COORDINATING TASKS IN M-FORM AND U-FORM ORGANISATIONS*

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Abstract

We model the coordination of specialised tasks inside an organisation as "attribute matching". Using this method, we compare the performance of organisational forms (M-form and U-form) in implementing changes such as innovation and reform. In our framework, organisational forms affect the information structure of an organisation and thus the way to coordinate changes. Compared to the U-form, the M-form organisation achieves better coordination but suffers from fewer economies of scale. The distinctive advantage of the M-form is flexibility of experimentation, which allows the organisation to introduce more innovation and reform. The theory is illustrated by the organisational differences between China and the former Soviet Union and sheds light on their different reform strategies, particularly with regard to the prevalence of the experimental approach in China.

Keywords: Coordination, task, organisation, reform, innovation, China, Russia.
JEL Nos.: D20, D80, H11, H70, L22, P11.

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"Organizations are systems of coordinated action among individuals and groups."

James March and Herbert Simon, *Organizations*, 2nd edition, 1993

1 Introduction

Understanding how economic activities are coordinated inside organizations has always been one of the most fascinating questions in economics. Since Adam Smith, economists have recognized that the benefit of organizing large-scale production comes from coordinated specialization. When there is no specialization, all agents perform the same operations, there is then no need for coordination and no gain from having agents work together in one organization. Coordination becomes crucial whenever there is specialization. On the other hand, coordination is also costly, which limits the extent of specialization within organizations (Becker and Murphy, 1992).

The coordination problem in organizations is less well understood than the incentive problem. For example, most models of coordination feature costs of coordination in reduced form. Lack of a workable model of coordination is a reason for our poorer understanding of coordination inside organizations. In this paper, we introduce a model based on the concept of coordination as matching the attributes of specialized tasks. This concept is inspired by the notion of "design attributes" first introduced by Milgrom and Roberts (1990, 1992) in their studies of the organization of firms. Using the concept of design attributes, Milgrom and Roberts studied alternative forms of communication (e.g., prices or planned attributes) that should be used to coordinate a given decision. They find that non-price communication is optimal when errors of "fit" are very costly and the number of alternative possible designs that fit well is large. While Milgrom and Roberts focus on the form of communication, we make use of this concept to examine how alternative organizational forms affect communication channels and thus coordination when the need for attribute matching is pervasive.

Task coordination is like assembling complementary parts, such as the assembling of subroutines for a software package, synchronizing travel plans and accommodating logistics for a conference, reforming an economy by restructuring enterprises and establishing corresponding social safety nets and legal institutions, etc. Each complementary part is characterized by its attributes in dimensions such as time, location, technical specifications, 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. In

an assembly line 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 into the body of a mini-Morris, a software package will not work unless all the subroutines fit to each other, and a conference will be a disaster if room allocation conflicts with other academic programs. Note that our concept of coordination differs from the coordination problem in games with multiple equilibria.

The attribute matching problem is especially pervasive in implementing changes such as innovation and reform within an organization, because by its nature such a problem cannot be solved by automation. In these situations, it is not sufficient to match all attributes in blueprints. Blueprints are often imperfect and incomplete, leaving room for unexpected contingencies. For example, blueprints for reforms do not specify details of attribute changes, because most of the attribute changes, which are induced by reforms, are not well understood at the time a blueprint is designed. Attribute mismatches in implementing innovations and reforms, which we call "attribute shocks," are thus inevitable. Coordination is then especially important to respond to those unexpected contingencies.

But the quality of the coordination, i.e. the adjustment of attributes depends itself on the quality of communication inside an organization. The communication problem arises because only managers directly and frequently engaging in a particular task have first-hand information and knowledge about that task. Communication is necessary for others to use such information and knowledge, but communication is likely to be imperfect because message transmission, due to technical bugs as well as human misunderstanding, can go wrong. Hayek's (1945) famous notion of "local information," the information about particular location and circumstance, is well suited to our framework – direct involvement in a task gives rise to good knowledge about that task. The communication problems we consider do not necessarily relate to geographic distance and are more general. They arise whenever the absence of direct involvement in a task implies poorer knowledge about it. For convenience, we often refer to a manager as "local manager" and the knowledge he possesses as "local information." But the term "local" used here does not necessarily carry a geographical meaning.

It is important to note that the communication problem is endogenous, depending on how tasks and decision-making power are assigned within an organization. That is, the organizational form matters. We define an M-form (multi-divisional form) organization as one that consists of "self-contained units" where complementary tasks are grouped together. In contrast, a U-form (unitary form) organization is decomposed

into "specialized units" where similar tasks are grouped together. Because the M-form and the U-form organizations assign tasks differently, the communication problems they face are different.

In our model, a simple trade-off emerges between better coordination and less economies of scale in the M-form compared to the U-form. In the self-contained units of the M-form, local managers can more easily solve the coordination problem by making good use of local information, but then the advantages of specialization are not fully appropriated and there is duplication of local coordination. In the U-form organization, coordination of specialized units is centralized by top managers so that economies of scale are obtained, but the coordination problem is harder to solve, as the top managers have to rely on imperfect information about attribute shocks transmitted by local managers. Obviously, the M-form is better than the U-form in promoting innovation or reform if the quality of communication is low and the value of scale economies is not high.

A less obvious, but more important, result is that the M-form organization is able to promote innovation or reform through experimentation, that is, it can experiment an innovation or reform program in some part of the organization first before implementing it in the entire organization. Experimentation gives an option value of waiting when the blueprint has uncertain outcomes, which reduces the cost of learning about the quality of the blueprint. But the fundamental reason why the M-form is capable of carrying out experimentation is its organizational form: each unit is self contained and coordination is carried out by local managers. In contrast, in the U-form, the benefits of experimentation cannot be reaped because coordination is centralized.

Therefore, in addition to the common two alternatives of "no change" and "full scale change," the M-form organization has an additional alternative of "change with experimentation." In this sense, the M-form is a more flexible organizational form, which can promote more innovation or reform. In contrast, the U-form is more rigid, and if a change occurs, it happens in a comprehensive way. This rigidity tends to be deleterious for innovation or reform. The flexibility of the M-form can lead to a higher propensity to innovation or reform, an important dynamic advantage compared to the U-form.

We use the example of agricultural reforms to illustrate the relevance of our theory in understanding the reform experiences of China and the Soviet Union in the 1980s as well as Russia in the 1990s. There is a striking difference between the organization of the Soviet planning administration on one hand, and that of the Chinese planning administration, on the other hand (Qian and Xu, 1993). The Soviet economy was organized into many specialized or functional ministries (e.g., Ministry of Cereal and Grain Production, Ministry of Tractors and Farm Machinery, Ministry of Fertilizer Production, etc.). This corresponds to a

U-form organization (also known as "branch organization"). In contrast, the Chinese economy has been organized mainly on a geographical basis. This corresponds to an M-form organization (also known as "regional organization"). According to our theory, the Chinese economy with its M-form structure is prone to reform via regional experimentation. On the other hand, when reform comes in the Soviet U-form economy, it is comprehensive and coordinated from the center, and thus more difficult to do. While the contrast between "big-bang" approach in Eastern Europe and Russia and the "experimental" approach in China has been well recognized in the literature (e.g., McMillan and Naughton, 1992; Dewatripont and Roland, 1997; Sachs and Woo, 2000), our paper goes one step further to investigate the deeper reasons of how the pre-reform organizational differences have led different countries to pursue different strategies. It also accounts for the numerous coordination failures of comprehensive reforms in the Soviet Union.

The notion of M-form and U-form organizations was pioneered by the influential works of Chandler and Williamson. Chandler (1962, 1977) documented important cases of some large American corporations that replaced the U-form corporate form by the M-form in the first half of the 20th century. According to Chandler, serious problems arose under the U-form between functional departments, such as production and sales, when the firm introduced new products or adopted innovations. In the case of Du Pont, before 1921 whenever a new chemical was developed such as explosives and paints, coordination difficulties resulted in too many mistakes, which convinced du Pont to reorganize the firm into an M-form with multi-divisions by products. Similarly, before 1925, Sears, the largest mail-order firm in the U.S., was organized as a U-form corporation with the headquarters in Chicago and departments responsible for specialized functions nationwide, such as procurement, sales, and distribution. When Sears expanded into many new territories and became involved in new businesses, its coordination problems became severe. In 1939 Sears was reorganized into the M-form with multi-functional and autonomous territorial divisions. Later, Williamson (1975, 1985) theorized that the overload problem of the headquarters was the main problem with the U-form corporation. He argued that, with daily operations being decentralized to self-contained divisions, the M-form corporations reduce the work overload at the headquarters and create time for top managers to engage in strategic planning.

Following Chandler and Williamson, some formal studies on the M-form and the U-form organizations have been undertaken. Aghion and Tirole (1995) analyzed how M-form and U-form organizations generate and solve the overload problem. Maskin, Qian, and Xu (2000) provide an analysis of incentive problems in M-form and U-form organizations. They have demonstrated that different organizational forms give rise to different information about managers' performance. They therefore differ according to how incentives encourage good performance. In order to focus on the coordination problem, our paper assumes away the

incentive problem and takes the team theoretical approach.[1] Our paper is also related to the management science literature that distinguishes between product-focused and process-focused corporations analyzed as the result of minimization of coordination costs in unstable environments (see, for example, Athey and Schmutzler, 1994).

