/2(1-ä) +äð]}/{1-ä[p(1-ë^2)^2+(1-p)]}

= p{ë^4[A + äA/(1-ä)] + 2ë^2(1-ë^2)[A/2 + ä[ð + A/2(1-ä)]]}/{1-ä[p(1-ë^2)^2+(1-p)]}.

Comparing ð$_{u2}$ with ð$_{u1}$, because A > (A+1)/2 and A/2(1-ä) ≥ ð, then ð$_{u2}$ > ð$_{u1}$.■

<u>Proof of Proposition 4:</u> (1) For ë = 1, $ð_{u2}$ = $ð_{m2}$ > $ð_{m1}$ and $c_{u2} < c_{m1} < c_{m2}$. Therefore, for ë large enough, by continuity, $U_2 > M_2$ and $U_2 > M_1$.

(2) If ë is small enough, U_2 will always be dominated by M_1 or M_2. The rest of the proposition follows directly from Proposition 2.■

<u>Proof of Proposition 5:</u> $ð_{m11}$ > $ð_{m2}$ if and only if

$$\{A(p^2+p(1-p)(1+ä))\}/(1-ä)[1-ä(1-p)^2] > pA/\{(1-ä)[1-(1-p)ä]\},$$

if and only if

$$[1-ä(1-p)](p^2+p(1-p)(1+ä)) > p(1-ä(1-p)^2),$$

if and only if

$$[1-ä(1-p)](1+ä(1-p)) > 1-ä(1-p)^2,$$

if and only if

$$1-ä^2(1-p)^2 > 1-ä(1-p)^2,$$

which is verified since ä < 1.

Similarly, $c_{m11} < c_{m2}$ if and only if

$$2C[1+äp(1-p)]/[1-ä(1-p)^2] < 2C/[1-(1-p)ä],$$

if and only if

$$(1-ä(1-p))(1+äp(1-p)) < 1-ä(1-p)^2$$

if and only if

$$ä^2p(1-p)^2 > 0,$$

which is verified.■

<u>Proof of Proposition 6:</u> (1) $ð_{m11}$ > $ð_{m1}$ if and only if

$$\{A(p^2+p(1-p)(1+ä))\}/(1-ä)[1-ä(1-p)^2] > [pA(1+ä)+(1-ä)]/2(1-ä)[1-(1-p)ä],$$

if and only if

$$2\{A(p^2+p(1-p)(1+ä))\}[1-(1-p)ä] > [pA(1+ä)+(1-ä)][1-ä(1-p)^2],$$

if and only if

$$[2pA][1-ä^2(1-p)^2] > [pA(1+ä)+(1-ä)][1-ä(1-p)^2].$$

Because $pA > 1$ if and only if $2pA > pA(1+ä)+(1-ä)$, furthermore, $1-ä^2(1-p)^2 > 1-ä(1-p)^2$, then the above inequality holds.

Similarly, $c_{m11} > c_{m1}$ if and only if

$$2C[1+äp(1-p)]/[1-ä(1-p)^2] > C(1+pä)/[1-(1-p)ä],$$

if and only if

$$2 - 2ä(1-p)^2 - 2ä^2p(1-p)^2 > 1 - ä(1-p)^2 + pä - ä^2p(1-p)^2,$$

if and only if

$$1 > ä[p + (1-p)^2 + äp(1-p)^2],$$

if and only if

$$1 - ä > -äp(1-p)(1-ä(1-p)),$$

which is always valid since $1 > ä(1-p)$.

(2) $M_{11} > M_1$ if and only if

$$\{A(p^2+p(1-p)(1+ä))-2C(1-ä)(1+äp(1-p))\}[1-ä(1-p)]$$

$$> \{pA(1+ä)/2+(1-ä)/2-C(1-ä)(1+pä)\}[1-ä(1-p)^2]$$

if and only if

$$A(p^2+p(1-p)(1+ä)-pA(1+ä)/2-(1-ä)/2+C(1-ä)(1+pä)-2C(1-ä)(1+äp(1-p))$$

$$> ä(1-p)\{A(p^2+p(1-p)(1+ä))-2C(1-ä)(1+äp(1-p))-(1-p)[pA(1+ä)/2+(1-ä)/2-C(1-ä)(1+pä)]\}$$

if and only if

$$(pA-1)(1-ä)/2+pAä(1-p)-C(1-ä)[1-pä(2p-1)]$$

$$> ä(1-p)\{pA[1+ä(1-p)+p]/2-(1-p)(1-ä)/2-C(1-ä)(1+p+äp(1-p))\}$$

if and only if

$$(pA-1)(1-ä)/2+pAä(1-p)-ä(1-p)[pA(1+ä(1-p)+p)/2-(1-p)(1-ä)/2]$$

$$> C(1-ä)[1-pä(2p-1)]-ä(1-p)C(1-ä)(1+p+äp(1-p))$$

if and only if

$$(pA/2)[1-ä+2ä(1-p)-ä(1-p)(1+p+ä(1-p))]-(1-ä)(1-ä(1-p)^2)/2$$

$$> C(1-ä)[1-pä(2p-1)-ä(1-p)(1+p+äp(1-p))]$$

if and only if

$$(pA/2)[1-ä+ä(1-p)(1-p-ä(1-p))]-(1-ä)(1-ä(1-p)^2)/2$$

$$> C(1-ä)[1-ä+äp(1-p)(1-ä(1-p))]$$

if and only if

$$pA(1+ä(1-p)^2) > 2C[1-ä+äp(1-p)(1-ä(1-p))]+(1-ä(1-p)^2).$$ ■

<u>Proof of Proposition 7:</u> (1) If p=1, we know from proposition 2 that M_2 dominates M_1. It is easy to check that M_{11} and M_2 are equivalent and equal to A/(1-ä) - 2C. If ë = 1, then U_2 = A/(1-ä) - C which clearly dominates. If p < 1 but ë = 1, $U_2 > M_1$, because $ð_{u2} = ð_{m2} > ð_{m1}$ and $c_{u2} < c_{m1}$. At ë = 1, $U_2 > M_{11}$ if and only if

