Experimentation in Federal Systems*

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Abstract

Will decentralization lead to a laboratory in policy experimentation, or is centralization necessary to prevent free-riding in the innovation process? We present a model where experiments have two dimensions: all prefer quality, but preferences differ in the type of policy. To mitigate free-riding, a district selects an experiment that is less attractive for the neighbor. This distortion magnifies as heterogeneity vanishes; hence districts benefit from being heterogeneous. Centralization, requiring ex post costly policy harmonization, may generate a benign competition where districts experiment with policies appealing to the median voter. In both systems, the districts prefer limiting transparency to mitigate free-riding.

Key words: Experimentation, innovation, political systems, decentralization vs. centralization, learning, free-riding, laboratory, tournament, transparency

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1 Introduction

Just as people learn from each other, so do governments. Whilst people learn from each other about good restaurants and career choices, governments learn from each other about good policies. Governments observe their neighbors, as well as states and countries further afield, and imitate their policy successes while avoiding their policy failures. The spread of policies in this way – known as policy *diffusion* – has most famously been documented as a strength of federal systems. Yet information need not be constrained within political borders, and policies diffuse across countries as well, from friends to sworn enemies.[1]

In recent times researchers have progressed beyond anecdote and intuition on this issue, documenting the rate, extent, and usefulness of policy diffusion. In the context of United States federalism, Volden (2006) shows how policy successes spread progressively through similar states. Analogously, across country borders, Buera, Monge-Naranjo, and Primiceri (2011) show how learning from similar countries accounts for a majority of the movement toward market policies and economic growth throughout the late twentieth century.

Despite these positive findings, the outlook on policy experimentation and diffusion is not entirely positive and much remains unknown. In fact, the positive finding that *similar* states may *learn* from each other also suggest its shortcomings. On the one hand, states that are dissimilar may not learn that much from each other's policies. On the other, for similar states where the learning externality is large, basic economic theory suggests that a free-riding problem will be pervasive. Why should a state undertake a costly and risky policy experiment if it can wait for its neighbors to do the same and learn from their experience?

Putting the pieces together, we are left with many open questions. Whilst policy diffusion is surely occurring in practice, are we getting as much experimentation as we should? Indeed, if free-riding is rampant, why is it that some states are choosing to incur the costs and risks of experimentation rather than free ride? And even when policy experiments are undertaken, are the experiments that are undertaken the "right" experiments? That is, in a world with similar and dissimilar states, are the experiments that are undertaken those that cast off the most useful information to the broadest possible array of states?

The objective of this paper is to shed light on exactly these questions. We present a

[1] The history of military technology, for one, is rife with imitation by the enemy.

simple model of policy experimentation with two states (or "districts"). A key novelty is that the states do not share the same policy preferences – they may be similar or dissimilar – and, therefore, the usefulness of a policy experiment varies across states. For instance, a policy experiment that successfully implements a liberal outcome is of more use to a left-leaning state than it is to a state preferring right-wing outcomes. Formally, we think of policy outcomes as having two components: a spatial preference component to capture differences across states, and a quality, public good component, that captures the transferability of successful policy innovation.

We present three sets of results. On decentralization, we first find that preference heterogeneity provides some positive news: The incentive to free ride declines in the heterogeneity of states. The less similar a neighboring state is to another, the less useful is information revealed by each other's experiments and the more inclined is each to engage in its own experiments. With the ability to choose which policy to experiment with, states are able to take the free-riding problem into their own hands. To reduce the free-riding by other states, states deliberately choose policies that are *less* attractive to the other states. They do this even to the degree that they sacrifice their own welfare by experimenting with policies other their own ideal policies. When policy types and ideal points are points on a line, equilibrium policy choices diverge, and they diverge more as heterogeneity declines, since the incentive to free-riding would otherwise increase. For this reason, some heterogeneity is optimal in our model.

The inefficiency of policy experimentation raises the question of whether a better outcome can be achieved. Our second set of results analyze centralization, and how a carefully designed federalist system can provide the incentives for policy experimentation while at the same time inducing the right sort of experiments to be undertaken. The literature typically assumes that centralization requires costly policy harmonization on one of the already developed policy alternatives. This choice might be made by a median voter, with ideal points between the districts' own ideal point. The threat of harmonization can discourage experimentation, since a district might, in any case, be forced to adopt the neighbor's policy. If this is costly, however, the incentive to experiment may increase when the uniformity requirement is imposed, and the equilibrium type of policies may diverge less, and in fact converge towards the median voter's ideal point. This uncovers a benefit of centralization that has to date been unknown, to the best of our knowledge.

Note that our view of federalism is inherently dynamic, and we refer to it as *progressive federalism*: Early in the process the individual states control their policy domain, but they exercise control in the shadow of future centralization. Political power is progressively centralized over time.

Our final set of results contributes to debate on whether policy transparency is beneficial. More transpareny means that one district can more easily adopt the other neighbor's successful experiment - which is beneficial - but this benefit makes it more tempting to free-ride. To mitigate the larger incentive to free-ride, the equilibrium experiments diverge, or converge less. This cost tends to outweight the direct benefit of transparency, so all districts would benefit from reducing transparency in our model.

The idea that a federalist system facilitates policy experimentation is, of course, not new. It has been prominent in academic and policy circles at least since the time of Justice Louis Brandeis, who uttered the famous phrase:

> *"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."*
> Justice Brandeis, 1932.

The justice presents an optimistic perspective on federalism, yet he leaves unspecified how a federalist system induces experimentation to take place, let alone how it induces the right experiments to be undertaken. Brandeis may be correct that a policy experiment in a single state is without risk to the rest of the country, but he ignores the possibility that the experiment may also be without benefit if states are heterogeneous. Also left unspecified in the justice's optimistic account is why a federal system is required at all. Why can't the policy laboratory work in the absence of a federal system altogether? To turn this question around, left unaddressed is whether policy experimentation is impacted at all by states formally lashing themselves together in a federal system.

A contribution of our model is to provide a positive explanation for the formal commitment to a federal system. We show why the *ex ante* commitment to federalism – specifically, a progressive federal system – is to the benefit of the states who choose to participate. The benefit we characterize, however, should not be thought of as the benefit of joining a policy laboratory. Rather, the appropriate metaphor for a progressive federal system is that of a tournament. If power in a federal system is to ultimately be centralized – and coordinated – the dynamic stages of federalism resemble a tournament, what might be thought of as a policy tournament. The powerful incentive effects of a tournament drive experimentation and efficiency, and it is these benefits that provide the rationale for the states to lash themselves together into a federal system in the first place.

To the best of our knowledge, our conception of progressive federalism as an incentive system has appeared previously in neither the academic literature, policy debates, nor actual federalist constitutions. Nevertheless, and perhaps surprisingly, the dynamics of progressive federalism contact the history and empirics of federalism at several prominent points. Most prominently, our theory predicts that power will increasingly concentrate at the centre of federal systems, a pattern that has emerged clearly in the United States and in Europe, as well as many other federal systems. Our model also predicts that this centralization will proceed in step with learning as policies in effect diffuse from the states up to the central authority. Rabe (2004, 2006) documents this informational channel for the case of the United States. Of course, the possibility that power may concentrate in the center in federal systems has not escaped theorists of federalism. Indeed, de Figueiredo and Weingast (2005) label the threat as one of the twin dilemmas of federalism. The novelty of our contribution is to observe that rather than this dynamic reflecting an unavoidable power grab or an instability in federalism (Riker 1964; Bednar 1996), the progressive concentration of power can occur as an intentional and desirable feature of institutional design.

The paper is organized as follows. After a short literature review, Section 2 describes the simple model, the first-best outcome, the equilibrium under decentralization, and the optimal level of heterogeneity. Section 3 analyzes the outcome under centralization, and shows when the uniformity requirement is actually beneficial. Section 4 ties our model to the debate on transparency. Section 5 is further discussing the results, Section 6 concludes, and the Appendix contains all proofs.

1.1 Related Literature

A federalist system offers many chances for free-riding by the participating states, including but far from limited to those surrounding policy experimentation. Indeed, free riding is the second of the twin dilemmas of federalism according to de Figueiredo and Weingast (2005). The importance of free riding has captured a substantial amount of research attention, with many notable contributions that explain how the collective action problem can be solved (such as via repetition; see Bendor and Mookherjee 1987). Despite this attention, the amount of research into the specific problem of policy experimentation and free riding has been surprisingly small.

The pioneering study in this domain is Rose-Ackerman (1980) who demonstrates how free riding in federal systems dampens the incentive of office-seeking politicians to experiment with policy. Cai and Treisman (2009) explicitly compare such an outcome to that possible under centralized government as candidates seeking national office attempt to construct majority winning coalitions. Strumpf (2002) compares the decentralized outcome to a centralized policymaker who is compelled to harmonize policies across all districts. Volden, Ting, and Carpenter (2009) make the important point that policy diffusion is often difficult to distinguish from individual policy learning, although they limit attention to binary policy action and overlook the inefficiencies in policy choice that are our interest here.[2]

A recent paper by Bednar (2011) asks how a federalist system can 'nudge' states toward productive experimentation. She considers a variety of inducements, from shifting public attention to offering party-based rewards, that seek to nudge the interests of individual states such that they align with those of the national polity. We differ from Bednar in providing a formal model rather than adopting a verbal treatment and by showing the power-sharing agreement itself structures the incentive system within the system. Ironically, in a separate survey of the federalism literature, Bednar (2011b, p. 282) argues that "perhaps the most revolutionary research shift moving forward is to develop a theory of the dynamics of federalism's boundaries." Although our work was completed independently, its principal results demonstrate the utility in her prescient projection.[3]

Among the various research streams on federalism, without doubt the most prominent is that following Tiebout's (1956) famous model of sorting and policy competition. Our conception of policy competition is very different from that of Tiebout; specifically, we do not allow for inter-district movement of people. Nevertheless, we find that an intriguing connection appears between our work and that of Tiebout through the degree of district heterogeneity that is central to our work and that is generated by Tiebout-style sorting. We return to this connection in the discussion section of the paper.