The rest of the paper is organized as follows. Section 2 introduces the modelling of task coordination as attribute matching. Section 3 explores the basic thesis on the advantage of the M-form in carrying out experimentation in a model of 2 regions and 2 functions. Section 4 generalizes the model to n regions and m functions. Section 5 derives conditions under which the M-form and the U-form are optimal organizational forms. Section 6 discusses at length an empirical application of the theory to economic reforms in China and the Soviet Union (and later Russia) in the 1980s and the 1990s. Section 7 concludes by illustrating other possible applications.

2 Modelling Task Coordination as Attribute Matching

For the ease of exposition we first consider an organization with two regions "A" and "B" and two functions "1" and "2." The model allows for other interpretations such as "A" and "B" as two products and "1" and "2" as two processes. In the subsequent analysis, we will only use the term of region, which corresponds directly to our China and the Soviet Union example. Later in this paper we will consider the case with n regions and m functions. In the two by two case, there are a total of four tasks to be coordinated: $1A, 2A, 1B$, and $2B$, where task ir concerns function i in region r.

We assume an infinite time horizon. In each period, there is a flow of ideas for innovation or reform that have the potential to improve the output of the organization (without changing the structure of the organization itself). Suppose that prior to any reform, the existing technology generates payoffs of $\frac{R}{2}$ in every period in region A and in region B respectively. With the discount factor δ, the net present value of status quo (i.e., no reform) payoffs for the entire organization is given by $\frac{R}{1-\delta}$. One successful reform will raise the payoff from each region by $\frac{R}{2}$ in every period from the time the reform is introduced. That is, with a total of i successful reforms in the past in both regions, the net present value of payoffs will be $\frac{(1+i)R}{1-\delta}$.

[1] The team theory literature includes, among others, Marschak and Radner (1972) on the economic theory of teams, Weitzman (1974) on coordination using price and quantity, Crémer (1980) and Aoki (1986) on the optimal partition of workshops inside an organization, Bolton and Dewatripont (1994) on the firm as a communication network, Garicano (2000) on the organization of knowledge in production, in addition to the works of Milgrom and Roberts cited above.

The model assumes that only one reform can be carried out in each period, but there is no limit on the total number of reforms to be carried out, that is, reforms can raise payoffs without bound.

A reform faces two potential problems. The first problem concerns the quality of its "blueprint." A blueprint for reform has an uncertain outcome: it turns out to be "good" with probability p and "bad" with probability $1-p$. We assume that blueprints that are available over time are stochastically independent. Furthermore, if a blueprint turns out to be good, then it will apply equally well to two regions. A good blueprint, together with correct coordination in implementation (to be discussed below), raises the payoff from each region permanently by $\frac{R}{2}$ as described above. But a bad blueprint always reduces the payoff from each region by $\frac{R}{2}$ in every period from the time the reform is introduced. To ensure that a reform is worthwhile in expected terms, we require

Assumption 1 $p > \frac{1}{2}$.

A successful reform not only requires a good blueprint but also good implementation. At the heart of implementation is what we called "task coordination." Imagine that all reform programs are so designed that all attributes are matched perfectly *ex ante* in the blueprints. However, in implementing a program, "attribute shocks" occur which are not taken care of in the blueprints. Attributes must then be mutually adjusted to observed attribute shocks (Milgrom and Roberts, 1990, 1992). Attribute shocks can be more severe or more frequent if many of the attribute changes are not specified in a blueprint, which is quite likely with reforms. In our model, "attribute matching" will take place (and only take place) between tasks $1A$ and $2A$ within region A and between tasks $1B$ and $2B$ within region B. We call attribute matching during the reform implementation task coordination. Because there is a flow of reform blueprints arriving over time, task coordination is an on-going activity.

Although obtaining a blueprint is assumed to be costless, implementing it is not. We assume that task coordination requires a one time setup cost, which is normalized to C for two managers (and thus $\frac{C}{2}$ for each manager). This cost can be interpreted as a training cost, that is, to implement a reform blueprint managers need to be trained on how to match attributes. The following assumption ensures that the payoff increase from a good blueprint and good implementation is worth the setup cost:

Assumption 2 $\frac{R}{(1-\delta)} > C$.

Unlike blueprints, good coordination (i.e., successful attribute matching) in one region cannot be "copied" to another region, because of the differences in local conditions. For example, the same reform program which

reallocates land to household farmers may induce farmers to change to different crops in different regions, which creates different attribute matching problems. Therefore, if a blueprint tried in one region is found to be good and coordination is successful, then the same blueprint can be used elsewhere, but separate coordination is still needed in order to adjust attributes to local conditions before a successful outcome can be achieved.

In our model, it is possible that the manager who coordinates is not the manager who collects information about attribute shocks. In such a case, the coordinating manager relies on the message sent by the manager collecting information. The probability of each message being correct is λ. With $\lambda \leq 1$, information transmission is generally imperfect. Imperfect information transmission may arise from the fact that two managers have different idiosyncratic knowledge and different interpretations of the same message. They may speak different languages; for example, engineering language differs from marketing language. Moreover, their communication may be restricted to short messages (such as messages carried by phone calls, faxes, memos, meetings, etc.), which may be subject to ambiguous interpretations. Such noises in information transmission are assumed to be independent across tasks as well as over time.

We define U-form and M-form organizations as follows. A U-form organization is set up along "functional lines." Two middle managers – manager 1 and manager 2 are responsible for collecting information about attribute shocks, the former for tasks $1A$ and $1B$ and the latter for tasks $2A$ and $2B$. Because the two tasks that need attribute matching are not assigned to the same middle manager, the two middle managers need to send the information to the top manager, who, after receiving the information from the two managers, matches attributes between tasks $1A$ and $2A$ and between $1B$ and $2B$. This type of organization can be represented by Figure 1.

An M-form organization is set up along "regional lines." Middle manager A is responsible for collecting information about shocks in tasks $1A$ and $2A$, and Middle manager B is responsible for collecting information about shocks in tasks $1B$ and $2B$. Because the two tasks which require attribute matching are assigned to the same manager, the middle managers can match attributes locally by themselves. The top manager's job is just to provide reform blueprints and to decide the reform strategy. This type of organization can be represented by Figure 2.

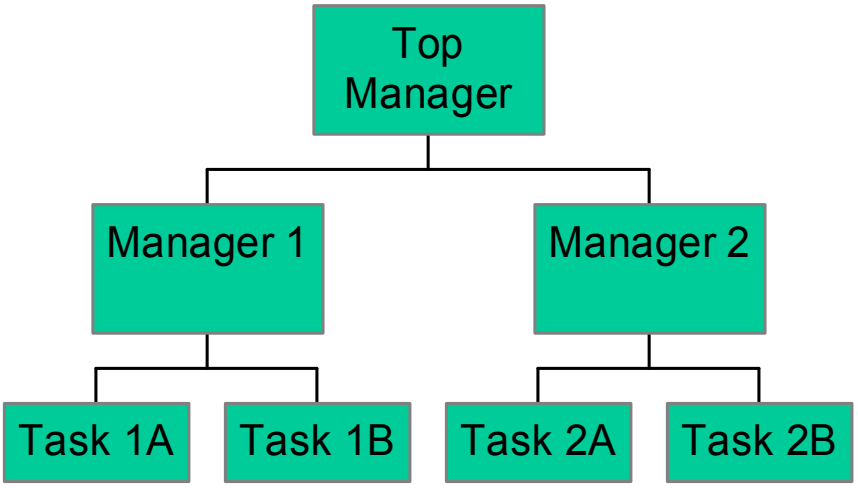

Figure 1: U-Form Organization

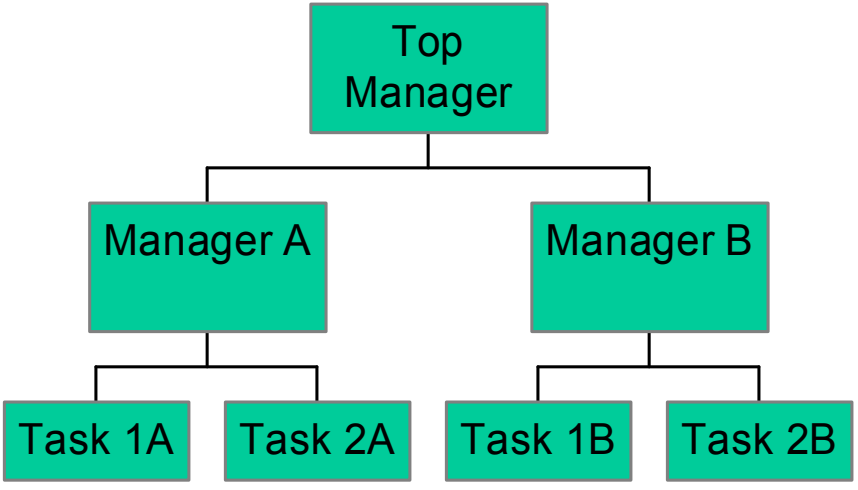

Figure 2: M-Form Organization

Example. Coordinating agriculture reform in the centrally planned economy

In this example, we regard the national economy as an organization. Suppose agricultural reform is aimed at replacing collective farming by household farming. Possible blueprints for such a reform involve types of contracts, methods of transfer of land, etc. There is blueprint uncertainty, which could be due to the uncertainty about farmers' tolerance of risks and their skills. Although the purpose of the reform is to improve efficiency by providing incentives to household farmers, farmers' incentives alone may not be sufficient to make the reform successful because coordination of reform is important. For instance, when farmers change crops or products, attributes related to physical infrastructure requirements must be matched. That is, in addition to blueprint quality, a successful agricultural reform also requires successful attribute matching among complementary reform tasks. What are these tasks? To illustrate our point, we focus on the following two tasks: harvesting and transport/storage (in Section 6 we give more detailed real life examples from Chinese and Russian agricultural reforms). So task 1A in our model would be harvesting in region A and task 2A would be transport/storage in region A.

