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Abstract

Consider a principal (say a central government) which allocates a fixed budget among multiple agents (say local governments). Each agent chooses a policy or technology. After observing the success or failure of each agent, the principal allocates a larger share of the budget to agents who succeeded than to those who failed. Under these conditions, a Nash equilibrium may have all agents herd, all choosing the same technology, even though the principal would prefer that they experiment, with different agents choosing different technologies. Relatedly, under some conditions all risk-averse agents may choose a technology whose outcome is risky, over a technology whose outcome is certain.

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1 Introduction

A principal often wants agents to experiment with different policies, approaches, and technologies. For example, the federal government may want different states to try out different ways of evaluating teachers; the World Bank may want different countries to try different infrastructure projects that could promote development; a CEO may want different subsidiaries to explore sales in different countries. Such experimentation allows a policy found to work well to be used by other agents. A different benefit arises when agents cannot easily switch from one policy to another, but the principal can allocate more resources to an agent who succeeded, and less to an agent who failed. If all agents, however, adopt the same policy, such reallocation is meaningless, and so benefits from reallocation are not achievable. But a principal faces the problem that agents, on their own, may not sufficiently experiment. In particular, we shall see that if an agent's utility increases in the budget he receives from the principal in period 2, and if each agent is risk-averse, then in period 1 a Nash equilibrium may have all agents choose the same policy or technology.

Several examples of insufficient experimentation come to mind. The Common Core is used by most states in the United States for education. The Washington Consensus, used by the International Monetary Fund and the World Bank in the Clinton years, offers an example of countries not experimenting. Discussing foreign aid, Easterly (2006) argues that the World Bank and other aid organizations did not encourage enough experimentation. One reason may be that countries did not want to risk the experimentation.

The importance of experimentation in government was well stated by President Franklin Roosevelt, who said that "The country needs and, unless I mistake its temper, the country demands bold, persistent experimentation. It is common sense to take a method and try it: If it fails, admit it frankly and try another. But above all, try something. The millions who are in want will not stand by silently forever while the things to satisfy their needs are within easy reach" (Address at Oglethorpe University in Atlanta, Georgia May 22, 1932). And indeed, experimentation by local governments has led to changes in national policy. State governments pioneered many new programs in the United States, including unemployment compensation, minimum-wage laws, public financing of political campaigns, no-fault insurance, hospital cost containment, and prohibitions against discrimination in housing and employment. Relatedly, much of the economic success in China is attributed to the fostering of experimentation by local officials (Montinola, Qian, and Weingast 1995).

2 Literature

The idea that competition between governments can lead to political innovations, and that decentralized government can lead to experimentation, is an old one. In 1888 Bryce wrote that "Federalism enables a people to try experiments in legislation and administration which could not be safely tried in a large centralized country. A comparatively small commonwealth like an American state easily makes and unmakes its laws; mistakes are not serious, for they are soon corrected; other states profit by the experience of a law or a method which has worked well or ill in the state that has tried it" (Bryce [1888] 2004, p. 257). A half-century later, U.S. Supreme Court justice Louis Brandeis viewed states as laboratories of democracy, writing in 1932 that "It is one of the happy incidents of the federal system that a single courageous state may, if its citizens choose, serve as a laboratory; and try novel social and economic experiments without risk to the rest of the country" (New State Ice Co. v. Lieberman, 285 U.S. 262, at 311 (1932)). In the academic literature, Oates (1999) speaks of "laboratory federalism," pointing out that welfare reform in the United States in 1996 followed these considerations (see also Inman and Rubinfeld 1997). Our analysis sheds further light on states as a laboratory of democracy.

Decentralized decision making can also reduce the risk that a bad decision will apply throughout the country. This effect is highlighted by Arcuri and Dari-Mattiacci (2009), who claim that in a decentralized system bad decisions are more frequent than in a centralized system, but their consequences are locally confined. The analysis below shows that under plausible conditions this result does not apply. Callander and Harstad (2012) consider incentives of a state in a federal system to experiment when it can imitate another state, but states differ in their policy preferences.

Economic agents may ignore their private information and, as in a herd, pursue unwise policies. Two types of explanations for rational herding appear in the literature. First, rational Bayesian decision makers will ignore their private information and instead mimic the actions of other economic agents (see Banerjee 1992, and Bikhchandani, Hirshleifer, and Welch 1992). Second, managers may mimic others to signal their ability (see Scharfstein and Stein 1990).