The question of efficient experimentation has long been a question of more general interest in economics, captured famously by models of multi-armed bandits. Recently this literature has been extended to environments with multiple experimenters by Bolton and

[2] An interesting computational approach is proposed by Kollman, Miller, and Page (2000). They show that decentralized, parallel, search outpeforms centralized search on problems of moderate complexity.

[3] Several other papers explore how federalist institutions and features determine the alignment of incentives between states and the national interests, although these offer very different institutional solutions to ours and do not touch upon policy experimentation (Persson and Tabellini 1996; Cremer and Palfrey 1999, 2000).

Harris (1999). They characterize how free riding undermines the efficiency of equilibrium (see also Keller, Rady, and Cripps 2005). Our model is a considerable simplification of these general formulations, yet our results suggest that preference heterogeneity may carry more general force in mitigating the free riding problem when multiple agents coexist. Although simple, our model does extend the experimentation literature by allowing for heterogeneity of preferences and policy choice, moving beyond the previous focus on binary and predetermined actions. We also take up the question of institutional design and experimentation that has not previously been considered.

2 Experimentation under Decentralization

2.1 The Model

We now present a framework for studying policy experimentation. Although the model is extremely simple, it captures the essential elements of policy experimentation in quite general settings. The game consist of two districts and three stages. Each agent should be thought of as a political unit, a state in a federal system or one of two independent countries. We refer to them as districts.

First, each district $i \in \{A, B\}$ simultaneously decides the type of its initial policy or experiment $x_i \in \Re$.

Second, each district decides whether to play safe by doing nothing or experiment with the policy. With probability p, an experiment succeeds and raises the value of the policy by 1, but the cost of the experiment is $k > 0$. Parameter k can represent the benefit of the safe option relative to the expected benefit of the risky option, but it can also simply measure the investment cost of developing and enhancing the value of the policy.

Third, after the districts have observed the outcomes of the experiments, each district i decides on its final policy location, y_i. We assume that a district must adopt one of the two policies chosen at the first stage, so $y_i \in \{x_A, x_B\}$. This is natural if adopting a completely new policy requires sufficiently high additional costs (these costs can then be abstracted from here).

The districts have different preferences over policies: A's ideal point is $t_A = -h/2 \leq 0$ while B's ideal point is $t_B = h/2 \geq 0$. Thus, $h \geq 0$ measures the heterogeneity or the distance between the ideal points. Assuming that the ideal points are symmetrically located around the origin is just a normalization. To simplify, we let the preference over policies be represented by a disutility-function that is symmetric around the ideal point: $c(y_i - t_i) = c(t_i - y_i)$. We also assume $c(\cdot)$ to be convex, U-shaped, and to satisfy $c'(0) = 0$. With this, the payoff to each district is:

$$u_i = I_{y_i} - c(y_i - t_i) - J_i k.$$

The index-function $I_{y_i} \in \{0, 1\}$ equals 1 if the policy, chosen by i at stage three, has proven successful. The index function $J_i \in \{0, 1\}$ equals 1 if i decided to experiment at the first stage.

We define a_i as the extent to which district i *accommodates* the neighbor by experimenting on a policy that is closer to the center than i's ideal point:

$$a_A \equiv x_A - (-h/2) \text{ and } a_B \equiv h/2 - x_B.$$

So, at stage three, i can choose between its own experiment, perhaps generating a relatively low distance cost, $c(a_i)$ or the neighbor's policy, generating disutility $c(h - a_j)$, $j \in \{A, B\} \setminus i$.

Autarky: To understand the model, consider the case with only one district. At the third stage, district i must necessarily stick to the location picked at the first stage, so $y_i = x_i$. Anticipating this, i always prefers to experiment at its own ideal point to minimize the distance cost. Thus, $y_i = x_i = t_i \Rightarrow d_i = l_i = 0$. At the second stage, district i finds it optimal to experiment if the cost is smaller than the expected benefit from the experiment:

$$p > k,$$

which is henceforth assumed to hold. Naturally, district i's decision $(x_i, J_i, y_i) = (t_i, 1, t_i)$ implements the first-best outcome.

The first-best: With two experimenting districts, it is possible that one experiment will succeed while the other fails. In this case, the district with the failed experiment can discard his own policy and adopt the other, although doing so may involve incurring a greater distance-cost. From a social welfare perspective, therefore, we have that the optimal experiments may involve policy positive accommodation or *convergence.*

Proposition 1 *The first-best requires convergence:*

$$t_A \leq x_A < 0 < x_B \leq t_B \Leftrightarrow a_i \in [0, h/2), \forall i \in \{A, B\}.$$

Furthermore, for each k and p, there exists $h' \in [0, \infty)$ and $h'' \in (h', \infty)$ such that:
(i) For $h > h''$, each district experiments at its ideal point: $x_A = t_A$ and $x_B = t_B$.
(ii) For $h \in [h', h'']$, the district's converge from their ideal points and the optimal $a_i > 0$ satisfies:

$$\begin{aligned} \frac{c'(a_i)}{c'(h - a_i) + c'(a_i)} &= p(1-p), \; i \in \{A,B\} \;\; \Rightarrow \\ \frac{\partial a_i}{\partial h} &\in (0,1). \end{aligned} \tag{1}$$

(iii) For $h < h'$, only one district experiments. The nonexperimenting district locates at its ideal, whereas the experimenting district optimally accommodates by $a_i \in (0, h/2)$, satisfying:

$$c'(a_i) = pc'(h - a_i).$$

Efficiency calls for the districts to converge in their policy choice. Thus, if an experimenter succeeds, the policy is of less value to him (than if he had experimented at his ideal point), but it is potentially much more valuable to the neighbor, if her experiment should fail. The social benefit of convergence emerges from the concavity of utility over the type of policy.

Such accomodation is beneficial, however, only if heterogeneity is sufficiently small. If the heterogeneity, h, becomes too great, a district prefers his own failed experiment to the other district's successful experiment, and in this event it is optimal for the districts to simply experiment at their own ideal points.

By the same token, the convergence of experiments is never complete. This is intuitive. If both districts experiment then there is a chance that both will succeed (or fail), in which case convergence is ex-post inefficient as the districts are forced to locate away from their ideal. Thus, with a cost of convergence and only a probabilistic benefit from doing so, it is not a surprise that full convergence is suboptimal.[4]

This point does make prominent, however, that an important variable in the analysis is when the experimental outcomes are mismatched (one success and one failure). Thus, the size of $p(1-p)$ is important in driving first-best behavior. This is evident explicitly within the convergent behavior of case (ii), equation (1). The left hand side of the optimality condition is increasing in the degree of convergence (the size of a_i) by the

[4] This is evident in the condition in case (ii). If convergence is complete the left hand side is $\frac{1}{2}$, yet the maximum posisble value for the right hand side is $\frac{1}{4}$.

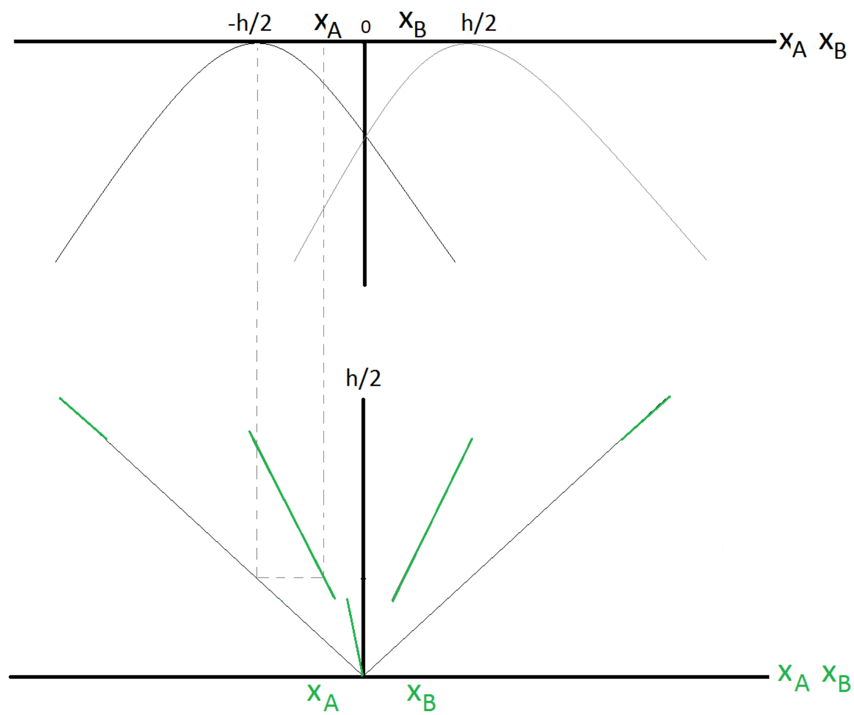


Figure 1: *Top figure draws* $-c(t_A - x)$ and $-c(t_B - x)$ *to show first-best convergence for a given h. The below figure draws (in black 45-degrees line) ideal points as function of h, measured on the vertical axis, and first-best experimental locations (in green) as functions of h. Unless h is very large, the first-best requires convergence.*

convexity of $c(.)$. As $p \to \frac{1}{2}$ the right hand side increases and the first best requires increased convergence. On the other hand, as $p(1-p)$ approaches 0, due either to the experiments almost surely succeeding or failing, convergence decreases and in the limit the districts locate at their ideal points.