Although anticipating changes of crops or products, reform blueprint designers do not know what crops will be changed and how will they be changed ex ante so that attribute matching is left to the implementation stage. Changing crops, such as changing production from grain to vegetables, fruits, or fishes has important implications for transport/storage. Grains, vegetables, fruits, and fish are harvested at different times. They have different physical and biological properties. Some are more sensitive to temperature, or more fragile mechanically, or have special requirements (e.g. live fish requires water and oxigen in transport/storage); some come out in large quantity in a short period of time; and others have to be delivered very quickly. Attributes to be matched between harvesting and transport/storage are then in terms of timing, location, technical specifications of harvesting and transport/storage, quantity harvested and capacities of transport/storage, etc.

If an economy is organized as a U-form, then the two specialized ministries are responsible for harvesting and transport/storage respectively, and a central authority such as Gosplan is responsible for matching the attributes between the two types of tasks. Information on attribute shocks then has to be transmitted from the two ministries to the central authority. If an economy is organized as an M-form, the two regional governments are each responsible for matching the attributes between the two types of tasks within their own region, and information on attribute shocks is only used locally.

3 M-form vs. U-form

We start with a comparison of the M-form and the U-form under the following reform strategy: always start a reform program in both units of the organization in each period. We call this strategy "full scale reform" or "reform without experimentation."

Consider first the M-form. Because each unit manager is responsible for attribute matching, perfect coordination can always be achieved. However, whenever a new reform program is introduced, setup cost C must be incurred because two managers are involved in coordination.

We define stage i as the stage at which a total of i reform programs have been successfully implemented before. Therefore, at stage i, the current period status quo (i.e., no reform) payoff for the two regions is given by $(i+1)R$. Let a new reform program be implemented in each period and let V_i be the net present value of future payoffs at stage i. Then V_i can be defined recursively as follows (with δ being the discount factor):

$$V_i = -C + p[(i+2)R + \delta V_{i+1}] + (1-p)[iR + \delta V_i].$$

Let $a = \frac{1}{1-(1-p)\delta}$. We have

$$\begin{aligned} V_i &= a[-C + p(i+2)R + (1-p)iR + p\delta V_{i+1}] \\ &= -aC + 2paR + aRi + ap\delta V_{i+1}. \end{aligned}$$

From the above recursive formula, we calculate

$$V_o = -aC\sum_{i=0}^{\infty}(ap\delta)^i + 2paR\sum_{i=0}^{\infty}(ap\delta)^i + aR\sum_{i=0}^{\infty} i(ap\delta)^i,$$

where V_o is finite because

$$ap\delta = \frac{p\delta}{1-(1-p)\delta} < 1$$

for all $\delta < 1$.

Using formulae $\sum_{i=1}^{\infty} ix^i = \frac{x}{(x-1)^2}$ and $\sum_{i=0}^{\infty} x^i = \frac{1}{1-x}$, and the fact that $\frac{a}{1-ap\delta} = \frac{1}{1-\delta}$, we obtain

$$\begin{aligned} V_o &= -\frac{aC}{1-ap\delta} + \frac{2pRa}{1-ap\delta} + \frac{Rp\delta a^2}{(1-ap\delta)^2} \\ &= -\frac{C}{1-\delta} + \frac{2pR}{1-\delta} + \frac{Rp\delta}{(1-\delta)^2} \\ &= -\frac{C}{1-\delta} + \frac{pR}{1-\delta}\left(2 + \frac{\delta}{(1-\delta)}\right) \end{aligned}$$

Therefore, under the M-form, the net present value at stage 0 is

$$V_o^{MF} = -\frac{C}{1-\delta} + \frac{pR}{1-\delta}\left(2 + \frac{\delta}{(1-\delta)}\right).$$

Under the U-form, the top manager is responsible for coordinating the four tasks. He receives four messages through noisy communication, each corresponding to one of the four tasks. To simplify the analysis, we assume that all signals for each function are perfectly correlated so that it is sufficient for a manager to communicate only one signal. When the program is bad, the reform fails, and a new program will be tried in the next period. If the program is good, there are two possibilities due to the assumption of perfect correlation of signals: with probability λ^2, coordination is successful for both regions A and B; with probability $\left(1-\lambda^2\right)$, coordination fails, which gives the same outcome as a bad program.

Because only the top manager matches attributes, whenever a reform is introduced, a setup cost $\frac{C}{2}$ is paid under the U-form instead of C under the M-form. Therefore, we obtain the recursive formula for V_i under the U-form:

$$V_i = -\frac{C}{2} + p\{\lambda^2[(i+2)R + \delta V_{i+1}] + \left(1-\lambda^2\right)(iR + \delta V_i)\} + (1-p)(iR + \delta V_i).$$

It is easy to see that the net present value under the U-form is similar to that under the M-form with $\frac{C}{2}$ replacing C and $\lambda^2 p$ replacing p. Thus under U-form, the net present value at stage 0 is

$$V_o^{UF} = -\frac{C}{2(1-\delta)} + \frac{p\lambda^2 R}{1-\delta}\left(2 + \frac{\delta}{(1-\delta)}\right).$$

Comparing the M-form and the U-form, we obtain in a straightforward way

Proposition 1 *Under full scale reform, The M-form has a higher net present value than the U-form when the setup cost C is low or the communication quality λ is low, and vice versa.*

Proposition 1 formulates the basic tradeoff between coordination and scale economies in implementing reforms 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 suffers from duplication of the setup costs because two local managers are responsible for attribute matching instead of one top manager.

Next we consider an alternative reform strategy under the M-form: start a reform program in one of the two units first and extend it to another unit in the next period if it is a success. We call this strategy "reform with experimentation." Again let V_i be the net present value of future payoffs at stage i. In stage i, let a new reform program start in unit A whereas the status quo is maintained in unit B. We call unit A the experimenting unit. The setup cost in the current period is $C/2$ because only unit A's manager coordinates. There are now two possibilities. If the program is good, the current period payoff is $\frac{(i+2)R}{2}$ in unit A and $\frac{(i+1)R}{2}$ in unit B. In the next period, the previous successful reform program can be used in unit B after a setup cost $C/2$ is paid (because unit B's manager needs to match attributes according to local conditions) and unit A will try a new reform program. If the program is bad, the current period payoff is $\frac{iR}{2}$ in the experimenting unit A and is $\frac{(i+1)R}{2}$ in the non-experimenting unit B. In the next period, a new experiment in unit A will take place. We thus calculate V_i as follows:

$$V_i = -\frac{C}{2} + p\left\{\frac{(i+2)\,R}{2} + \frac{(i+1)R}{2} - \delta\frac{C}{2} + \delta V_{i+1}\right\} + (1-p)\left\{\frac{iR}{2} + \frac{(i+1)R}{2} + \delta V_i\right\},$$

or

$$\begin{aligned} V_i &= -(1+p\delta)\frac{C}{2} + p\left(\frac{3}{2}R + iR + \delta V_{i+1}\right) + (1-p)\left(\frac{R}{2} + iR + \delta V_i\right) \\ &= -(1+p\delta)\frac{C}{2} + (i+1)\,R + \frac{R}{2}(2p-1) + p\delta V_{i+1} + (1-p)\,\delta V_i \\ &= a\left(-(1+p\delta)\frac{C}{2} + (i+1)\,R + \frac{R}{2}(2p-1)\right) + ap\delta V_{i+1}. \end{aligned}$$

From the above recursive formula, we calculate

$$\begin{aligned} V_o &= a\left(-(1+p\delta)\frac{C}{2} + \frac{R}{2}(2p-1)\right)\sum_{i=0}^{\infty}(ap\delta)^i + aR\sum_{i=0}^{\infty}(i+1)(ap\delta)^i \\ &= \frac{1}{1-\delta}\left(-(1+p\delta)\frac{C}{2} + \frac{R}{2}(2p-1)\right) + \left(\frac{p\delta R}{(1-\delta)^2} + \frac{R}{1-\delta}\right) \\ &= \frac{-(1+p\delta)\,C}{2(1-\delta)} + \frac{R}{1-\delta}\left(p + \frac{1}{2} + \frac{p\delta}{1-\delta}\right) \\ &= \frac{-(1+p\delta)\,C}{2(1-\delta)} + \frac{R}{1-\delta}\left(\frac{1}{2} + \frac{p}{1-\delta}\right). \end{aligned}$$

Therefore, under M-form with experimentation, the net present value at stage 0 is

$$V_o^{ME} = -\frac{(1+p\delta)\,C}{2(1-\delta)} + \frac{R}{1-\delta}\left(\frac{1}{2} + \frac{p}{1-\delta}\right).$$

Proposition 2 *The difference in net present value between the M-form with experimentation and the M-form*

without experimentation is given by

$$V_o^{ME} - V_o^{MF} = \frac{1}{1-\delta}\left((1-p\delta)\frac{C}{2} - (p-\frac{1}{2})R\right).$$

The relative advantage of the M-form with experimentation over the M-form without experimentation decreases with p and increases with C.

The first term $\frac{(1-p\delta)C}{2(1-\delta)}$ indicates the option value of waiting to learn about the quality of the blueprint before sinking C in the other unit of organization. This option value of waiting increases as p decreases, i.e. as there is greater uncertainty about the value of the blueprint. Therefore, experimentation can save on setup costs because of the option value of early reversal of a bad blueprint (Dewatripont and Roland, 1995). The second term $-\frac{(p-\frac{1}{2})R}{1-\delta}$(which is negative by Assumption 1) shows the cost of delaying reform in the other unit under experimentation. This cost decreases as p decreases. Overall, the comparative advantage of experimentation increases as p decreases. Therefore, there is a trade-off between the option value of waiting and the cost of delaying reform in the entire organization.