$$[pA-C(1-ä)]/(1-ä)[1-ä(1-p)] > \{pA(1+ä(1-p))-2C(1-ä)(1+äp(1-p))\}/(1-ä)[1-ä(1-p)^2]$$

if and only if

$$(1-ä(1-p)^2)(pA-C(1-ä)) > [1-ä(1-p)]\{pA(1+ä(1-p))-2C(1-ä)(1+äp(1-p))\}$$

if and only if

$$pA\{(1-ä(1-p)^2)-[1-ä^2(1-p)^2]\} > C(1-ä)\{(1-ä(1-p)^2)-2(1+äp(1-p))(1-ä(1-p))\}$$

if and only if

$$-pAä(1-p)^2 > -C[1-ä(1-p)^2(1+2äp)]$$

if and only if

$$pAä(1-p)^2 < C[1-ä(1-p)^2(1+2äp)].$$

We verify that 1 > $ä(1-p)^2(1+2äp)$ for all p and ä < 1. Therefore, when $C > C^2 = pAä(1-p)^2/[1-ä(1-$

$p)^2(1+2äp)]$, $U_2 > M_{11}$ at ë = 1.

(2) If ë is low enough, then U_2 is dominated. By proposition 6, M_1 dominates if and only if $C > C^1$.

(3) By Proposition 5, M_{11} always dominates M_2. By Proposition 2, $M_2 > M_1$ for p > . Therefore, $M_{11} > M_1$ for p > . Again if ë is low enough, U_2 is dominated. The rest follows from proposition 6. Because M_{11}, M_1 and M_2 are independent of ë, for such p, $M_{11} > U_2$ for low enough values of ë . Similarly, because both M_{11} and M_1 are independent of ë and, by Proposition 6, M_{11} dominates M_1 for $C < C^1$. For any such C, U_2 goes to 0 when ë becomes small, then M_{11} also dominates U_2 for ë low enough. From the proof of (1), we know that $M_{11} > U_2$ if ë = 1 and $C < C^2$.■

<u>Proof of Proposition 8:</u> Because

$$(ð_{m2} - ð_{m1})\{1-ä[p(1-ë^{4k})+1-p]\} = p\{ë^{4k}(A + äA/(1-ä) - (A+1)/2 - äð_k\} - (1-p)ë^{4k}/2$$

$$= pë^{4k}[A/2 + äA/(1-ä) - äð_k] + (-p-1+p)ë^{4k}/2$$

$$= pë^{4k}ä[A/(1-ä) - ð_k] + ë^{4k}(pA - 1)/2.$$

Since $ð_k = A/(1-ä)$ for k = 0 and decreases in k, $ð_k \leq A/(1-ä)$. Therefore, as $1-ä[p(1-ë^{4k})+1-p] > 0$ and $pA > 1$, $ð_{m2} > ð_{m1}$.■

<u>Proof of Proposition 9:</u> (1) Given any ë < 1 and p, $ð_{u2}$ is independent of k and $ð_{m2}$ is a decreasing function of k. For ë < 1, $ð_{m2} > ð_{u2}$ at k = 0, therefore, such k* exists. In particular, at p = 1,

$$ð_{m2}/ð_{u2} = ë^{4k}[(1-(1-ë^2)ä]/ë^2[1-(1-ë^{4k})].$$

Then k*(ë, 1) = 1/2.

(2) We have:

$$ð_{m2}/ð_{u2} = ë^{4k-2}(1-(1-ë^2)ä)\{1-ä[p(1-ë^2)^2+1-p]\}/[1-ä(p(1-ë^{4k})+1-p)][1-(1-ë^2)^2ä],$$

from which we derive:

$$d(ð_{m2}/ð_{u2})/dp > 0$$

if and only if

$$- [1-ä(p(1-ë^{4k})+1-p)][(1-ë^{2})^{2}-1] + [1-ä(p(1-ë^{2})^{2}+1-p)][(1-ë^{4k})-1] > 0,$$

if and only if

$$(1-ä)[(1-ë^{4k})-(1-ë^{2})^{2}] > 0.$$

Let $k^*(ë)$ be such that $1-ë^{4k^*(ë)} = (1-ë^{2})^{2}$, then $0 < k^*(ë) < 1/2$ and $d(ð_{m2}/ð_{u2})/dp > 0$ if and only if $k > k^*(ë)$.

By part (1), at $p = 1$, $ð_{m2} > ð_{u2}$ if and only if $k < 1/2$. Then, for $k > 1/2$, $ð_{m2} < ð_{u2}$ at $p = 1$, then $d(ð_{m2}/ð_{u2})/dp > 0$ implies that $ð_{m2} < ð_{u2}$ for all p. For $k^*(ë) < k < 1/2$, $ð_{m2} > ð_{u2}$ at $p = 1$, then $d(ð_{m2}/ð_{u2})/dp > 0$ implies that there exists p such that $ð_{m2} > ð_{u2}$ for $p > p^*$ and $ð_{m2} < ð_{u2}$ for $p < p^*$. For $k < k^*(ë)$, $ð_{m2} > ð_{u2}$ at $p = 1$, then $d(ð_{m2}/ð_{u2})/dp < 0$ implies that $ð_{m2} > ð_{u2}$ for all p.■

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[1]... A local manager engaging a particular task has first-hand information and knowledge about that task, and thus "local" here may no necessarily carry a geographic meaning.