We can also establish how the optimal amount of convergence varies in the distance between the districts' ideal points. As this heterogeneity h increases, for fixed a_i it must be that $h - a_i$ is increasing. For the condition in case (ii) to hold, therefore, requires that a_i increase. Thus, the districts are choosing policies further from their ideal points as the difference between their ideologies increases.

A final possibility is that it may be efficient that only one district experiments. This can occur only for very similar districts, where h is small. The necessary and sufficient condition for a single experimenter to ever be optimal (i.e., for $h' > 0$) is $2p(1-p) - k < 0$, since, otherwise, it is socially optimal that both experiment even at $h = 0$.

To bring the intuition for our results into sharp focus, we can specialize utility to the quadratic functional form where $c(d_i) = -qd_i^2$ for some parameter $q > 0$. We can then calculate the requirements of Proposition 1 precisely (which turn out to be independent of q).

Corollary 1 *For quadratic utility, the first-best policies satisfy the conditions:*
Case (ii) When both districts experiment and converge,

$$a_i = p(1-p)h \ \forall i \in \{A, B\}.$$

Case (iii) When only district $i \in \{A, B\}$ experiments, $j \neq i$ sets $a_j = 0$ while:

$$a_i = \frac{p}{1+p}h.$$

In this case we can provide precise comparative statics. In case (ii), we have $da_i/dh = p(1-p) \in \left(0, \frac{1}{4}\right]$. Thus, as h increases the districts are choosing policies further from their ideal points, but the rate is slow enough that the distance between their chosen policies increases; $d(x_B - x_A)/dh = 1 - 2p(1-p) \in \left[\frac{1}{2}, 1\right)$.

2.2 The Equilibrium under Decentralization

We now solve the game by backwards induction. The last stage of the game is trivial: The investment cost is sunk and each $i \in$ {A,B} picks the final policy maximizing its utility:

$$y_i = \arg \max_{x_j \in \{x_A, x_B\}} I_{x_j} - c(x_j - t_i). \tag{2}$$

If $c(\cdot)$ is sufficiently small (assumed here), i always picks the policy that succeeds rather than the one that fails. If both succeeds or both fails, then i prefers the policy that is closest to its ideal point.

Next, consider the incentive to experiment, as a function of the initial locations. As a first observation, note that, if $x_A = x_B$, both districts are willing to experiment in equilibrium if and only if:

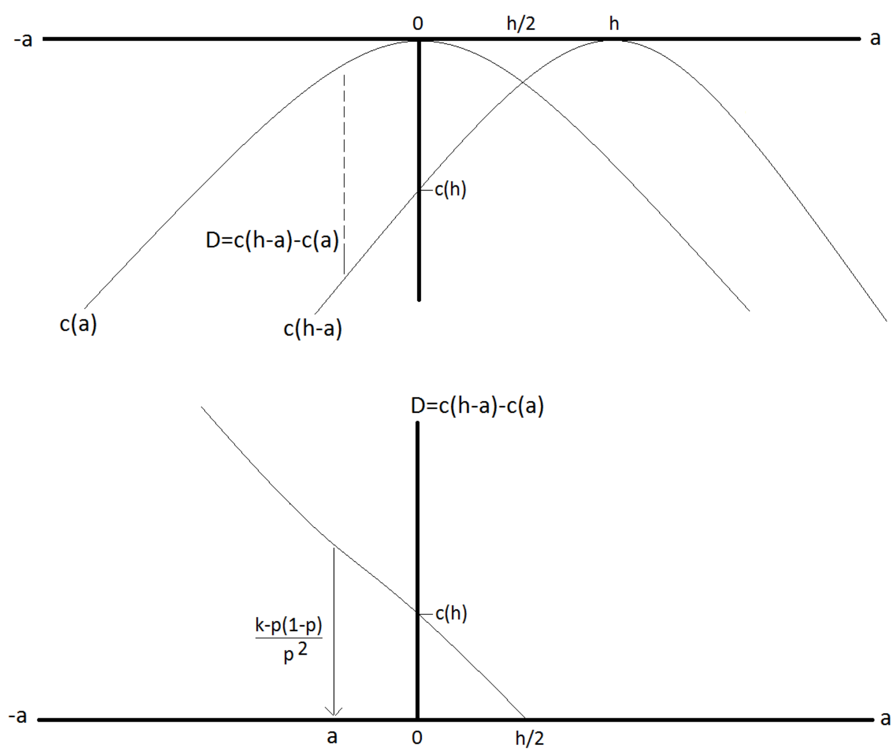
$$p(1-p) - k \geq 0. \tag{3}$$

From now we typically assume $k - p(1-p) > 0$, implying that one does *not* want to experiment if someone else experiments on the exact same policy. The term $k - p(1-p)$, which is frequently appearing in the equations below, represents the *cost* or disutility a district would get from experimenting at the same point as the neighbor's experiment, compared to not experimenting. To be incentivized to experiment, a district must be compensated for this "duplication-loss" by getting a more favorable (closer) policy if its own experiment succeed. I.e., $D_i \equiv c(h - a_j) - c(a_i)$, $j \neq i$, must be sufficiently large. This comparison explains many of the below results.

Proposition 2. *Taking locations as given, both districts experiment with their policy if only if:*

$$c(h - a_j) - c(a_i) \geq \frac{k - p(1-p)}{p^2} \ \forall i, j \in \{A, B\}, i \neq j. \tag{4}$$

If $x_A = x_B$, (4) boils down to (3), as expected. When (3) fails, then both districts experiment only if each values its own location sufficiently more than the neighbor's location. This difference must be larger if an experiment is costly (k large) and unlikely to succeed (p small).



The top figure shows how to derive D=c(h-a)-c(a). The second figure draws this distance as a function of a. The equilibrium a must be so small that D is sufficiently large to generate incentives for both to experiment. This may require a to be negative.

Equilibrium locations: At stage one, the districts anticipate this. Each district understands that if its initial location, x_i, is sufficiently attractive to the neighbor, then the neighbor will free-ride by not investing in its own experiment. To prevent such free-riding, each district has an incentive to select an x_i which is quite unattractive, from the neighbor's point of view. This implies that the districts' experimental locations may be further apart than the districts' ideal points.

Proposition 3. *There exists* $h'_d \in (0, h^*_d)$ *, where* h^*_d *is given by*

$$c\left(h^*_d\right) \equiv \frac{k - p\left(1-p\right)}{p^2}, \tag{5}$$

such that:

(i) *If* $h \geq h^*_d$*, the districts always experiment at ideal points and* $a_i = 0, \forall i \in \{A, B\}$*.*

(ii) *If* $h \in [h'_d, h^*_d)$*, there is only one symmetric equilibrium where both experiments. In this equilibrium, experiments diverge:*

$$x_A < t_A \text{ and } t_B < x_B \;\Leftrightarrow\; a_i < 0, \forall i \in \{A, B\}, \tag{6}$$

and the divergence satisfy:

$$c\left(h - a_i\right) - c\left(a_i\right) = \frac{k - p\left(1-p\right)}{p^2}, \forall i \in \{A, B\} \Rightarrow \tag{7}$$

$$\frac{\partial a_i}{\partial h} = \frac{c'\left(h - a_i\right)}{c'\left(h - a_i\right) + c'\left(a_i\right)} > 1. \tag{8}$$

(iii) *If* $h < h'_d$*, only one district experiments in every equilibrium. The experimental location is at the experimenter's ideal point.*

Figure 3 draws locations on the horizontal axes and heterogeneity on the vertical axis, such that ideal points are represented by the two straight lines. For large h, experiments' locations, given by the green lines, are at ideal points. For smaller heterogeneity, locations diverge, until they diverge so much that it is no longer an equilibrium where both experiments. For lower h, only one experiments, and does so at its ideal point. The threshold h'_d is implicitly derived in the Appendix for quadratic $c(\cdot)$.

The decentralized equilibrium is thus quite different from the first-best. Rather than converging, the two districts diverge and select policies that are more different than their actual ideal points. This divergence is necessary to ensure that both districts are willing to experiment rather than free-ride. Perversely, the more similar are the districts' ideal

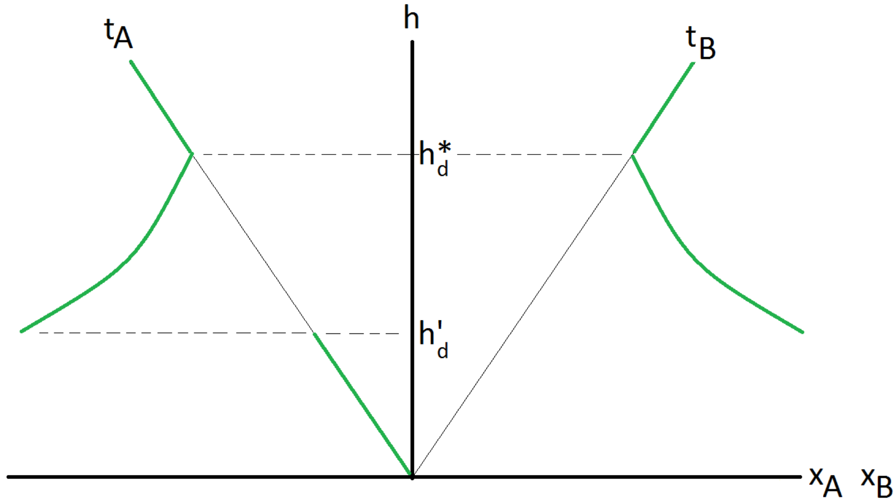


Figure 2: *The green line shows equilibrium experimental locations (on the horizontal axis) as a function of heterogeneity (on the vertical axis): When heterogeneity declines, locations may diverge.*

points, the more different are their experiments, in equilibrium.

$$\frac{\partial (x_B - x_A)}{\partial h} < 0, \; h \in (h_d', h_d^*) \,.$$

This inequality follows from (8), which is true since $c'(a_i) < 0$ when $a_i < 0$. Policies are thus not converging as districts become more similar. This point suggest that efficiency may be lower if the districts are similar, than when they are different. This is confirmed in the next subsection.