When $p = 1$,

$$V_o^{ME} - V_o^{MF} = \frac{C}{2} - \frac{R}{2(1-\delta)}$$

which is negative by Assumption 2. Therefore, there is no advantage of doing experimentation if the blueprints are known to be good.

Under the M-form organization, there are three alternatives: no reform, reform without experimentation, and reform with experimentation. The reform strategy is preferred to status quo if and only if $V_o^{MF} > \frac{R}{1-\delta}$ or $V_o^{ME} > \frac{R}{1-\delta}$. Therefore, the overall M-form payoffs are given by

$$\begin{aligned} V_o^M &= \max\left\{\frac{R}{1-\delta}, V_o^{ME}, V_o^{MF}\right\} \\ &= \max\left\{\frac{R}{1-\delta}, -\frac{(1+p\delta)C}{2(1-\delta)} + \frac{R}{1-\delta}\left(\frac{1}{2} + \frac{p}{1-\delta}\right), -\frac{C}{1-\delta} + \frac{pR}{1-\delta}\left(2 + \frac{\delta}{(1-\delta)}\right)\right\}. \end{aligned}$$

It is easy to calculate that

$$\frac{\partial}{\partial p}V_o^{MF} = \frac{R}{1-\delta}(2 + \frac{\delta}{1-\delta})$$

and

$$\frac{\partial}{\partial p}V_o^{ME} = \frac{1}{1-\delta}(\frac{R}{1-\delta} - \frac{\delta C}{2}).$$

We thus have $\frac{\partial}{\partial p}V_o^{MF} > \frac{\partial}{\partial p}V_o^{ME}$. By Assumption 2, we must also have $\frac{\partial}{\partial p}V_o^{ME} > 0$. Therefore we can define p^* such that $V_o^{MF} = V_o^{ME}$, from which we solve for $p^* = \frac{C+R}{C\delta+2R}$. We also define p^{MF} such that V_o^{MF}

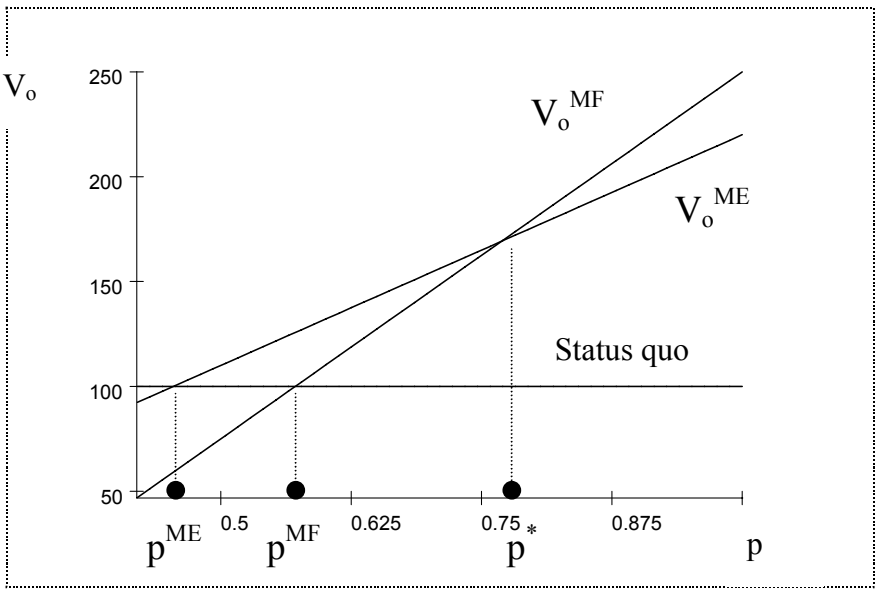

Figure 3: M-form: full scale reform (V_0^{MF}) vs. experimentation (V_0^{ME})

$= \frac{R}{1-\delta}$ and p^{ME} such that $V_o^{ME} = \frac{R}{1-\delta}$, where $\frac{R}{1-\delta}$ is the net present value of the status quo (no reform). With these notations, we have the following:

Proposition 3 *Comparing the M-form with and without experimentation:*

(1) the M-form with experimentation dominates the M-form without experimentation if and only if $p < p^*$*; and*

(2) *the M-form with experimentation dominates the status quo while the M-form without experimentation does not if and only if* $p \in \left(p^{ME}, p^{MF}\right)$*, where* $p^{ME} < p^{MF} < p^*$.

Proof Straightforward calculation solves for p^{ME} and p^{MF} and gives $p^{ME} < p^{MF}$. Then $\frac{\partial}{\partial p} V_o^{MF} > \frac{\partial}{\partial p} V_o^{ME} > 0$ implies $p^{MF} < p^*$.

Figure 3 shows an example with $C = 40, \delta = 0.6, R = 40$. With these parameter values, we have $p^{ME} = 0.45 < p^{MF} = 0.57 < p^* = 0.77$.

A similar experimentation strategy is not feasible under the U-form. Indeed, the U-form organization does not benefit from experimentation because of the complications involved in coordinating activities. First

of all, since the setup costs are bourne at the center and not in the units, they will still have to be incurred at the center with or without experimentation. Moreover, there is no additional benefit in coordination but only complications arising.[2]

Therefore, under a U-form organization, there are only two alternatives: no reform or full scale reform. The overall U-form payoffs are given by

$$\begin{aligned} V_o^U &= \max\left\{\frac{R}{1-\delta}, V_o^{UF}\right\} \\ &= \max\left\{\frac{R}{1-\delta}, -\frac{C}{2(1-\delta)} + \frac{p\lambda^2 R}{1-\delta}\left(2+\frac{\delta}{(1-\delta)}\right)\right\}. \end{aligned}$$

Because

$$\frac{\partial}{\partial p}V_o^{UF} = \frac{\lambda^2 R}{1-\delta}(2+\frac{\delta}{1-\delta}),$$

we can define p^{UF} such that $V_o^{UF} = \frac{R}{1-\delta}$. We obtain:

Proposition 4 *Comparing the U-form with the M-Form:*

(1) *the U-form is better for carrying out reforms and yields a higher net present value when the quality of communication λ is high;*

(2) *the M-form is better for carrying out reforms when the quality of communication λ is low; and the M-form with experimentation yields a higher net present value than either the U-form or the M-form without experimentation if in addition the uncertainty of reform blueprint $p < p^*$.*

Proof (1) Consider $\lambda = 1$ and $p = \frac{1}{2}$. We have

$$\begin{aligned} V_o^{UF} &= -\frac{C}{2(1-\delta)} + \frac{R}{2(1-\delta)}\left(2+\frac{\delta}{(1-\delta)}\right) \\ &> -\frac{C}{1-\delta} + \frac{R}{2(1-\delta)}\left(2+\frac{\delta}{(1-\delta)}\right) = V_o^{MF} \end{aligned}$$

[2] To illustrate this in an easy way, think of changes in computer software where task 1 represents change in the operating system and task 2 change in a word processor. Experimentation under U-form 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.

and

$$\begin{aligned} V_o^{UF} &= -\frac{C}{2(1-\delta)} + \frac{R}{2(1-\delta)}\left(2 + \frac{\delta}{(1-\delta)}\right) \\ &> -\frac{\left(1+\frac{1}{2}\delta\right)C}{2(1-\delta)} + \frac{R}{2(1-\delta)}\left(1 + \frac{1}{1-\delta}\right) = V_o^{ME}. \end{aligned}$$

Because

$$\frac{\partial}{\partial p}V_o^{UF} = \frac{\partial}{\partial p}V_o^{MF} > \frac{\partial}{\partial p}V_o^{ME},$$

then for all $p > \frac{1}{2}$, V_o^{UF} is larger than either V_o^{MF} or V_o^{ME}. This also holds for λ large enough.

(2) Note that at $p = 0$,

$$\begin{aligned} V_o^{MF} &= -\frac{C}{1-\delta} \\ &< -\frac{C}{2(1-\delta)} = V_o^{UF} \\ &< -\frac{C}{2(1-\delta)} + \frac{R}{2(1-\delta)} = V_o^{ME}, \end{aligned}$$

and V_o^{UF}, V_o^{MF} and V_o^{ME} all have constant slopes in p. As λ falls, the slope of V_o^{UF} becomes smaller than the slope of V_o^{MF} first and then than that of V_o^{ME}. As λ falls, $p^{UF} > p^{ME}$, then the M-form promotes more reform. The proof is completed by using Proposition 3.

When the quality of communication is high, coordination is easy, then the U-form benefits strongly from its advantage in scale economies. When the quality of communication is low, coordination becomes harder under the U-form, but is still easy under the M-form. If furthermore the quality of the reform blueprint is more uncertain, under the M-form, experimentation will be optimal. This shows an important advantage of the M-form compared to the U-form: the flexibility to experiment. Although the U-form has an advantage of scale economy to avoid the duplication of setup costs, it does not have the flexibility of carrying out experiments in only part of the organization. The fundamental reason why the M-form has that flexibility is precisely its organizational duplication: each region is self contained and coordination is carried out locally by more than one manager. While economists traditionally tend to emphasize the importance of scale economies and specialization for efficiency, there is the other side of the coin: the requirements for task coordination impose a limit to scale economy and specialization.