The analysis here relates to work on hierarchies and selection in organizations. Keren and Levhari (1989) consider a multi-divisional firm in which delegation entails a loss of control. Harrington (1999a and 1999b) considers a hierarchy in which agents who perform better advance to higher levels, focusing on why the agents promoted may be the most rigid ones.

Other work examines how a policy's success reveals information about an agent's competence. Such arguments are made by Rogoff and Sibert (1988) and by Rogoff (1990). Besley and Case (1995) go further by considering how "yardstick competition" allows the performance of different agents to be compared.

Removal of managers found to be of low quality, and how much resources to allocate to managers of different estimated quality, is studied by Filson (2000).

3 Assumptions

Consider one principal and $n \geq 2$ agents. In period 1, each agent chooses either technology (or policy) A, or else technology B. An agent is constrained to use the same technology in period 2 that he used in period 1. Different technologies are appropriate for different states of nature. In one state of nature A succeeds and

B fails; in the other state of nature A fails and B succeeds. Each event occurs with probability 1/2. In period 1 an agent's expected utility is independent of any choice he makes, and so we ignore that. An agent's utility in period 2, $v(g_i)$ increases with his budget in period 2, g_i, or $v' > 0$; we also suppose that $v'' \leq 0$. We could, more generally, have an agent's utility depend on the output generated by his spending in period 2, with the output higher if he has a successful technology. But because in much of the analysis we assume the technologies are equally likely to succeed, and an agent uses in period 2 the technology he adopted in period 1, the effects of his choice in period 1 can be characterized by the budget he gets in period 2. The agents can be viewed as engaging in rent seeking, with the prize being the budget the principal allocates. But whereas standard models of rent seeking focus on costly effort, we focus on the choice of policies or technologies, and the incentives to herd.

The principal must allocate all of his budget, which is exogenously given, among the agents. At the end of period 1, the principal observes each agent's success. In period 2, the principal allocates budgets among agents. Each agent spends the budget, using the technology he selected in period 1. For any given budget, the principal's benefit is higher if the technology succeeds than if it fails.

More specifically, the principal has the risk-neutral utility function

$$\sum_{i=1}^{n} e_i g_i, \tag{1}$$

where e_i is the effectiveness of the technology used by agent i; g_i is the budget the principal allocates to agent i in period 2. For any agent i, $e_i = e_H$ when the technology succeeds, and $e_i = e_L < e_H$ when it fails.

The principal faces a budget constraint when he allocates budgets in period 2:

$$\sum_{i=1}^{n} g_i = K, \tag{2}$$

where the aggregate budget, K, is exogenous. He must allocate all of the budget to the agents. The principal may want different agents to try different technologies. Such variety allows him to allocate different budgets to agents using different technologies. The possibility of this allocation creates risk for the agents.

The timing of the game is summarized as follows. In period 1:

1. Each agent chooses technology A or else technology B.

2. Nature determines which technology succeeds.

3. The principal observes the success or failure of each agent.

In period 2:

1. The principal gives agent i the budget g_i.

2. Each agent spends his budget, using the technology he adopted in period 1.

3. Payoffs are realized.

We solve the game backwards to find the subgame-perfect Nash equilibrium.

4 Equilibrium

4.1 The principal

In period 2, the principal maximizes his utility (1) subject to the budget constraint (2). If some agents had a technology that succeeded, the principal divides the budget equally among those agents. Such behavior can be justified when the marginal product of spending on a successful technology e_H is higher than the marginal product of spending on a failed technology e_L.[1] If no agent used a successful technology, the principal, who by assumption must use all his budget, divides the budget equally among all agents. Consequently, the budget an agent gets depends on whether the technology he chose succeeded and on the number of other agents who chose a successful technology.

Formally, let g_H be the budget the principal gives to an agent whose technology succeeded, and g_L the budget he gives to an agent whose technology failed. Let n_H be the number of agents who chose the successful technology. Then the following characterizes the equilibrium strategy:

$$\begin{cases} g_H = K/n_H; & g_L = 0, & \text{if } 0 < n_H \leq n; \\ g_H = 0; & g_L = K/n, & \text{if } n_H = 0. \end{cases} \tag{3}$$

4.2 Agents

In period 1, anticipating the principal's budgetary decision in period 2, each agent chooses technology A or else technology B to maximize his utility $v(g_i)$. We first examine whether an equilibrium exists with all agents choosing the same technology.