Given the amount of heterogeneity, note that policies, given by (7), must diverge more if each experiment is costly (k large) and unlikely to succeed (p small). This is intuitive.

A note on the equilibria if $h < h_d'$: In this case, there are multiple equilibria, but all of them requires that exactly one district experiment. For every deterministic equilibrium, the experimenting district must be experimenting at its ideal point. A large set of locations for the non-experimenting district can be supported in equilibrium, if a slight deviation makes both districts believe that it is then (only) the deviating district that is supposed to experiment. There are certain constraints on equilibrium locations for the nonexperimenting district, but we have chosen to not report on these here.

2.3 Optimal Heterogeneity

Suppose that $h > h_d^*$. Both districts are then strictly preferring to experiment at their ideal points. If one district fails and the other succeeds, the first can adopt the other's policy. This option value is larger if the neighbor's experimental location is somewhat closer. Thus, both districts benefit if their ideal points are closer, as long as $h > h_d^*$.

Once $h \leq h_d^*$ binds, however, then moving the ideal points closer will force each district to select a policy that is further away from its ideal point. This is costly, and each district is also loosing when the neighbor is experimenting with a policy that is further away. The benefit of a closer neighbor is always outweighed by the disutility that this neighbor is selecting an experiment that is still further away, it can be shown.

Combined, both districts would benefit if their neighbor is exactly so different that $h = h_d^*$. More homogenous districts are thus not necessarily beneficial in this framework, since that may create more free-riding. The free-riding is mitigated, in equilibrium, by diverging policies, but this harms both districts.

Proposition 4. *Equilibrium payoffs are strictly higher at $h = h_d^*$ than at any other $h \geq h_d'$. In fact, h_d^* is a global optimum if*

$$k \leq 2p\frac{1-p}{2-p}.$$

As a numerical example, if $p = 1/2$, the latter requirement is $k \leq 1/3$, still ensuring $p > k$ and allowing $k - p(1-p) > 0$. Then, for $k = 1/3$, the optimal heterogeneity is $h_d^* = c^{-1}(1/3)$. If $c(h) = h^2$, this implies that $h_d^* = \sqrt{1/3}$ and $h = 0$ are both global optimum. Any other h generates less payoff. For a slightly smaller k, h_d^* is strictly better than $h = 0$.

3 Centralization

3.1 Model and Equilibrium

By "centralization" we mean that the final decision y_i, at stage three, is not necessarily taken by i. We will first analyze the case where the decision-maker has an ideal point equal to 0, half-way between the two districts' ideal points. This "median voter" determines both y_A and y_B and, by assumption, sets $y_A = y_B$ both equal to either x_A or to x_B. If there were any (arbitrarily small) coordination gains from having the same policy, the median voter would strictly benefit from $y_A = y_B$, and the assumption would follow as a result. The game is otherwise as before: The two districts are first deciding on initial locations, x_A and x_B. Thereafter, each decides whether to pay the cost k in the hope of a success with probability p. Both districts anticipate, of course, that the final decision on y_i is taken by the median voter who may consider both locations and the experiments' outcomes. The game is now solved by backwards induction.

At stage three, the median voter sets policies such as to maximize its payoff:

$$y_A = y_B = \arg \max_{x_j \in \{x_A, x_B\}} I_{x_j} - c(x_j).$$

Thus, if both (or none) of the locations $\{x_A, x_B\}$ have proven successful, then the chosen policy will be the one closest to the median voter. If the distances are equal, each is assumed to be chosen with probability 1/2. If one experiment succeeds and the other fails (or is not initiated), then the median voter will pick the successful policy (if the two distances are sufficiently similar).

This is all anticipated at the second stage. The incentive to experiment may be smaller or larger than it was under decentralization. As a negative force, a successful experiment pays off less than under decentralization since one might, even after a success, have to implement the neighbor's policy if also the neighbor succeeds (occurring with probability p). As a positive force, if the neighbor happens to fail (occurring with probability $1-p$), then it is more beneficial to succeed under centralization since a success is then necessary to eliminate the chance of having to implement the neighbor's failed policy. The negative force dominates if $p > 1/2$, while the positive force dominates if $p < 1/2$. Thus, centralization can implement a beneficial competition or "tournament" between the districts, where each district may be incentivized by the fear and cost of loosing to the other district.

Proposition 5. *Given locations, both district experiment if:*

$$c(h - a_j) - c(a_i) \geq 2\frac{k - p(1-p)}{p}, \; i, j \in \{\text{A,B}\}, i \neq j. \tag{9}$$

At the first stage, each experimenting district recognizes that also the neighbor will experiment if and only if the distances are sufficiently different. This may require that the experiments diverge relative to ideal points, particularly if heterogeneity is small, just as in the case under decentralization. However, if heterogeneity is so large that $h \geq h_c^*$, given by:

$$c(h_c^*) \equiv 2\frac{k - p(1-p)}{p}, \tag{10}$$

then both districts are willing to experiment (and (9) holds) even if the initial locations are at ideal points. If heterogeneity increases further, then the optimal initial locations are no longer at ideal points, as would have been the case under decentralization. Instead, each district caters to the median voter by selecting a policy which is as close as possible to the median voter's ideal points, without violating (9). This implies that convergence is possible under centralization, and in fact quite likely if heterogeneity is large.

Proposition 6. *There exists $h'_c < h^*_c < h''_c$ such that:*

(i) *If heterogeneity is small, $h \in (h'_c, h^*_c)$, experiments diverge ($x_A < t_A < t_B < x_B$) to ensure that (9) holds with equality, implying $a_i = a < 0$ satisfying:*

$$c\left(h-a\right)-c\left(a\right)=2\frac{k-p\left(1-p\right)}{p}, \tag{11}$$

provided that the required a also satisfies:

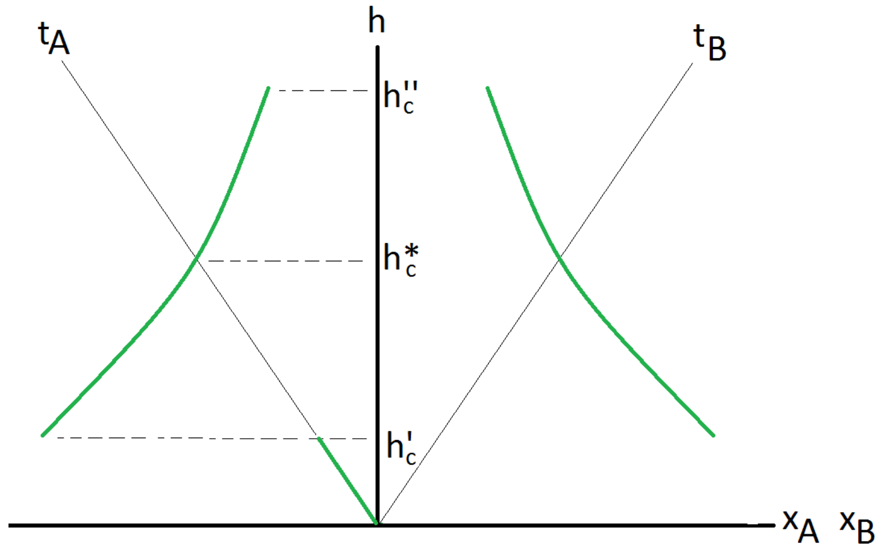
$$c\left(a_i\right)<2\frac{2p\left(1-p\right)-k}{1+p}, \tag{12}$$

implicitly defining the lower boundary h'_c.

(ii) *If heterogeneity is large, $h \in (h^*_c, h''_c)$, experiments converge ($t_A < x_A < x_B < t_B$) and ensure that (9) holds with equality, implying (11), provided that the required $a > 0$ satisfies:*

$$c\left(a\right)<\frac{p^2+\left(1-p\right)^2}{p^2\left(1-p\right)}\left[k-p\left(1-p\right)\right],$$

implicitly defining the upper boundary h''_c.



The green lines show locations of experiments (on the horizontal axis) as functions of h, on the vertical axis. For large h, locations converge.

In contrast to decentralization, if heterogeneity increases under centralization, locations do not end up at the districts' ideal points, but they continue by converging towards the median voter's ideal point as heterogeneity increases further. It may well be that the experiments converge more, in equilibrium, than what is required in the first-best. This possibility reveals the power of using centralization as a tournament.

Although $h > h_c^*$ induces the districts to converge, this benefit is outweighted by the cost of heterogeneity when uniformity is required:

Proposition 7. *Equilibrium payoff is higher at $h = h_c^*$ than at any other $h \in [h_c', h_c'']$. At h_c^*, $a_i = 0$.*

3.2 Welfare Comparison: Centralization or Decentralization?

Centralization imposes a cost but it also generates a potential benefit. The cost is that the uniformity is imposed at the third stage, even if the outcome of both experiments is the same. The potential benefit is that the incentive to experiment may increase, requiring less divergence.