Figure 4 shows the previous example with $C = 40, \delta = 0.6, R = 40$ *again. Notice that the payoffs under the M-form are independent of* λ *but the payoffs under the U-form increase with* λ. *At* $\lambda_2 = 0.8$, *the*

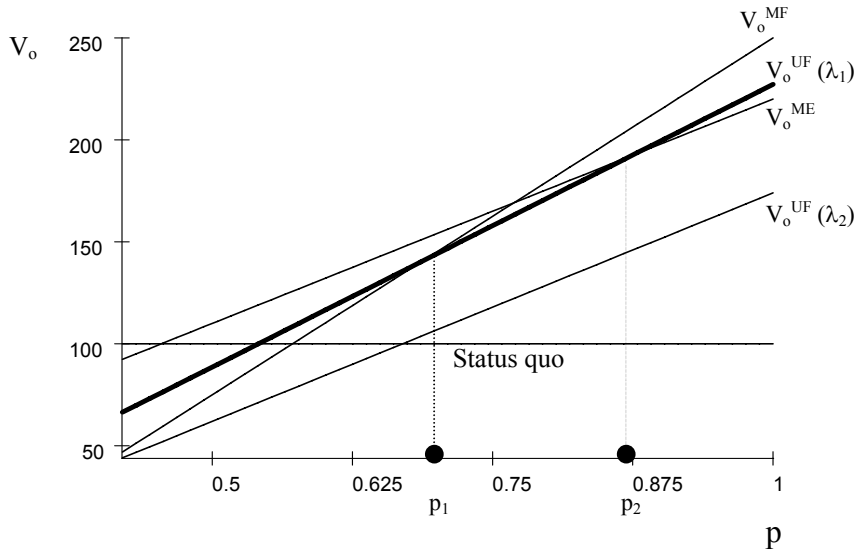

Figure 4: M-form vs. U-form

M-form under both strategies dominates the U-form. At $\lambda_1 = 0.89$*, the M-form dominates the U-form due to latter's flexibility: when p is high, i.e.* $p > p_2$ *although* $V_o^{UF} > V_o^{ME}$*, the M-form with full scale reform dominates the U-form (*$V_o^{MF} > V_o^{UF}$*); when p is low, i.e.* $p < p_1$ *although* $V_o^{UF} > V_o^{MF}$*, the M-form with experimentation dominates the U-form (*$V_o^{ME} > V_o^{UF}$*). When* λ *is sufficiently close to one, then the U-form dominates the M-form regardless of latter's strategies. This point is obvious thus we do not show it in the figure.*

4 Generalization

We now generalize the above model to n regions and m functions. We normalize the setup cost of implementing reforms under the M-form to C and that under the U-form to $\frac{C}{n}$. The status quo payoff of the entire organization is $\frac{R}{1-\delta}$ (or equivalently $\frac{R}{n(1-\delta)}$ in each region).

Consider the M-form first. The organization has n units along regional lines. Within each region, a middle level manager is responsible for coordinating m tasks within the region and perfect coordination is

always achieved. Let α be the fraction of experimenting regions where $\alpha \in \left[\frac{1}{n}, 1\right]$. In particular, $\alpha = 1$ means a full scale reform, and $\frac{1}{n} \leq \alpha \leq \frac{n-1}{n}$ means a reform with experimentation in a fraction α of regions.

The net present value of payoffs in stage i under the M-form is the following:

$$V_i = -\alpha C + p\left\{(i+1)R + \alpha R - \delta(1-\alpha)C + \delta V_{i+1}\right\} + (1-p)\left\{(i+1)R - \alpha R + \delta V_i\right\}.$$

Recall that $a = \frac{1}{1-(1-p)\delta}$. We then obtain the following recursive formula as follows:

$$V_o^{M_\alpha} = a[-(\alpha + p\delta(1-\alpha))C + \alpha R(2p-1)]\sum_{i=0}^{\infty}(ap\delta)^i + aR\sum_{i=0}^{\infty}(i+1)(ap\delta)^i.$$

Therefore, the net present value at stage 0 under the M-form with experimentation in a fraction α of regions is given by

$$V_o^{M_\alpha} = -\frac{\alpha + (1-\alpha)p\delta}{1-\delta}C + \frac{R}{1-\delta}\left(\alpha(2p-1) + 1 + \frac{p\delta}{1-\delta}\right).$$

Note that $V_o^{M_\alpha}$ is linear in α, and

$$\frac{\partial}{\partial\alpha}V_o^{M_\alpha} = -\frac{1-p\delta}{1-\delta}C + \frac{R}{1-\delta}(2p-1).$$

Therefore, we have the following result, which is parallel to Proposition 3:

Proposition 5 *Let $p^* = \frac{C+R}{C\delta+2R}$. Under Assumption 2, $p^* < 1$. Moreover,*

(1) *If $p > p^*$, it is optimal for the M-form not to do experiments.*

(2) *If $p < p^*$, it is optimal for the M-form to experiment in one region.*

Proof: Obvious.

From Proposition 5, the net present values of reform under the M-form with optimal strategies α corresponding p are

$$V_o^{M_\alpha} = \begin{cases} -\frac{C}{1-\delta} + \frac{pR}{1-\delta}\left(2 + \frac{\delta}{1-\delta}\right), & \alpha = 1,\ p \geq p^* \\ -\frac{C}{1-\delta}\left(\frac{1+(n-1)p\delta}{n}\right) + \frac{R}{1-\delta}\left(\frac{2p+n-1}{n} + \frac{p\delta}{1-\delta}\right), & \alpha = \frac{1}{n},\ p < p^* \end{cases}.$$

When $p > p^*$, the optimal $\alpha = 1$, a change in n has no effect on $V_o^{M_\alpha}$. However, when $p < p^*$, the optimal $\alpha = \frac{1}{n}$, and we have

$$\frac{\partial V_o^{M_\alpha}}{\partial n} = \frac{1}{(1-\delta)n^2}(R + C - p(C\delta + 2R)) > 0.$$

This demonstrates a size advantage of doing experimentation under the M-form. As long as experimentation is efficient ($p < p^*$), the more regions an economy has the higher the value of experimentation will be.

Under the U-form, the organization has m units along functional lines. Within each unit, a middle level manager is responsible for collecting information about attribute shocks and sending a message to the top manager. The top manager receives correct information with probability λ^m and coordinates m tasks for all n regions. For the U-form organization, the recursive formula for the net present value of payoffs in stage i is the following:

$$V_o^{UF} = -\frac{C}{n} + p\{\lambda^m[(i+2)R + \delta V_{i+1}] + (1-\lambda^m)(iR + \delta V_i)\} + (1-p)(iR + \delta V_i).$$

Again, the net present value under the U-form is obtained by replacing C with $\frac{C}{n}$ and p with $\lambda^m p$ in V_o^{MF}. Thus, under the U-form, the net present value at stage 0 is

$$V_o^{UF} = -\frac{C}{n(1-\delta)} + \frac{p\lambda^m R}{1-\delta}\left(2 + \frac{\delta}{(1-\delta)}\right).$$

From this expression we can see easily that an increase in n will increases V_o^{UF} due to the economy of scale advantage of the U-form, and this result is independent of the value of p and λ. Moreover, with Assumption 1 (i.e., $p > \frac{1}{2}$), we have

$$\frac{\partial}{\partial n} V_o^{UF} > \frac{\partial}{\partial n} V_o^{M_\alpha}.$$

This means that when the number of regions increases, the marginal impact from scale economies under the U-form outweighs the marginal impact of the size advantage of experimentation under the M-form.

Finally, when m increases, the U-form suffers from an disadvantage in coordinating attribute matching:

$$\frac{\partial}{\partial m} V_o^{UF} = (\ln \lambda)\lambda^m \frac{pR}{1-\delta}\left(2 + \frac{\delta}{(1-\delta)}\right) < 0.$$

We summarize the above results in the following proposition.

Proposition 6 *(1) The U-form has a larger positive effect from the increase in the number of regions than the M-form (*$\frac{\partial}{\partial n} V_o^{UF} > \frac{\partial}{\partial n} V_o^{M_\alpha} \geq 0$*).*

(2) *The U-form also has a larger negative effect from the increase in the the number of funcitons than the M-form (*$\frac{\partial}{\partial m} V_o^{UF} < \frac{\partial}{\partial m} V_o^{M_\alpha} = 0$*).*

In the reform application of the model, it is conceivable that an agricultural reform that involves giving more decision rights to household farmers may increase the number of functions m, which might give advantage to the M-form. In the business firm application of the model, some implications of these results are the following. If the growth of a company involves a major increase in the number of products leaving

the number of functions to be coordinated unchanged, then the U-form should have the advantage. On the other hand, if the growth of business of a company involves an increase of the number of functions to be coordinated, the M-form will have the advantage. Particularly, when companies are growing at a time when technologies become more developed, more functions are to be coordinated within the company so m becomes larger, as compared to the earlier stage of a company when m was small. These results may shed light on the evolution of organizational forms of companies when businesses grow: companies tend to change from an U-form at the early stage to an M-form at the later stage.

5 Conditions for the Optimality of M-Form and U-Form

The above discussion focuses on two organizational forms: the M-form and the U-form. In theory, many other organizational forms are possible. In this section, we provide a set of conditions under which the M-form and the U-form dominate other organizational forms so that our focus on these two forms can be justified. We restrict our attention to the case of two regions and two functions only, but the underlying principle is general.

Figure 5 illustrates possible types of organizational forms in the case of two regions and two functions. Figures 5(a) and 5(b) are the U-form and the M-form respectively. Figure 5(c) is the flat organizational form in which all coordination is done by one manager. Figures 5(d) and 5(e) are skewed organizational forms where one middle management coordinates two or three tasks and the center coordinates the residual task(s). Figure 5(f) is a symmetric form but represents a different partition of tasks than the M-form or U-form. Figure 5(g) is a stand alone organizational form without middle managers. Other alternatives not present in Figure 5 are cases where one manager is responsible for one task only. With more than two regions and two tasks there are more possibilities but the two by two case serves as a good illustration.