If agent i adopts technology A while all other agents adopt technology A, then, from (3), in period 2 he will get the budget K/n. His utility would be

$$v(K/n). \tag{4}$$

Thus, an agent who chooses the same technology others use is assured of a fixed utility whether the technology he chose succeeds or fails.

[1] An arbitrary unequal allocation of K among agents who succeeded, or among all agents who selected the same failed technology, can be the principal's best response, because the marginal product of resources is uniform among them. Because, however, we consider identical agents, we assume equal allocations.

If agent i chooses technology B while all other agents choose technology A, with probability 1/2 (when technology B succeeds) he will get K; with probability 1/2 (when technology B fails) he will get 0. Thus agent i's expected utility would be

$$(1/2)(v(K) + v(0)). \tag{5}$$

An agent who chooses a different technology from others gets a zero budget if his technology fails, hurting a risk-averse agent.

Thus whether agent i herds depends on the difference between (4) and (5):

$$\left[\frac{v(K) + v(0)}{2} - v(K/2)\right] + \left[v(K/2) - v(K/n)\right]. \tag{6}$$

Note that $K/2$ in expression (6) is the expected budget when choosing technology B. Therefore, the sign of the first term depends on the agent's attitude toward risk. For a risk-averse agent the term is negative. If the agent is risk-neutral, the term is 0. The second term, which is non-negative, captures how the utility gained for certain by herding is less attractive with more agents. Therefore, the degree of the agent's risk aversion and the number of agents determine whether the agents herd. With more agents, taking risk is more attractive. If the agent is sufficiently risk-averse, however, the first effect dominates the second effect, and an agent prefers to herd.

For illustration, let an agent's utility function exhibit constant absolute risk aversion, such as $v(g_i) = -\exp(-\rho g_i)$, $\rho > 0$. The Taylor expansion approximates (**??**) as

$$v\left(\frac{K}{2} + \frac{1}{2}\frac{v''(K/2)}{v'(K/2)}\frac{K^2}{4}\right), \tag{7}$$

where $-\frac{1}{2}\frac{v''(K/2)}{v'(K/2)}\frac{K^2}{4}$ corresponds to the risk premium for choosing technology B. Using the specified utility function, the certainty equivalent of this gamble is approximately

$$\frac{K}{2} - \frac{\rho K^2}{8}. \tag{8}$$

Therefore the agent herds when

$$\frac{1}{n} + \frac{\rho K}{8} \geq 1/2. \tag{9}$$

Thus, (9) demonstrates that when an agent is risk-averse and the aggregate budget is large, herding can appear even with many agents.

Is the equilibrium with herding unique, or does there exist an equilibrium with $x > 0$ agents adopting technology B and $n - x$ agents adopting technology A? Given that all other agents adopt technology A, an agent also adopts technology A if and only if the following holds:

$$v(K/n) \geq \frac{1}{2}v(K) + \frac{1}{2}v(0), \tag{10}$$

and then there exists an equilibrium with herding.

We consider next outcomes when $n \geq 4$, because, subject to the assumption that agents are sufficiently risk averse (10), all agents herd for $n = 2$ and $n = 3$. When $n = 2$, as we can demonstrate with (10), in equilibrium the agents herd. When $n = 3$, an outcome in which two agents choose technology A and the other agent chooses technology B (or vice versa) is unstable: an agent in the minority gains by switching to the technology chosen by the majority (see (10)).

For $n \geq 4$, if agents do not herd then an agent adopting technology A gains nothing by deviating to technology B; hence the following relation should hold:

$$\frac{v\left(\frac{K}{n-x}\right) + v(0)}{2} - \frac{v\left(\frac{K}{x+1}\right) + v(0)}{2} \geq 0. \tag{11}$$

Similarly, for an equilibrium without herding the agent adopting technology B should not want to deviate to technology A:

$$\frac{v(K/x) + v(0)}{2} - \frac{v\left(\frac{K}{n-x+1}\right) + v(0)}{2} \geq 0. \tag{12}$$

These conditions reduce to $(n-1)/2 \leq x \leq (n+1)/2$, meaning that for any $n \geq 4$, an equilibrium without herding also exists. In this equilibrium, an agent is not completely insured even if he deviates to the technology chosen by the majority; rather, by behaving like the majority, he gets a smaller budget when his technology succeeds. Thus with many sufficiently risk-averse agents, in equilibrium the agents may herd, but need not.