We write "potential" benefit since, if $p > 1/2$, then the incentive to experiment under centralization is lower than under decentralization. If, at the same time, $h < h_c^*$, then policies diverge under centralization, and more so than under decentralization. In this case, decentralization is clearly better than centralization. This informal argument suggests that centralization can only be beneficial if p is small. The following result confirms this.

Proposition 8. *Suppose $h \in (h'_c, h^*_c) \cap (h'_d, h''_d)$ If $p \geq 1/2$, decentralization is better than centralization. If $c(a) = qa^2$, centralization is better for h small, q small, k large and p small, i.e., if:*

$$qh^2 < [k - p(1-p)] \frac{1/4p^2 - 1}{1/2 - p(1-p)}$$

4 Transparency

4.1 Transparency under Decentralization

So far, we have assumed that a district can perfectly well adopt the neighbor's policy, except for some cost if they have different ideal points. In reality, it may also be the case that a district can only imperfectly observe and learn the neighbor's policy.

Let $\alpha \in [0,1]$ measure the fraction (as well as the magnitude) a district can capture of the neighbor's successful experiment. Thus, if A adopts B's successful policy, A's payoff (abstracting from any investment cost) is $\alpha - c(h - a_B)$.

Intuitively, more transparency makes it more tempting to free-ride. This makes more divergence necessary when α is large. A small α can thus be optimal, since divergence can decrease correspondingly.

Proposition 9.

(i) Given locations, low transparency α makes it more likely that both districts experiment. They do, if:

$$c(h - a_j) - c(a_i) \geq \alpha - \frac{p-k}{p^2} \ \forall i, j \in \{A, B\}, i \neq j. \tag{13}$$

(ii) There exists $h'_\alpha < h^*_\alpha$, defined by:

$$c(h^*_\alpha) = \alpha - \frac{p-k}{p^2} \ ,$$

such that districts experiment at ideal points for $h \geq h^*_\alpha$, while for $h \in [h'_\alpha, h^*_\alpha]$, experi-

ments diverge and $a_i = a < 0$ *satisfies:*

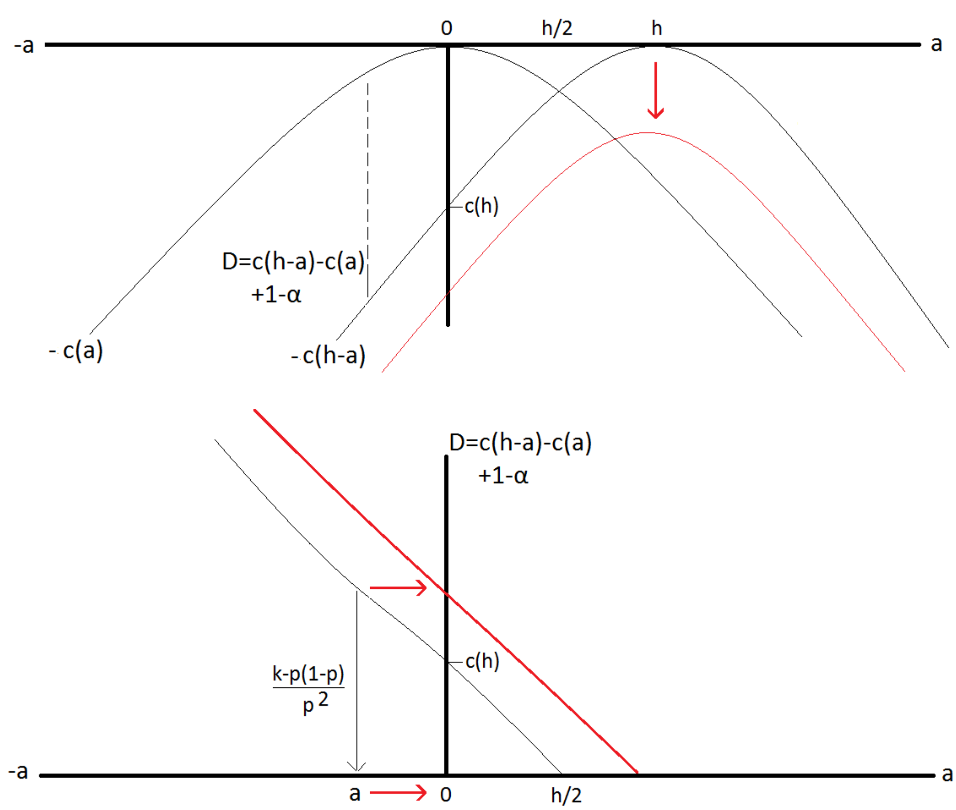
$$c(h-a) - c(a) = \alpha - \frac{p-k}{p^2} \Rightarrow \quad (14)$$

$$\frac{\partial a}{\partial \alpha} < 0. \quad (15)$$

(iii) The optimal level of transparency, α_d^**, ensures that* $a = 0$ *in equilibrium. Consequently,* α_d^* *increases in* h *and decreases in* p *and* k*:*

$$\alpha_d^* = c(h) + \frac{p-k}{p^2}. \quad (16)$$

(iv) If α^* *can be freely adjusted, every* $h \leq h_1^*$ *gives the sayme payoff.*



With lower transparency, the neighbor's policy becomes less attractive and experimentation is wortwhile, even if divergence is less (the curves shift to the red ones).

Part (i)-(ii) are first just generalizing Propositions 2-3 to the case where $\alpha < 1$. Importantly, (15) says that the larger is transparency, the larger is equilibrium divergence.

The divergence is intended to discourage the neighbor from free-riding, but it also harms the diverging party, so it is socially optimal to choose $\alpha < 1$ so small that no divergence is necessary for encouraging experimentation. This implies that the optimal α is smaller if h is small (part (iii)). Interestingly, note that h is here irrelevant for the payoffs when α can adjust: A district is then always experimenting at its ideal point, and α is set such that the benefit of the neighbor's policy is just small enough to movitate both to experiment, no matter h. More similar districts should thus permit less transparency to discourage free-riding.

4.2 Transparency under Centralization

Under centralization, transparency tends to be more beneficial than under decentralization, since one district is always adopting the other district's policy, even when both experiments succeed. This makes it optimal with a transparency that is larger than the one that would have eliminated divergence. Some divergence should be tolerated, if that can be combined with more transparency.

Proposition 10.
(i) The larger the transparency, the larger is divergence (or the lower is convergence):

$$\partial a / \partial \alpha < 0.$$

(ii) The optimal level of transparency leads to divergence, $a < 0$.
(iii) If $c(a) = qa^2$, the optimally implemented a and the optimal α are:

$$\begin{aligned} a &= -\frac{1-p}{2}h \\ &\Leftrightarrow \\ \alpha_c^* &= qh^2\left(\frac{2}{p}-1\right) - 2\frac{k-p(1-p/2)}{p^2}, \text{ where} \\ \alpha_c^* &> \alpha_d^* \text{ if} \\ qh^2 &> \frac{k-p(1-p)}{2p(1-p)}. \end{aligned}$$

5 Discussion

From a normative perspective, the objective of politics is to identify and implement good policies.[5] Everything else is a means to an end. This point is made clearly in a brief policy paper by Besley (2001), where he emphasizes the phrase "policy competition." Besley delineates policy competition from the standard notion of political competition – that between candidates for office – to establish that the latter is a means to the former. The framework we introduce here can be thought of as expanding upon the notion of policy competition, positioning policy competition explicitly at the center of the design of political institutions.

Our main contribution is twofold. First, we show that absent institutions to shape policy competition constructively, the inherent district incentives to experiment are destructive. Specifically, in the absence of institutional constraints – that is, in a decentralized federal system or absent federalism altogether – policy competition becomes a virtual race to the bottom. Each district seeks to provide the *least* attractive policy alternative, hoping that their fellow districts are inspired to try harder and experiment with a new policy. The end result is that the forces of policy competition drives policy choice in the wrong direction.

Our second contribution is to show how policy competition can be harnessed positively by appropriately-designed political institutions. The key to the design of such institutions is to realign the competitive forces so that competition runs in the right direction. This is done by establishing a sort-of policy tournament. Unlike standard tournaments, however, the winning district earns no accolade or prize other than the freedom to implement its policy of choice. Instead, the tournament carries a negative prize: the loser incurs the punishment of being forced to implement the other district's policy, whether it wishes to or not.

One may wonder, then, why anyone would willingly submit to a tournament with a negative prize. A corollary of our main results is an explanation of just this puzzle. It is only by binding themselves to a negative prize tournament that the states can harness the positive implications of policy competition. From this perspective, the ex post inefficiency of forced policy coordination should not be lamented, rather it should be celebrated as the price of generating more efficient ex ante incentives.

These results offer a reinterpretation of the purpose of federal systems. This reinterpretation can be pushed deeper. One connection is to the practice of coordinating

[5] Where a "good" policy is the maximand of some social welfare function.

policies across states – frequently referred to as policy *harmonization* in the EU. Popular accounts frequently take harmonization as an end in itself, desirable to avoid the costs of coordination or merely to increase continent-wide harmony. From the perspective of a policy tournament, however, policy coordination becomes an incentive mechanism rather than an end in itself.