We assume that in the economy there are the following distinct types of knowledge: knowledge on functions and kowledge on regions related to identifying/describing attribute shocks; and knowledge on blueprints related to strategic decisions (selection of blueprints). We further assume that each manager can aquire only one type of knowledge. This is because the capacity of human beings to aquire knowledge is limited and the character of knowledge is specialized. Formally, we make the following assumption about the knowledge of a manager:

Assumption K *A manager's knowledge is limited to one of the following:*

(K1) functions for any given region;

(K2) regions for any given function;

(K3) blueprints.

An example of (K1) is knowledge about functions of harvesting or transporting within a mountain region; An example of (K2) is knowledge about a mountain region and a river region for the function of transporting. Moreover, we suppose that as long as information on attribute shocks is known coordinating-task per se does not rely on knowledge (K1), (K2) and (K3).

We first demonstrate that both the M-form and U-form satisfy Assumption K. Under the M-form, the top manager engages in strategic decision which requires knowledge (K3). Each of the two middle managers engages in collecting attribute shock information and coordinates tasks accordingly in his own region. The information collection and task coordination within a region require knowledge (K1). Therefore, Assumption K is satisfied. Under the U-form, each of the two middle managers is responsible for one of the two functions respectively; and each of them collects information on attribute shocks associated with that function in the two regions requiring knowledge (K2); and transmits the information to the top manager. The top manager then coordinates, which does not rely on knowledge (K1) or (K2). Moreover, the top manager takes up strategic decisions requiring knowledge (K3). Again, Assumption K is satisfied. In both of these organizational forms, the number of managers hired for the entire organization is 3.

Because any organization requires all three types of knowledges to run, Assumption K rules out any organizational form employing fewer than 3 managers. Organizational forms (c), (d), (e) and (g) all employ 1 or 2 managers and thus violate Assumption K.

Among all organizational forms employing 3 managers the M-form and the U-form organizations are the only ones that satisfy Assumption K. In the organizational form (f) in Figure 5, one manager is responsible for tasks 1A and 2B, and the other for tasks 1B and 2A. This would imply that each of them must have both knowledge (K1) and (K2), a violation of Assumption K.

Therefore, all the organizational forms satisfying Assumption K other than the M-form and the U-form must hire more than 3 managers. If we assume that hiring additional managers entails additional costs, then an organizational form that employs more than 3 managers does not have a cost advantage over an organizational form that employs only 3 managers. When this cost is sufficiently high, it rules out an organizational form such as for example 4 managers each responsible for collecting information on one region and one function only and an additional manager for strategic decisions.

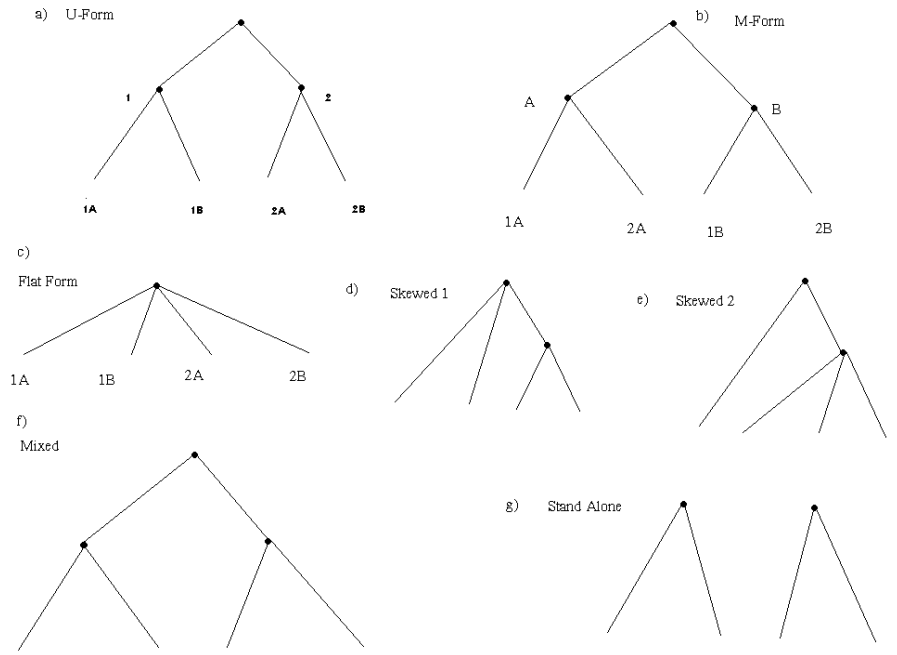

Figure 5: General Organizational Forms.

To conclude, under Assumption K and assuming costly managers, the M-form and the U-form are the only optimal organizational forms. A more complete analysis of the optimality of different organizational forms deriving from primitive assumptions is beyond the scope of this paper but is an important avenue for further research.

6 An Application: Agricultural Reform in China and the Soviet Union

Organizational forms of government in centrally planned economies can have a substantial impact on reform strategies and outcomes. The Chinese reform process is often characterized as gradual and experimental in contrast to that in the Soviet Union and Central and Eastern Europe. Less noticed is the fact that various reform experiments were introduced in the Soviet Union in the 1980s but failed. Those failures have discredited the experimental approach which was abandoned during the later transition. Our theory opens new perspectives on understanding how the differences in organizational forms in the Soviet Union and China might have affected their coordination capabilities which in turn have led to different reform paths.

Institutional Background of Central Planning in China and the Soviet Union. Before the reform, both China and the Soviet Union were centrally planned economies. The organization of the Soviet economy was the classical textbook case of central planning (Gregory and Stuart, 1989; Kornai, 1992). The Gosplan, the central planning bureau, supervised dozens of ministries, each specializing in one industry. At the same time, the degree of industrial concentration by region was very high. This organization made central coordination essential. Indeed, in the late 1970s, the Gosplan was responsible for about 12 million products (Nove, 1983). This corresponds to a U-form organization.

China started its central planning system in 1953 following the Soviet model. However, in 1958 and 1970, twice before the current reform, China drastically changed its planning system into one mainly based on regions, not industries. Most state-owned enterprises were under the supervision of regional governments of provinces, cities and counties. Typically, the production of each region was diversified and relatively self-contained (Granick, 1990; Qian and Xu, 1993). With regional governments taking major responsibilities for coordinating tasks across industries, the central government's role in coordination was greatly reduced compared to that in the Soviet Union. In the 1970s, the State Planning Commission at the central government level was responsible for no more than 1,000 products. This corresponds to an M-form organization.

We use agricultural reform in China and the Soviet Union (later Russia) to illustrate how organizational forms of governments may affect reform strategies and outcomes. We will demonstrate that the success of China's agricultural reform is closely related to the roles of regional governments in solving various coordination problems. In contrast, agricultural reform in the Soviet Union throughout the 1980s and even that in Russia in the 1990s suffered from major coordination problems, and many of these coordination failures can be attributed to the U-form structure inherited from the Soviet system.

Agricultural Reform. Agricultural reforms in both countries were aimed at replacing collective farming by household farming. In terms of our model, there are many possible blueprints for such a reform. A reform blueprint may include several dimensions: (1) the type and duration of contracts; (2) the method of transfer of land such as through sale and free distribution; and (3) the form of division of land concerning plot size and location. A reform blueprint entails uncertainty. For instance, along the dimension of contract type, the use rights of land may be partly delegated to households for a short time period, or they may be leased to households for a longer period of time. Alternatively, ownership of land may be transferred to households altogether. These different types of contracts have different incentive effects on households but also have different risk-bearing implications. Leasing contracts entail weaker incentives but do not impose big risks on households. While full ownership transfer gives first best incentives, it also imposes the bigger risks. As the government is not fully aware of the exact tradeoff between incentives and risk-bearing ability of households (which in turn depend on other institutions in place), there is uncertainty about the effects of each type of contract. Blueprint uncertainty thus relates to the uncertainty about farmers' preferences and to the effects of existing risk-sharing arrangements.

In addition to a good blueprint, successful reform requires good coordination, which means attribute matching among complementary tasks. These tasks may involve, for instance, the establishment of physical infrastructure (water, transport, roads, canals, telecommunication, electricity, storage), informational infrastructure (technical support, information about markets), legal infrastructure (securing ownership titles, methods for conflict resolution), and credit and savings institutions. Below we will detail attribute matching and coordination (or its failure) in agricultural reform in China and the Soviet Union (and later Russia) respectively.

Attribute Matching in Agricultural Reform in China. Household farming allows households to choose new crops or products for profits. Indeed, in China, there have been huge shifts in the composition of agricultural production since the reform. For example, the total national output of aquatic products increased from 4.6 million tons in 1978 to 41.2 million tons in 1999. Correspondingly, the share of fishery in total agriculture

output increased from 1.4% to 10.3%. In the following, we use the specific example of Xinhui county in Guangdong Province to illustrate how regional governments solve the coordination problems in the fishery sector.[3]

When farmers choose to shift from grain production to fish farming, the physical and informational infrastructure requirements must be adapted. Attribute matching may occur in the following dimensions:

(1) Conditions required for raising fish or fishing may be in conflict with requirements for water transport and irrigation of grain fields in terms of quality, quantity, location and timing of using water;

(2) Fish species may be region specific; moreover, selections of fish species and grain species are different in different areas;

(3) Transport and storage means required for harvesting fish differ from those for harvesting grain; and

(4) Disease control is different for fish and plants.