Note that if the agents could collude, agreeing on the technology each would use, then they would prefer to use the same technology. If all agents herd, aggregate payoffs to the agents are $nv(K/n)$. If x agents use one technology and $n-x$ use the other, then with probability 1/2 each of these x agents gets the payoff $v(K/x)$ and other agents each gets $v(0)$, which we suppose equals 0. If v is strictly concave, we have $nv(K/n) > (n-1)v(K/(n-1)) > (n-2)v(K/(n-2))$.... Hence, aggregate payoffs to the n agents when they all herd is greater than when $x < n$ choose one technology and $n - x$ choose the other technology.

The prediction that agents may herd is supported by some evidence. A study of innovations in welfare policy by states in the U.S. finds that national, but not local conditions, affect what reforms states adopt (Lieberman and Shaw 2000). The authors cite their results as evidence of herding. In our terms, if conditions facing agent A would make him favor technology A, and conditions facing agent B would make him favor technology B, but they nevertheless both choose technology A, then our model would explain such behavior by risk-averse agents herding. The principal here could be the federal government. But similar results would appear if instead businesses or people that the states wanted to attract preferred to locate in states that successfully innovated.

4.3 Welfare

Although in equilibrium all agents may choose the same technology, the principal may prefer that they do not. From (1), the principal's expected utility (which equals expected output by agents), when all agents adopt technology A, is

$$\frac{1}{2}ne_H\frac{K}{n}+\frac{1}{2}ne_L\frac{K}{n}=\frac{1}{2}e_HK+\frac{1}{2}e_LK. \tag{13}$$

The first term in this expression is associated with technology A succeeding; the second term is associated with the technology failing. On the other hand, with $n-x$ $(0<x<n)$ agents adopting technology A and x agents adopting technology B, the principal's expected utility is

$$\frac{1}{2}(n-x)e_H\frac{K}{n-x}+\frac{1}{2}xe_H\frac{K}{x}=e_HK. \tag{14}$$

Accordingly, if $e_H>e_L$ the principal prefers non-herding. Intuitively, if all agents use the same technology, the technology used by any one agent will either fail or succeed. If instead some agents tried a technology different from what other agents used, then once again those agents' technology will either fail or succeed, but the principal can give more money to agents with a successful technology.

If the principal suffers from herding by agents, why doesn't the principal just tell the agents what to do? One reason is that he may be unable to directly control the actions of each agent, and the principal's ability to give proper incentives by penalizing agents in period 2 is not time consistent or credible. Moreover, even with multiple agents, if they are sufficiently risk-averse, each agent will want to do what the others do, and the agents may coordinate. As (10) suggests, coordination is more beneficial with fewer agents. Also, if, say, technology A requires slightly less effort from an agent, then each will want to use it.

For further insight into welfare, consider asymmetric technologies: the probability, s, that technology A succeeds (while technology B fails), is less than the probability that technology B succeeds (while technology A fails). The condition that $s<1/2$ means that technology A is inferior to technology B. Then (6) becomes

$$\left[(1-s)v(K)+sv(0)-v\left((1-s)K\right)\right]+\left[v\left((1-s)K\right)-v\left(K/n\right)\right]. \tag{15}$$

Given the number of agents n, the second effect is greater in comparison with (6); an agent who chooses superior technology B expects to get a higher budget. The first term, however, suggests that if the agent is sufficiently risk-averse, herd behavior still occurs. For instance, using $v(g_i)=-\exp(-\rho g_i)$, with $\rho>0$, the certainty equivalent of gambling, by choosing technology B, while others adopt technology A, is

$$(1-s)K-\frac{\rho s(1-s)K^2}{2}. \tag{16}$$

Then an agent adopts technology A when all others do if

$$\frac{1}{n} + \frac{\rho s(1-s)K}{2} \geq 1 - s. \tag{17}$$

Comparing this condition with (9), shows that if $s < 1/2$ (and so technology A is inferior to technology B) agents would not necessarily herd as they did if $s = 1/2$.