Our model takes a stark and extreme line on policy coordination and the dual issue of exit from the federal system. Coordination is always imposed in the final stage and states have no option to exit. Once a design perspective is adopted, though, focus quickly moves beyond what is possible with institutional design to what is optimal. At the heart of the design question is how to most efficiently provide the incentives for states to experiment and converge. It may be that these incentives are induced most cheaply and effectively by forcing coordination only when both policies fail or when they both succeed. In fact, we can show that the incentives to experiment is larger if uniformity is required if, and only if, both experiments fail. Such a design may appear unrealistic, yet the same ends may be achieved by more recognizable mechanisms such as allowing states the option to exit the federal system in some circumstances (generally or on specific issues).[6] Of course, other complications may arise from these features – such as verification of the outcomes of experiments – yet, in principle, there is no reason to expect that the particular mechanism we study here induces maximal efficiency. The dimensions of choice available to the designer are unlimited, extending well beyond coordination and exit. It is possible that legislative institutions (such as bicameralism) shape experimentation, as well as supermajority rules and the strategic setting of the scope of the federal union itself (*a la* Mundell (1961) for currency areas and Alesina and Spolaore (1997) for federalism).

A novel feature of our model is that a "progressive centralization" of authority is built into the design of the federal system itself. As mentioned in the introduction, the striking aspect of this feature is that just such a dynamic is evident in the history of the U.S. and E.U., among other federal systems. Unfortunately, our model is limited to a single cycle – with one observation of centralization of authority – on a single policy issue. It seems reasonable to conjecture – and desirable to model – that extending our model to a longer horizon will generate an increasing concentration of power in the center.

Although the overall pattern in the history of the U.S. and E.U. is toward greater

[6]See Bednar (2007) for an interesting discussion of the incentive effects of exit options in federal systems.

centralization of authority, it is notable that some issues have moved in the opposite direction, with authority devolved from the center back to the states. A prominent example of this decentralization of authority in the U.S. is welfare reform policy in the 1990's.[7] Although this example seemingly runs counter to our model, we would like to suggest that it, in fact, reaffirms our theory. It is not easy to see that once centralized, an issue becomes relatively stagnant with minimal experimentation. This stability is fine in a stable world, yet it is restrictive in a changing world when shocks require that further experimentation be undertaken. Our conjecture is that when uncertainty is present – be it due to a shock or insufficiently attractive experimentation earlier in the process – the central authority will devolve an issue back to the states to restart the policy tournament and reignite policy experimentation. For welfare reform in the 1990's, it appears this is an accurate description of the state of the environment. As Bednar (2011, p. 511) argues, on welfare policy "By the early 1990's, there was a sense that the federal government had run out of ideas, and that the country needed much more diverse experimentation in order to discover policy improvement." If our conjecture is true, the logic suggests not only that power will accumulate in the center in federal systems, but that a natural limit to the size or authority of the central government will obtain, where the natural limit is determined by the degree of stability in the environment over which policy rules.

An intriguing feature of our results is that the collective welfare of the states is maximized when the states are similar but not identical. If states are too similar, they are plagued by free riding and inefficiently low levels of experimentation. This result creates a surprising connection to the famous model of Tiebout. The implication is that in setting up a federal system, a degree of heterogeneity across the districts is preferable, and this is exactly what is generated by Tiebout style sorting. An interesting open question, therefore, is whether Tiebout sorting generates an efficient degree of inter-district heterogeneity.

The connection to Tiebout also suggests how a decentralized federal system may meaningfully differ from a collection of districts with no formal attachments. The difference may be in labor mobility. That is, if people within a decentralized federal system are able to relocate, Tiebout sorting may generate greater heterogeneity and more efficiency than would the same states without a formal federalist pact.

Finally, although we apply our ideas exclusively to policy competition, the issue of free riding and experimentation is of broad importance. Our framework and results

[7] We thank Craig Volden for this example.

can be adapted to these other settings. Theorists within organizational economics are interested in joint control problem within firms where they players – such as the boss and workers or managers and owners – have preference differences. Experimentation and learning is also key to joint ventures and research partnerships between firms, such as oil exploration ventures and pharmaceutical research into new drug compounds. Our key insight into the use of tournaments to reconcile incentives in collective choice environments is as applicable in these settings as it is in politics.

6 Conclusion

The prominence of policy experimentation in policy and popular discourse has not been matched by development of a formal understanding of the underlying phenomenon. The objective of this paper has been to close this gap, if only a small degree. Our model has exposed deeper incentives and forces within collective experimentation environments and, we think, provided a new perspective on the institutions of federal systems.

Many possible extensions to the model are left unpursued and questions are raised that we are unable to address within the scope of this article. We hope to take up some of these in subsequent work.

7 Appendix

Proof of Proposition 1 (the first-best):

Since the model is symmetric, we can drop subscripts i. The first-best requires that both experiment at locations that maximize:

$$\begin{aligned} u &= p^2 (1 - c(l)) - (1-p)^2 c(l) + p(1-p)(2 - c(l) - c(h)) - k \\ &= p(2-p) - c(l) - p(1-p)[c(h) - c(l)] - k. \end{aligned}$$

So, the first-best requires convergence: it should not be possible to increase both $c(l)$ and $c(h)$. When, for example, $t_A < x_A < t_B$, a larger x_A increases $c'(|x_A - t_A|)$, decreases $c'(|x_A - t_B|)$, and increases the average utility until the first-order condition holds:

$$c'(l) = p(1-p)[c'(h) + c'(l)] \Rightarrow (1).$$

The second-order condition is $-c''(|x_A - t_A|) - p(1-p)[c''(|x_A - t_B|) - c''(|x_A - t_A|)] <$

0, which always hold. *QED*

Proof of Proposition 2 (equilibrium experimentation, given locations).

Start with the case $|h-a_j|>|a_i|$, such that i's experimental location is closer to i's ideal point than is j's experimental location. We first assume:

$$c(h-a_j)<c(a_i)+1, \tag{17}$$

such that i prefers j's success to its own failed experiment. Then, if j experiments, i does too if:

$$p(1-c(a_i))+(1-p)[p(1-c(h-a_j))-(1-p)c(a_i)]-k\geq p(1-c(h-a_j))-(1-p)c(a_i)$$

$$\begin{aligned}
p(1-c(a_i))-k &\geq p^2(1-c(h-a_j))-p(1-p)c(a_i)\\
p-k &\geq p^2(1-c(h-a_j))+p^2c(a_i)\\
c(h-a_j)-c(a_i) &\geq \frac{k-p(1-p)}{p^2}.
\end{aligned} \tag{18}$$

When this condition holds, (17) is still satisfied if

$$k-p(1-p)<p^2\Leftrightarrow p>k,$$

which is already assumed to hold. For h large (and/or if $c(h-a_j)-c(a_i)$ large), (17) is violated, and then each district experiments since $p>k$.

If $|h-a_j|<|a_i|$, then, if j experiments, i does too if:

$$p(1-c(h-a_j))+(1-p)[p(1-c(a_i))-(1-p)c(h-a_j)]-k\geq p-c(h-a_j)$$

$$\begin{aligned}
p(1-p)-k &\geq -c(h-a_j)\left[1-p-(1-p)^2\right]+c(a_i)p(1-p)\\
&\geq p(1-p)[c(a_i)-c(h-a_j)]
\end{aligned}$$

which can never hold since the left-hand side is negative. Thus, i never experiments if j's experimental location is closer.

Q: Under quadratic utilities, $c(d) = qd^2$, (18) becomes

$$\begin{aligned} q(h-a_j)^2 - q(a_i)^2 &\geq \frac{k-p(1-p)}{p^2} \\ 2h\left(\frac{h}{2}-a_j\right) - q\left(a_i^2 - a_j^2\right) &\geq \frac{k-p(1-p)}{qp^2}. \end{aligned}$$

QED

Proof of Proposition 3 (equilibrium locations under decentralization).

Convergence cannot be an equilibrium: A district can never benefit from selecting $a_i > 0$, since that reduces i's payoff as well as j's incentive to experiment.

(i) If $h \geq h_d^*$, both districts experiment if located at their ideal points. If a district diverged, its distance cost increases and the neighbor's incentive to experiment would not increase.

(ii) If (5) fails, each district prefers to minimize $|a_i|$ while ensuring that the neighbor is still willing to experiment. The outcome is that (4) must bind with equality for both districts.

Slopes in the symmetric equilibrium where $a = a_i$: By recognizing $c(h-a) - c(-a)$ is a constant, and differentiating it, we get:

$$\begin{aligned} c'(h-a)(dh-da) + c'(a)\,da &= 0 \\ \frac{da}{dh} &= \frac{c'(h-a)}{c'(h-a)-c'(a)} > 1, \end{aligned}$$

implying that the distance between the experiments, $x_B - x_A = h - 2a$, decreases in h :

$$\frac{\partial(x_B - x_A)}{\partial h} = 1 - 2\frac{c'(h-a)}{c'(h-a)+c'(a)} < -1 < 0.$$

(iii) If i decides to experiment at its ideal point, anticipating that this will lead the neighbor to free-ride, then $u_i = p - k$. This payoff is larger than the payoff in the symmetric equilibrium if:

$$p - k > p(1-c(a)) + (1-p)\left[p(1-c(h-a)) - (1-p)c(a)\right] - k \Rightarrow$$

$$\begin{aligned} c(a) &> (1-p)\left[p(1-c(h-a)+c(a))\right] \Rightarrow \\ c(a) &> (p-k)\frac{1-p}{p} = k - \frac{k-p(1-p)}{p}. \end{aligned} \tag{19}$$

This expression cannot hold for $h \approx h_d^*$, where $c(a) \approx 0$, but it necessarily hold for $h \to 0$, since then $a \to -\infty$. So, (19) binds for some $h_c' \in (0, h_d^*)$.