In a developed market economy, some aspects of these coordinations are taken care of by the market, and some by vertical integration. Government's role is nevertheless still often desirable, as for example in infrastructure investment. However, in transition economies, there are a greater number of missing markets at the beginning of the reform. Under China's M-form structure, Xinhui County government has had the responsibility of coordinating activities in agriculture, industry, transportation, commerce, and R&D within the county. It has successfully made attribute matching in the growing fishery sector during the reform, which ensured a smooth transition to household farming along all four dimensions listed above:

First, a key factor in the growth of aquatic industry is the increase of the aquatic production area. Total aquatic production area can be increased by using rivers, ponds, and reservoirs. The coordination role of local government is important here. Attributes to be matched in order to increase the aquatic production area include timing, origination/destination/route, quality/quantity of water transmission to match demands in aquatic production, irrigation and transport. If too much water is diverted from a river into fishing ponds at a wrong time, the water level of the river may decrease too much, making transport difficult or leaving too little water for irrigation of rice fields. Water sharing for the purpose of irrigation and aquatic ponds has been coordinated by the county government. Part of the coordination is done by building new reservoirs to ensure regular water supply. It would be much more difficult to coordinate transport, irrigation, and aquatic activities if these were controlled by different specialized ministries separately.

[3] Information on Xinhui County is from Annals of Xinhui County (1995, 1997) by Xinhui Xianzhi Editorial Committee. For a general account of fishery sector reform nationwide, see Xia (1998), which provides examples from many other counties such as Shunde county in Guangdong province and Rongcheng county in Shandong province.

Second, the selection of species best suitable for the county is also important. Some species fit better than others to a particular region's weather, water quality, water plants, plankton etc. The county government's Aquatic Bureau took the initiative in coordinating technological changes in aquatic production, such as helping select aquatic species best suitable for the county and giving technical support to aquatic farmers. For example, in 1979 the Aquatic Bureau helped to coordinate an enlargement of production of fingerling and fry. By 1985, the area of fish ponds for growing fingerling and fry increased by 65.8% compared with 1976; and the output of fingerling and fry increased by 130% over the same time period.

Third, the supply of fish feed and cold storage for harvested fish are other important factors that affect aquatic production. There are important attribute matching problems involved in fish feed supply (and similarly in cold storage services). When a new species of fish is introduced or whenever there is substantial change in weather conditions, requirements for fish feed (or for storage) must be adjusted accordingly, which in turn requires adjustments in raw materials used by fish feed plants. When markets were not yet well developed to take care of these problems, the county government played again an important coordination role. In 1979 the county government built a cold storage plant – the Xinhui County Yamen Cold Storage Plant, which has provided ice, cold storage and processing (e.g. quick frozen) for aquatic industry in the county. In 1983 and 1984, jointly with some township governments the county government built two fish feed plants (Tangxia Fish Feed Plant and Hetang State-Township Joint Fish Feed Plant).

Fourth, disease control, in particular prevention of contagious fish diseases, is another critical factor and often requires an emergency response. Diseases may indeed spread via different waterways at a considerable speed. Disease control requires coordination between aquatic production, supply of drugs/disinfectants, transport, and irrigation, R&D for the region and solutions specific to the local fish species. Controlling aquatic diseases is an emergency matter, requiring quick actions to specify drugs/disinfectants and the corresponding methods of using them, so time is of overriding importance. This is similar to dispatching an ambulance to meet particular requests in a medical emergency (Milgrom and Roberts, 1992). In this situation, markets may not be able to coordinate in time. The capacity of county government in coordinating all affected sectors is then critical for implementing disease control measures. In Xinhui, the Disease Prevention and Vaccination Department under the County Aquatic Bureau has played such a coordination role, taking into account various ecological problems. The Department provided fish immunization services and other medicines for fishes, for example, in 1985 it provided vaccination for 4.3 million Buffalo fish which increased substantially the survival rate of these fish.

As a result of the coordination role of local government, Xinhui aquatic production increased rapidly

since the reform. Total aquatic production in Xinhui in 1985 increased by 2.3 times over that of 1978. The success of Chinese local governments like Xinhui illustrates the strong capacity of the M-form structure in coordinating attribute matching. The local government has a good knowledge of local conditions and can respond efficiently given its authority in making attribute matching at the local level.

Attribute Matching in Agricultural Reform in the Soviet Union. Under the Soviet system, farming was subordinated to many specialized ministries. In the 1980s, tasks related to agro-food industry were divided between 11 ministries: (1) Agriculture; (2) Trade; (3) Cereal and Grain Production; (4) Fruit and Vegetable Farming; (5) Machine Building for Animal Husbandry and Feed Production; (6) Tractors and Farm Machinery; (7) Land Reclamation and Water Resources; (8) Meat and Dairy Industry; (9) Food Industry; (10) Rural Construction; and (11) Fertilizer Production (Wegren, 1998, p. 62). Tractors were provided centrally by the so-called MTS stations. The tasks of providing inputs to the farmers, of managing their operations, storage, processing, transport, road infrastructure were all allocated to separate agencies over which collective farms had no control. Warehouses and processing plants were more likely to be located hundreds of kilometers away from farms (van Atta, 1993a). Within this organizational structure, any change in grain production had to involve at least seven ministries: Ministries of Agriculture, Trade, Cereal and Grain Production, Tractors and Farm Machinery, Food Industry, Rural Construction, and Fertilizer. Any farm (private or collective) that changed crops from grain to vegetable production would have had to deal with these ministries plus other two ministries: Land Reclamation and Water Resources, and Fruit and Vegetable Farming. Regional governments did not have the authority to solve the coordination problems.

In March 1989, the Central Committee of the Soviet Communist Party decided under Gorbachev's impulsion to launch a reform in agriculture whereby farmers could lease land with long term contracts up to 50 years. This may seem similar to the Chinese agricultural reform. However, this reform in the Soviet Union was carried out under the U-form organization of the economy. Leasing provides incentives to the farmers, but coordination continued to be done by various ministries in Moscow. Serious coordination problems arose not just at the production stage, but also at the distribution stage. In fact, by the end of the 1980s there was a consensus among experts of Soviet agriculture that the biggest problem in agriculture was at the distribution stage, not the production stage, precisely because of the coordination problems (Wädekin, 1992).

The distribution stage involves activities of harvesting, transportation, storage, and processing. The production unit harvests the output and stores it into temporary storage. The spoilable nature of output makes the length and condition of storage particularly critical. The transport unit then moves the output

from temporary storage to permanent storage or to processing facilities directly. The permanent storage unit must be able to store the output for a longer time with great care, otherwise grain will rot. Attributes related to distribution are harvest time, harvest location, harvest quantity, weather, temporary storage capacity, transport vehicle capability, etc.

Attribute matching may occur in the following dimensions, and the failure of any one of them would have severe consequences:

(1) Between production units and transport or permanent storage: given transport capacity and urgency priorities, sufficient transport facilities must be dispatched to the most urgent production units at the right time and to right location, otherwise harvested output will rot;

(2) Between permanent storage units and processing units: failure to transport inventories to processing units in the right order can still cause rotting even in the permanent storage unit.

In the Soviet Union, the activities of harvesting, storage, transport, process were under the supervision of separate ministries and their interactions were coordinated at the center. Therefore farmers were dependent on different ministries and there continued to be substantial waste at the storage, transport and processing stages. With the failures in coordination between production units, transport and storage, in Russia for example, about a quarter of total grain products (an average of 49 million tons of grain in 1986-1990) was wasted in temporary storage and in permanent storage; 30-40% of potatoes were lost to rot in storage places. It was reported that of the 40% loss in potatoes and vegetables, 1/3 was lost directly in transport and storage, 20% due to coordination failure, such as waiting for transport etc., which in turn resulted from coordination problems in other sectors, such as the lack of gas or oil, or spare parts (Wädekin, 1992). This clearly illustrates the lower coordination capability of the U-form and accords with our theoretical model.

Attribute Matching in Agricultural Reform in Russia. After the collapse of the Soviet Union, central planning was abandoned and reformers pushed for radical plans for private farming. However, the problems inherited from the U-form structure continued to cause trouble for reforms aimed at establishing household farms. Even though the ministries associated with central planning were abolished, implementation of reform still required coordination between physical, informational, and legal infrastructures, land transfer schemes, and credit and savings solutions. These coordination problems needed to be solved in the context of private farming. Private ownership of land would not have many effects if farmers did not have access to storage facilities or without a good road system to be able to transport their harvest. Private farmers also needed access to water, electricity and telephone service. They needed scientific and technical advice on what to grow and how. They also needed access to market infrastructure, which includes access to credit to purchase

inputs but also competitive upstream and downstream markets for the purchase of inputs and the sale of their output. All the attributes of farming still needed to be matched but the attributes of reform such as the provision of credit and access to market infrastructure also needed to be matched. The role of government in putting together these complementary attributes for private farming was important as there were no preexisting markets and government efforts were necessary to encourage the development of markets for land, for credit, for inputs, outputs and farming equipment.

Several ministries were therefore involved in coordination of agricultural reform, including ministries of (1) Agriculture; (2) Ownership Relations; (3) Industry, Science and Technology; (4) Communications; (5) Transport; (6) Commerce and Economic Development; (7) Antitrust and Support of Entrepreneurship. Even within the Ministry of Agriculture, 18 different departments were involved among which are Animal Husbandry, Plant Growing, Water Supply, Food Processing, Chemical Supplies and Plant Protection, Interactions between Regions, and Ownership Relations. Given the U-form organization and geographically dispersed production infrastructures, major coordination failures occurred under Yeltsin's reform plans.