The principal's expected utility when the agents herd is then

$$sne_H\frac{K}{n} + (1-s)ne_L\frac{K}{n} = se_HK + (1-s)e_LK, \tag{18}$$

and hence, comparing (18) with (13), the principal may anticipate that he will be worse off if the two technologies are asymmetric and all agents adopt the inferior technology than if the technologies are symmetric.

5 Riskless technology

The analysis so far considered whether agents will herd, under the assumption that both technologies are risky. This section introduces a riskless technology, examining whether agents will avoid a risky technology or project and examining how the principal's utility is affected.

Consider two technologies. Technology R is risky; its outcome will be either good (e_H) or bad (e_L). A technology with a good outcome has a higher marginal product of spending on the technology, or $e_H > e_L$. Again each outcome occurs with probability 1/2, and the outcome for each agent is independent of the outcomes for other agents. Technology C has a certain outcome, or a known marginal product of spending on it, e_C. For example, we can think that a jurisdiction can adopt a proven school reform (say, increasing the length of the school year), or adopt a novel school reform (say, introducing charter schools). The outcome of the novel reform is *ex ante* unknown, and so is risky.

An agent's utility increases with his budget (rather than with his output) in period 2. That is, an agent is a risk-averse budget maximizer. Let $e_L < e_C < e_H$. Note that if e_H is close to e_C and e_L is much smaller than e_C, the principal would want the agents to use the riskless technology. If e_H is much larger than e_C and e_L is close to e_C, the principal would want the agents to use the risky technology. We shall see, however, that the agents may herd on a choice the principal does not favor.

5.1 All agents adopt the risky technology

Consider first whether it is an equilibrium for all agents to adopt the risky technology. Suppose that all agents other than agent i adopt technology R. If agent i adopts technology R, his expected utility is

$$\frac{1}{2}\sum_{j=0}^{n-1}\frac{(n-1)!}{j!(n-1-j)!}\frac{v\left(\frac{K}{j+1}\right)}{2^{n-1}} + \frac{1}{2}\sum_{j=1}^{n-1}\frac{(n-1)!}{j!(n-1-j)!}\frac{v\left(0\right)}{2^{n-1}} + \frac{v\left(K/n\right)}{2^{n}}, \tag{19}$$

where j represents the number of successful agents other than agent i. The first term is associated with agent i's technology succeeding; the second and third terms relate to his technology failing. The expression $\frac{(n-1)!}{j!(n-1-j)!}\frac{1}{2^{n-1}}$ represents the probability that j agents among all agents other than agent i succeed. In particular, the third term applies when no agents succeed, so that the principal gives each agent K/n.

If instead the agent adopts technology C, the principal gives him resources only when all other agents fail; the agent's expected utility is then

$$\frac{v\left(K\right)}{2^{n-1}}+\left(1-\frac{1}{2^{n-1}}\right)v(0). \tag{20}$$

For intuition, let $n=2$. Then (19) becomes

$$\frac{v(K)}{4}+\frac{v(0)}{4}+\frac{v(K/2)}{2}, \tag{21}$$

and (20) becomes

$$(1/2)(v(K)+v(0)). \tag{22}$$

Therefore, he herds on (that is, adopts) technology R if and only if

$$v(K/2)\geq(1/2)(v(K)+v(0)), \tag{23}$$

meaning that the equilibrium can have all risk averse agents adopt the risky technology. Intuitively, an agent benefits from herding on a risky technology in two ways. It gives him a non-zero budget with a positive probability even if his technology fails. Second, if he adopts technology C, he gets a positive budget only when no agent adopting technology R succeeds; that outcome need not happen when the number of agents is large.

5.2 All agents adopt riskless technology

But it is also an equilibrium for all agents to adopt the riskless technology. To see this, consider again two agents. Suppose agent 1 chooses technology C. If agent 2 chooses technology C he gets $v(K/2)$. If agent 2 chooses technology R his expected benefit is $(1/2)(v(K)+v(0))$. So an equilibrium exists in which two agents herd on the riskless technology C if $v(K/2)\geq(1/2)(v(K)+v(0))$.