Q: Under quadratic utilities, when $h < h_d^*$, locations are:

$$\begin{aligned} q(h-a)^2 - qa^2 &= \frac{k - p(1-p)}{p^2} \\ h(h-2a) &= \frac{k - p(1-p)}{qp^2} \\ -a &= \frac{k - p(1-p)}{2qp^2 h} - \frac{h}{2}. \end{aligned}$$

So, h_d^* is defined by:

$$h_d^* = \sqrt{\frac{k - p(1-p)}{qp^2}}.$$

To find h_c', note that (19) binds if $h = h_c'$, implying:

$$\begin{aligned} q\left(\frac{k - p(1-p)}{2qp^2 h} - \frac{h}{2}\right)^2 &= k - \frac{k - p(1-p)}{p} \\ q\frac{h^2}{4} - \frac{k - p(1-p)}{2p^2} + \frac{1}{qh^2}\left(\frac{k - p(1-p)}{2p^2}\right)^2 &= k - \frac{k - p(1-p)}{p} \\ q\frac{h^2}{4} + \frac{1}{qh^2}\left(\frac{k - p(1-p)}{2p^2}\right)^2 &= k - \frac{k - p(1-p)}{p} + \frac{k - p(1-p)}{2p^2}. \end{aligned}$$

Payoffs under decentralization is:

$$\begin{aligned} u_d &= p(1 - c(a)) + (1-p)\left[p(1 - c(h-a)) - (1-p)c(a)\right] - k \\ &= p(2-p) - k - p(1-p)\left[c(h-a) - c(a)\right] - c(a) \\ &= p(2-p) - k - (1-p)\frac{k - p(1-p)}{p} - c(a) \\ &= p - \frac{k - p(1-p)}{p} - c(a) \\ &= p - \frac{k - p(1-p)}{p} - q\left(\frac{k - p(1-p)}{2qp^2 h} - \frac{h}{2}\right)^2. \end{aligned}$$

QED

Proof of Proposition 4 (Optimal heterogeneity under decentralization).

If $h > h_d^*$ increases, $c(h)$ increases and payoffs decline. If $h < h_d^*$ decreases, $c(a)$ as well as $c(h-a)$ increases and payoffs decline, as long as $h > h_d'$. If $h < h_d'$, only one district experiments and does so at the ideal point. For every $h < h'_d$, the sum of payoffs is at the highest when $h = 0$, and both locate at 0. The average payoff is then $p - k/2$. The average payoff at h_d^* is:

$$\begin{aligned}
& p + p(1-p)(1 - c(h_d^*)) - k \\
= \; & p + p(1-p)\left(1 - \frac{k - p(1-p)}{p^2}\right) - k \\
= \; & p(2-p) - (1-p)\frac{k - p(1-p)}{p} - k \\
= \; & p(2-p) + (1-p)^2 - \frac{k}{p} \\
= \; & 1 - \frac{k}{p} > 0.
\end{aligned}$$

So, the average payoff at h_d^* is higher than the average payoff at $h = 0$ if:

$$\begin{aligned}
1 - \frac{k}{p} &> p - k/2 \\
\frac{k - p(1-p)}{p/2} &< k \\
2p\frac{1-p}{2-p} &> k.
\end{aligned}$$

QED

Proof of Proposition 5 (Experimentation under centralization, given locations).
If j experiments, i does, as well, if:

$$\begin{aligned}
p^2 + 2(1-p)p - \frac{1}{2}(c(h-a_j) + c(a_i)) - k &\geq p(1 - c(h-a_j)) - \frac{1-p}{2}(c(h-aj) + c(a_i)) \\
(1-p)p - k &\geq -pc(h-a_j) + \frac{p}{2}(c(h-a_j) + c(a_i)) \\
c(h-a_j) - c(a_i) &\geq 2\frac{k - p(1-p)}{p}. \qquad (20)
\end{aligned}$$

QED

Proof of Proposition 6 (Equilibrium locations under centralization).

Note that when both experiment in an equilibrium where binds, district i's payoff is:

$$\begin{aligned}
& p^2-\left(p^2+(1-p)^2\right) \frac{c\left(h-a_j\right)+c\left(a_i\right)}{2}+(1-p) p\left[2-c\left(h-a_j\right)-c\left(a_i\right)\right]-k \\
= & p^2-(p+1-p)^2 \frac{c\left(h-a_j\right)+c\left(a_i\right)}{2}+2(1-p) p-k \\
= & (2-p) p-\frac{c\left(h-a_j\right)+c\left(a_i\right)}{2}-k \\
= & (2-p) p-\frac{c\left(h-a_j\right)-c\left(a_i\right)}{2}-c\left(a_i\right)-k .
\end{aligned}$$

So, i selects a_i as close as possible to zero, without violating (20), since that would have discouraged j from experimenting. Thus, when $a_i \neq 0$ is necessary, (20) will bind. By substituting (20) into the last equation, we can write i's payoff as:

$$\begin{aligned}
& (2-p) p-\frac{k-p(1-p)}{p}-c\left(a_i\right)-k \\
= & 1+(1-p) p-\frac{k}{p}-c\left(a_i\right)-k . \qquad (21)
\end{aligned}$$

If i moves x_i slightly towards the center, the neighbor stops experimenting. This gives the deviating agent payoff:

$$\begin{aligned}
& p-c(l)-k-\frac{1-p}{2}(c(h)-c(l)) \\
= & p-c(l)-k-\frac{1-p}{2}\left(\frac{2}{p}(k-p(1-p))\right) \\
= & p-c(l)-k-(1-p)\left(\frac{k-p(1-p)}{p}\right),
\end{aligned}$$

which is smaller than the equilibrium payoff if

$$\begin{aligned}
(1-p)\left(\frac{k-p(1-p)}{p}\right) & > \frac{k-p\left(1-p^2\right)}{p} \\
(1-p)\left(\frac{-p(1-p)}{1}\right) & > pk+\frac{-p\left(1-p^2\right)}{1} \\
p\left(1-p^2\right)-(1-p)(p(1-p)) & > pk \\
\left(1-p^2\right)-(1-p)^2 & > k \\
(1-p)(1+p-1+p) & > k \\
2p(1-p) & > k,
\end{aligned}$$

which must hold for two idential experiments to be socially optimal.

(i) Under divergence, an agent may consider to jump back to its ideal point even though the other will then not experiment. This would generate the utility:

$$\begin{aligned} & p-k-\frac{1-p}{2}c(h) \\ = \; & p-k-\frac{1-p}{2}\left[\frac{2}{p}\left(k-p(1-p)\right)+c(l)\right] \\ = \; & p-c(l)-k-\frac{1-p}{p}\left(k-p(1-p)\right)+\frac{1+p}{2}c(l) \end{aligned}$$

which is smaller than the equilibrium payoff if

$$\begin{aligned} -\frac{1-p}{p}\left(k-p(1-p)\right)+\frac{1+p}{2}c(l) &< -\frac{k-p\left(1-p^2\right)}{p} \\ \frac{1+p}{2}c(l) &< \frac{1-p}{p}\left(k-p(1-p)\right)-\frac{k-p\left(1-p^2\right)}{p} \\ \frac{1+p}{2}c(l) &< \left(1-p^2\right)-(1-p)^2-k \\ \frac{1+p}{2}c(l) &< 2p(1-p)-k. \end{aligned}$$

When divergence must be so large to satisfy (9) that this condition fails, then, in equilibrium, only one agent experiments, and that experiment is at the experimenter's ideal point.

(ii) Under convergence, then, rather than moving closer to the median voter, a district may consider jumping back to its ideal point, even though this would induce the median voter to always select the neighbor's policy whenever both policies fail or both succeeds. The benefit is that i will suffer less from its distance cost if it succeeds alone. Relative to the equilibrium payoff, an agent's benefit from this deviation is:

$$\begin{aligned} & p(1-p)c(l)-\left(p^2+(1-p)^2\right)\left[c(h)-c(l)\right]\frac{1}{2} \\ = \; & p(1-p)c(l)-\left(p^2+(1-p)^2\right)\left[\frac{2}{p}\left(k-p(1-p)\right)\right]\frac{1}{2} \\ = \; & p(1-p)c(l)-\left(\frac{1-2p+2p^2}{p}\right)\left[k-p(1-p)\right]. \end{aligned}$$

So, when ensuring that (9) holds with equality leads to so little convergence that:

$$c(l) < \frac{p^2 + (1-p)^2}{p^2(1-p)} [k - p(1-p)],$$

is satisfied, then the deviation does not pay off. When the inequality is reverted, then a symmetric converged equilibrium does not exist in pure strategies.

Q: Under quadratic utilities, when $h < h_d^*$, locations are:

$$\begin{aligned} q(h-a)^2 - qa^2 &= \frac{k - p(1-p)}{p/2} \\ h(h-2a) &= \frac{k - p(1-p)}{qp/2} \\ -a &= \frac{k - p(1-p)}{qph} - \frac{h}{2}. \end{aligned}$$

So, h_c^* is defined by:

$$h_d^* = \sqrt{\frac{k - p(1-p)}{qp/2}}.$$

Payoff is

$$\begin{aligned} u_c &= p^2 + 2(1-p)p - \frac{1}{2}(c(h-a) + c(a)) - k \\ &= p^2 + 2(1-p)p - \frac{1}{2}(c(h-a) - c(a)) - c(a) - k \\ &= p^2 + 2(1-p)p - \frac{k - p(1-p)}{p} - c(a) - k \\ &= p^2 + 2(1-p)p + (1-p) - \frac{1+p}{p}k - c(a) \\ &= 1 + p(1-p) - \frac{1+p}{p}k - c(a) \\ &= 1 + p(1-p) - \frac{1+p}{p}k - \left(\frac{k - p(1-p)}{qph} - \frac{h}{2}\right)^2 \text{ if Q.} \end{aligned}$$

QED

Proof of Proposition 7 (Optimal heterogeneity under centralization). The proof follows from the previous proof, where equilibrium payoff, measured by (21), turned out to decrease in the equilibrium $|a|$. *QED*

Proof of Proposition 8 (Welfare comparison).

$$\begin{aligned}
u_c &> u_d \text{ if} \\
1+p(1-p)-\frac{1+p}{p}k-c(a_c) &> p-\frac{k-p(1-p)}{p}-c(a_d) \\
p(1-p)-k-c(a_c) &> -c(a_d) \\
c(a_d)-c(a_c) &> k-p(1-p)
\end{aligned}$$

If $p > 1/2$, then if $a_d < 0$, then $a_c < a_d$ and centralization leads to both more distance-costs and uniformity-costs.