First, the U-form structure made it difficult to coordinate land privatization with the provision of adequate infrastructure such as roads, electricity, etc.. The lack of infrastructure may causes more serious problems for private farmers than for collective farms. This is because collective farms operate on a much larger scale and have less diverse production. A survey in Kostroma oblast done in mid-1991 by Wegren, one of the best known experts of Russian agriculture, found that only 15% of private farms were located less than one kilometer away from a telephone, 47% between 2 kilometers and 6 kilometers and 29% were located more than 7 kilometers from a phone. By January 1995, over a half of private farms had no running water, 20% had no electricity, 40% had no normal access roads and only 10% had animal sheds (Wegren, p. 172). All experts of Russian agriculture have pointed to the overall deficient infrastructure as a major cause of the failure of reforms. Storage capacity inherited from the Soviet system has remained inadequate, the poor road system has not only not been overhauled but has strongly declined in the 1990s due to strong contraction of infrastructure investment (Wegren, p. 128). Infrastructure investment should actually have increased given the previous imbalances if private farming was to be encouraged. These failures in physical infrastructure were such that "in some regions, the cost of shipping agricultural commodities between regions exceeds the producer prices" (Liefert-Swinnen, p.13).

Second, there was a failure to provide private farmers with basic public services since providing these involved the responsibility of different ministries. In general, the Russian privatization program did not provide private farmers alternative access to dwellings, schools, and all other public services such as medical

care, day care, that were typically provided by the collective farm system. If a peasant became a private farmer, he would lose access to all those services.

Third, the reform program failed to provide a system of market information (where to buy and sell and at what price) and more simply to provide competitive markets both for farming inputs and for farm output. In the absence of competitive input and output markets, private farmers face monopolies when purchasing inputs and monopsonies when selling their output. This substantially reduces the profit opportunities for private farmers who face high input prices and low output prices.

Fourth, private farmers faced very poor legal protections, such as in issues related to property rights, in enforcement of contracts, etc.. The spoilable nature of agricultural output makes it particularly prone to holdup by organized crime and corrupt officials.

Overall, experts on Russian reform agree that coordination failures were quite massive.[4] These massive coordination problems are one of the reasons that farmers were not very enthusiastic to engage in private farming. Without proper solutions to the coordination problems and the requisite attribute matching between land, labor, physical and market infrastructure, Russian private farmers would have to work under very primitive conditions. Wegren cites an article about how coordination problems hamper privatization in agriculture in Moscow oblast: once becoming private farmers "they immediately encountered massive problems – no machinery, nowhere to obtain gas, nowhere to sell produce, and so on. People saw this and did not want to follow their example." A survey by the World Bank in 1994 showed that 92% of collectively-owned

[4]It would be wrong to state that there were coordination failures at all levels of agricultural reform. There were for example some successes with credit to private farmers. Special efforts were indeed made between 1992 and 1994 to provide preferential credit to private farmers (at a subsidized interest rate of 25% as opposed to 170% for collective farms). The reason for the need for preferential credit was actually related to the failure to create competitive markets upstream and downstream for farmers who faced therefore increasing upstream prices and decreasing downstream prices, the famous "scissor's problem". This effort to provide preferential credit was however discontinued in 1994 due to the high cost for the federal budget. On the positive side, one can also cite the experiment of farm privatization in Nizhni Novgorod with the help of the International Finance Corporation. "It was introduced in conditions common to past Soviet economic experiments: special resources were made available for the experimental farms, advantages that were not available to non participants in the model. Nizhni farm privatization occurred as a result of significant Western and state intervention in order to create favorable conditions and the IFC spent millions of dollars in an effort to help several farms in Nizhegorodskaya oblast privatize (Wegren, p. 103)". Obviously, given the scarcity of resources and of coordination capacity, it was impossible to generalize the results of such an experiment. This ironically reminds of the fate of previous experiments under Russian planning under the U-form organization such as the failure of the Stakhanovite movement in the 1930s. The positive experiment of Nizhni Novgorod however also highlights the importance of coordination in reform.

or state-owned farm employees did not want to become private farmers (Brooks et al. 1994). A 1994 world bank sponsored survey in agriculture found that in two thirds of state farms, only less than 10 people (3 families) left (Wegren, 1998, p. 83). Wehrheim et al. (2000) argue that underdeveloped institutions and infrastructure are the main problem explaining the dismal results of reform of Russian agriculture. The evidence tends to show that despite radical market and incentive reforms, the coordination problems of Russian farming and in particular the post-harvest waste have been increasing in the nineties. (Laird, 1997).

Obviously, coordination problems are not the only reason for the dismal results in private farming reform in Russia. One can argue that the destruction of private farming in the thirties under Stalin killed the farming spirit in Russia and that this cultural change in the countryside can explain the lack of taste of Russian farmers for risk-taking. This is quite possible but does not contradict our analysis. Maybe the blueprint of agricultural reform was inadequate and another blueprint imposing less risks on farmers such as leasing arrangements should have been more emphasized. However, even in that case, similar coordination problems would have been encountered which would in all likelihood have strongly hampered such an alternative reform blueprint.

The contrast between Chinese and Russian agricultural reform is quite stark and illustrates the effect of organizational forms on the coordination of reform. The Chinese M-form with local government coordinating the various complementary aspects of agricultural reform allowed for flexible and swift coordination as local governments had good local knowledge and had authority over all aspects of reform. In contrast, the U-form of government that the Russian government inherited from the Soviet period did not do better in solving coordination problems in agricultural reform than it did at coordinating agricultural production under central planning.

7 Concluding Remarks

In this paper we introduced a method of modelling task coordination inside an organization as attribute matching. Using this method, we developed a theoretical analysis of organizational forms in order to understand the performance features of the M-form and U-form organizations. Although we used the economic reforms in China and the Soviet Union (and Russia) in the 1980s and 1990s as the empirical illustration, our theory has other applications as well. In addition to the application to the U-form and M-form corporations described in the introduction, we mention here briefly its relevance to organizational forms of government.

Two organizational forms of government have received much attention: the unitary state and the federal

state. France and Japan, 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 relatively little authority. This corresponds to the U-form organization in our framework. In contrast, the organizational form of the U.S. government is a primary example of federalism, where the fifty states have the constitutional rights and responsibilities for coordinating government activities inside their jurisdictions. This corresponds to the M-form organization.

One of the main predictions of our theory is about experimentation in the M-form organization. It has been perceived for a long time that the American federal system has facilitated experimenting innovative policies. It was argued in 1888 that "federalism enables people to try experiments which could not safely be tried in a large centralized country" (Bryce, 1901). A few decades later, the American Supreme Court Justice, Louis Brandeis, had a famous characterization of American federalism as the "laboratory of the states." By laboratories, he meant that the states could experiment with new solutions to social and economic problems. Those that worked could be applied nationally; those that failed could be discarded. He said in 1932, it is one of the happy incidents of the federal system that a single courageous state may "serve as a laboratory; and try novel societal and economic experiments without risk to the rest of the country" (Osborne, 1988). Indeed, many changes of government policies in the U.S. were initiated by some states, such as New York, Massachusetts, and California. And these experiments were later imitated by other states or by the federal government.

One example concerns state government's policy experiments prior to the New Deal policy of the federal government in the 1930s. Facing the challenges and risks associated with the rapid industrialization of the American economy in the early 20th century, a few states initiated innovative policies such as unemployment compensation schemes, massive public education programs, and schemes related to deposit insurance and social security. Most of those programs were complementary to each other and state government coordination was critical to the implementation. Later, many of the successful ones were institutionalized at the federal level. In fact, a large number of Roosevelt's New Deal policies were inspired or precisely copied from those successful state level experiments. Roosevelt acknowledged that "practically all the things we've done [in the New Deal] in the federal government are like things Al Smith did as Governor of New York." (Osborne, 1988).

Another example involves state government's policy experiments to deal with the challenges associated with the replacement of the traditional industries by high tech businesses in the last two decades of the 20th century. Starting the late 1970s, a sequence of new policies such as reform of public education systems,

creating public venture capital funds, setting up programs to match local academia and business to advance technological innovation began as "experiments" in the states of Massachusetts and California. With the help of the federal government, successful policies were learned by the Midwest and later spread out to the rest of the country. For instance, subsidized community college was rare before the mid-1970s. However, following the successful models of Massachusetts and California it has become a standard public education institution in most states.

Finally, we would like to indicate one avenue for further research, that is, the change of the organizational form itself. In the paper, we have treated the organizational forms as given and compared their static and dynamic properties. But we have not formally analyzed the "life cycle" of organizations such as the gradual shift from the U-form to the M-form in business organizations documented by Chandler. Although the comparative statics results from Section 4 may partly shed light on this issue by showing that an increase in the number of functions and complexity of products may give an advantage to the M-form despite the economies of scale of the U-form, more work is needed to understand the dynamics of organizational change. In our view, the overload problem emphasized by Williamson may be highly complementary to the task coordination problem analysed here; thus a more complete model should incorporate both of these aspects.

Such organizational dynamics becomes even more complex in government organizations as compared to business organizations since political economy issues play a role on top of efficiency. Thus, for example, the reasons for why the Soviet Union did not manage to change from the U-form to the M-form organization are in part due to politics. In fact, such a change actually occurred under Khrushchev in the late 1950s and early 1960s but the latter was deposed and the U-form organization was reinstated afterwards. Therefore, understanding the reasons for change (or its absence) of organizational forms of government will have to incorporate political economy considerations.

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