5.3 Welfare of principal

To examine the principal's welfare, we consider two agents. If both agents herd on the risky technology, the principal's expected utility is

$$\frac{3}{4}e_HK+\frac{1}{4}e_LK. \tag{24}$$

When both agents adopt risky technologies, output is lower ($e_L K$) only with probability 1/4. Thus the economy with an uncorrelated risky technology assures the principal of a higher payoff by herding than the payoff in (13). If both agents herd by adopting a riskless technology, the principal's expected utility is

$$e_C K. \tag{25}$$

The difference is

$$\frac{3}{4} e_H K + \frac{1}{4} e_L K - e_C K. \tag{26}$$

Thus (26) suggests that if the expected marginal product from the uncorrelated risky technology, $(e_H + e_L)/2$, is lower than the certain product of the riskless technology (e_C) but $(3/4))e_H + (1/4)e_L > e_C$ herding by the agents on the uncorrelated risky technology benefits the principal. It consequently means that experiments by agents (say, local governments) can benefit the principal (say, a central government).

6 Two risky technologies and one risk-free technology

In Section 3 and Section 4, the agents adopted one of two risky technologies A and B such that when one technology succeeds, having the outcome e_H, another technology fails, having the outcome e_L, $e_H > e_L$. Section 5 introduced a risk-free technology C which assures the principal of a constant marginal product e_C. Now suppose that the agents can adopt one of three technologies, including one risky technology A, another risky technology B, and riskless technology C, with $e_H > e_C > e_L$. Technology R differs from technologies A or B because with technology R each agent who uses that technology has an independent chance of succeeding; in contrast all agents who use technology A have the same outcome, all agents using technology B have the same outcome, the success of technology A implies the failure of technology B, and vice versa. Suppose again that each of technologies A and B succeeds with probability 1/2.

We first examine an agent's choice given that all other agents adopt technology A. An agent's utility when he also adopts technology A is then given by (4). His utility when he adopts technology B is given by (5). If the agent adopts technology C, then his utility is also given by (5); an agent who adopts the riskless technology still faces risk. This result is an extension of the results derived in Section 3 and Section 5. A sufficiently risk-averse agent would prefer to adopt technology A, and accordingly herding on a risky technology would be observed.

Consider next an agent's behavior given that all other agents adopt riskless technology C. An agent's utility when adopting technology C is given by (4). His utility when adopting technology A or technology B is (5). A risk-averse agent may adopt technology C if all others do.

Accordingly, there exist two types of equilibria with herding. All the agents adopt the same risky technology A or B, and all the agents adopt the riskless technology C. For $n = 2$, in the equilibrium with herding on risky technology A or B, the principal's welfare is given by (13). The principal is worse off than in the equilibrium with herding subject to an uncorrelated risky technology; the principal's payoff is then given by (24). The principal's utility when all agents choose the riskless technology is given by expression (25). These results suggest that the principal's payoff under insufficient experimentation by agents is greater when the effects of policy adoption by agents are independent. The reason, as before, is that independent outcomes allow the principal to reallocate his budget from agents with failed technologies to those with successful technologies.

7 Conclusion

We saw that decisions by a central authority on allocating a budget to multiple agents can have the undesirable effect of herding—the agents all adopt the same policies. To mitigate this effect, the principal may prefer to commit to give the same budget to all agents in period 2, rather than to allocate funds optimally in period 2 after he learns the success of each technology. Such commitment would eliminate the incentives of the agents to herd, including herding on a bad technology.

If herd behavior leads all jurisdictions to adopt the same policy or technology, then federalism may lead to low economic growth. Among studies finding that federalism may reduce growth are Baskaran and Feld (2009), who look at 23 OECD countries from 1975 to 2001. Similarly, a cross section study by Thornton (2007) of 19 OECD countries, which measures fiscal decentralization by the revenues over which sub-national governments have full autonomy, finds little effect of decentralization on growth. Several studies, however, indeed find that fiscal decentralization reduces growth (Davoodi and Zou 1998, Zhang and Zou 1998, and Xie, Zou and Davoodi 1999).

Lastly, note that some of the analysis presented above applies to private organizations, such as firms, rather than only to governments. For example, consider multi-divisional firms. Multiple divisions can let a firm identify capable agents before they are given wide responsibility or added resources. The same model can apply to delegation.

8 Notation

e_H Productivity factor for successful technology

e_L Productivity factor for failed technology

g_i Budget allocated to agent i in period 2

n Number of agents

n_H Number of agents who adopted successful technology

K Principal's budget

s Probability a technology succeeds

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