Quadratic cost-functions simplify the comparison:

$$\begin{aligned}
\left(\frac{k-p(1-p)}{2qp^2h}-\frac{h}{2}\right)^2-\left(\frac{k-p(1-p)}{qph}-\frac{h}{2}\right)^2 &> \frac{k-p(1-p)}{q} \\
\frac{k-p(1-p)}{qp^2h^2}\left(\left(\frac{1}{2p}\right)^2-1\right)-\frac{1}{p}\left(\frac{1}{2p}-1\right) &> 1 \\
\frac{k-p(1-p)}{qh^2}\left(\left(\frac{1}{2p}\right)^2-1\right) &> p^2+\left(\frac{1}{2}-p\right) \\
\frac{k-p(1-p)}{qh^2} &> \frac{1/2-p(1-p)}{1/4p^2-1}.
\end{aligned}$$

It is easy to see that if $p < 1/2$ increases marginally, the left-hand side decreases while the right-hand side increases. *QED*

Proof of Proposition 9 (transparency):

(i) If j experiments, i does, as well, if:

$$\begin{aligned}
& p(1-c(a_i))+(1-p)\left[p(\alpha-c(h-a_j))-(1-p)c(a_i)\right]-k \qquad (22) \\
&\geq p(\alpha-c(h-a_j))-(1-p)c(a_i) \\
p(1-c(a_i))-k &\geq p^2(\alpha-c(h-a_j))-p(1-p)c(a_i) \\
p-k &\geq p^2(\alpha-c(h-a_j))+p^2c(a_i) \\
c(h-a_j)-c(a_i) &\geq \frac{k-p(1-\alpha p)}{p^2}.
\end{aligned}$$

This condition always hold also if i never finds it optimal to adopt j's policy.

(ii) For $h = h_\alpha^*$, (13) holds even with $a_i = a_j = 0$. For larger h, i has no incentive to deviate from ideal point, since both districts experiment. For $h \in [h'_\alpha, h_\alpha^*]$, i chooses the smallest $|a_i|$ such that j is still experimenting, implying that (13) binds for both districts, and the equilibrium must be symmetric. As h declines, $|a_i|$ increases, until (at h'_α) a district prefers to jump to its ideal point even if this discourages the neighbor from experimenting (just like in the proof of Proposition 3).

(iiii) As long as $h > h^*_\alpha$, (13) does not bind and it is optimal to raise α. If $h \in [h'_\alpha, h^*_\alpha]$, $a_i = a$ is chosen such that (13) binds, and the average payoff is, in equilibrium (from the righ-hand side of (22)):

$$\begin{aligned} & p(\alpha - c(h - a_j)) - (1-p)\, c(a_i) \\ = \;& p(\alpha - [c(h-a_j) - c(a_i)]) - c(a_i) \\ = \;& p\alpha - \frac{k - p(1-\alpha p)}{p} - c(a_i) \\ = \;& \frac{p-k}{p} - c(a_i), \end{aligned} \tag{23}$$

decreasing in $|a_i|$, but otherwise independent of α. Consequently, α should be reduced, since this decreases (14), until it is satisfied even for $a = 0$. This gives the optimal $\alpha = \alpha^*_d$.

$$c(h) = \frac{k - p(1-\alpha p)}{p^2}$$

(iv) If α can be chosen freely, we can always achieve $a_i = 0$, ensuring that the payoff, given by (23), is $1 - k/p$, independent of h. When we require $\alpha \in [0,1]$, note that the lower boundary never binds if we try to satisfy (16). As h increases, however, the optimal α^*_d increases and reaches 1 when $h = h^*_\alpha$ for $\alpha = 1$, such that $c(h^*_1) = 1 - (p-k)/p^2$. For a larger $h > h^*_\alpha$, α cannot raise above 1, and payoffs decrease. *QED*

Proof of Proposition 10 (transparency under centralization):

(i) Both experiment if:

$$\left[p^2 + 2(1-p)p\right]\left[\frac{1+\alpha}{2}\right] \quad -\frac{1}{2}\left(c(h-a) + c(a)\right) - k \tag{24}$$

$$\begin{aligned} \geq p(\alpha - c(h-a)) \quad & -\frac{1-p}{2}\left(c(h-a) + c(a)\right) \\ \left[p^2 + 2(1-p)p\right]\left[\frac{1+\alpha}{2}\right] - ap \;&\geq\; k - pc(h-a) + \frac{p}{2}\left(c(h-a) + c(a)\right) \\ p - p^2\left(\frac{1+\alpha}{2}\right) \;&\geq\; k - \frac{p}{2}\left(c(h-a) - c(a)\right) \\ c(h-a) - c(a) \;&\geq\; 2\frac{k - p(1 - p(1+\alpha)/2)}{p}. \end{aligned} \tag{25}$$

Differentiating the last equation, when it binds, gives:

$$\begin{aligned} -c'(h-a)\,da - c'(a)\,da &= p\,d\alpha \\ \frac{da}{d\alpha} &= -\frac{p}{c'(h-a)+c'(a)} < 0. \end{aligned}$$

(ii) Payoff is (from the right-hand side of (24)):

$$\begin{aligned} & p(\alpha - c(h-a)) - \frac{1-p}{2}(c(h-a)+c(a)) \\ =\ & p\alpha - pc(h-a) + \frac{1-p}{2}(c(h-a)-c(a)) - (1-p)c(h-a) \\ =\ & p\alpha - c(h-a) + \frac{1-p}{2}(c(h-a)-c(a)) \\ =\ & p\alpha - c(h-a) + \frac{1-p}{2}\left(2\frac{k-p(1-p(1+\alpha)/2)}{p}\right) \\ =\ & p\alpha - c(h-a) + \frac{1-p}{p}\left[k-p\left(1-p\left(\frac{1+\alpha}{2}\right)\right)\right] \\ =\ & p\alpha + p(1-p)\frac{\alpha}{2} - c(h-a) + \frac{1-p}{p}\left[k-p\left(1-\frac{p}{2}\right)\right] \end{aligned}$$

So, the f.o.c. w.r.t. α gives:

$$\begin{aligned} p + \frac{p(1-p)}{2} + c'(h-a)\frac{\partial a}{\partial \alpha} &= 0 \\ \frac{p(3-p)}{2} &= \frac{c'(h-a)}{c'(h-a)+c'(a)}p \\ 1+\frac{1-p}{2} &= \frac{c'(h-a)}{c'(h-a)+c'(a)}, \end{aligned}$$

which requires $c'(a) < 0 \Rightarrow a < 0$. This implies that α must be larger than the level which would make (25) bind for $a = 0$:

$$\alpha_c^* > \frac{c(h)}{p} - 2\frac{k-p(1-p/2)}{p^2}.$$

(iii) Quadratic cost-functions imply that the f.o.c. becomes:

$$\begin{aligned} 1+\frac{1-p}{2} &= \frac{h-a}{h-a+a} = \frac{h-a}{h} \Rightarrow \\ \frac{a}{h} &= 1-\left(1+\frac{1-p}{2}\right) = -\frac{1-p}{2} < 0. \end{aligned}$$

This optimal a is implemented if (25) binds, which implies:

$$\begin{aligned}
c(h-a)-c(a) &= 2\frac{k-p(1-p(1+\alpha)/2)}{p} \\
q(h-a)^2-qa^2 &= 2\frac{k-p(1-p(1+\alpha)/2)}{p} \\
qh(h-2a) &= 2\frac{k-p(1-p(1+\alpha)/2)}{p} \\
qh^2\left(1+2\left(\frac{1-p}{2}\right)\right) &= 2\frac{k-p(1-p(1+\alpha)/2)}{p} \\
qh^2(2-p) &= 2\frac{k-p(1-p(1+\alpha)/2)}{p} \\
qh^2(2-p)+2\frac{p-k}{p} &= p(1+\alpha) \\
\alpha &= qh^2\left(\frac{2}{p}-1\right)+2\frac{p-k}{p^2}-1 \\
&= qh^2\left(\frac{2}{p}-1\right)-2\frac{k-p(1-p/2)}{p^2}
\end{aligned}$$

Under decentralization, Q implies

$$\alpha_d^* = qh^2+\frac{p-k}{p^2},$$

which is larger if

$$\begin{aligned}
qh^2+\frac{p-k}{p^2} &> qh^2\left(\frac{2}{p}-1\right)-2\frac{k-p(1-p/2)}{p^2} \\
\frac{p-k}{p^2}+2\frac{k-p(1-p/2)}{p^2} &> qh^2\left(\frac{2}{p}-2\right) \\
\frac{p+k-p(2-p)}{p} &> 2qh^2(1-p) \\
\frac{k-p(1-p)}{p(1-p)} &> 2qh^2 = 2c(h).
\end{aligned}$$

QED

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