Innovation and Imitation Across Jurisdictions

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Abstract

We consider cities which can increase the income of landowners or of capital owners by improving the quality of public services. The improvement can come from innovation or from imitation. We find that when cities aim to benefit landowners, too many cities innovate; but too few cities innovate when the city aims to benefit capital owners. Redistribution across cities can ameliorate these inefficiencies.

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1 Introduction

Jurisdictions compete. A well-studied form of such competition involves taxes—each jurisdiction may want to set taxes somewhat lower than do other jurisdictions, aiming to attract residents (and so increase property values) or to attract employers (and so increase wages). But jurisdictions can also compete in the services they provide. This aspect of competition is less well-studied, and is the concern of the current paper. To be concrete, we consider cities which at some expense can adopt a policy that raises the productivity of capital in one city or the other. Such an increase in the return to capital reallocates capital across cities, and thereby affects the return to land in the different cities. These effects create spillovers or externalities across cities. We shall also consider a different externality, allowing one city to benefit from a policy innovation adopted by another city, perhaps by imitating a successful policy. We shall see that under plausible conditions the cities may spend too much on innovation rather than too little, or spend more than required to maximize aggregate welfare across the cities. Our results are in some ways the opposite of those that appear under tax competition. Under tax competition, cities lower taxes excessively, and provide too few services. We show that cities may spend too much, or too early.

Our analysis can have several applications. We examine whether decentralization promotes socially optimal policy innovation. Our result that maximizing land values can lead to worse outcomes than maximizing the returns to capital raises the possibility that expanded homeownership may lead to worse policies. And we examine how the central government may be able to improve decentralized decisions by redistributing income across cities.

Though we shall speak of innovation, the general ideas hold more broadly. Instead of innovation, we can speak of experimentation, with a city adopting a policy in one period, whose results become known to both cities. One city can then learn from another. Another view is that a city can introduce a new policy either in period 1 or in period 2. Adopting the policy in period 1 costs F; the cost in period 2 is $M < F$. Then results similar to ours will hold—in particular, when each city aims to maximize its land values, both cities may adopt the policy in period 1, though social optimality requires that both do it in period 2, or that only one city adopt it in period 1.

2 Literature

2.1 Race to the bottom

Strategic interaction among governments—how the policy in one jurisdiction depends on what other jurisdictions do—is widely studied (for a survey see Brueckner 2006). Our model considers the "resource-flow" effect, where the distribution of resources (such as capital) across jurisdictions depends on the policy choices of all jurisdictions. Most commonly studied is tax competition, where a high tax on rich individuals encourages their migration, or where a high tax on capital reduces investment. In general, and in our model as well, the Nash equilibrium in the resource-flow model is inefficient, with the details of the model determining whether the decision variables are set too high or too low.

Nevertheless, the standard story of policy in jurisdictions facing labor or capital mobility is a "race to the bottom:" a jurisdiction which imposes more onerous regulations or taxes on its citizens or firms will see movement out of the jurisdiction, a fall in the tax base, and perhaps a need to raise tax rates further, driving even more people out (see Peterson 1995, chapter 2). Jurisdictions may face a prisoners' dilemma, in which all would be better off if a central government coordinated their policies; the desire to coordinate policies motivates, for example, strengthening the European Union, and maintaining federal control in the United States over welfare or environmental programs.

A clear statement of the argument, as applied to environmental policy, is given by Stewart (1977)

> Given the mobility of industry and commerce, any individual state or community may rationally decline unilaterally to adopt high environment standards that entail substantial costs for industry and obstacles to economic development for fear that the resulting environmental gains will be more than offset by movement of capital to other areas with lower standards. If each locality reasons in the same way, all will adopt lower standards of environmental quality than they would prefer if there were some binding mechanism that enabled them simultaneously to enact higher standards, thus eliminating the threatened loss of industry or development.

2.2 Policy innovation and imitation

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 saw 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. Liebmann, 285 U.S. 262, at 311 (1932)).[1]

[1] Sometimes, of course, bad policies can be imitated. The California Fair Trade Law of 1931 was copied verbatim by ten other states, including two serious typographical errors (Walker 1971).

In the academic literature, Oates (1999) speaks of "laboratory federalism" and points out that welfare reform in the United States in 1996 followed these considerations (see also Inman and Rubinfeld 1997).

Electoral considerations can strengthen the incentives for a local policymaker to innovate. Kotsogiannis and Schwager (2006), building on Rose-Ackerman (1980), show how the incentive to signal above-average ability to the electorate can motivate politicians at the local level to implement new policies with uncertain outcomes.

On the other hand, when outcomes are correlated across states, learning involves an externality—the information obtained by one state can be used by another, and therefore each policymaker has an incentive to free-ride on each other's innovative efforts (Rose-Ackerman 1980 and Strumpf 2002). Scotchmer (1991) finds that investment by jurisdictions is optimal for a given distribution of land. But because of the negative spillover, this optimality may not hold for innovations which can be imitated. Indeed, as in patent races, investment can be excessive.

Empirical work addresses these ideas. One topic is whether some states are more likely to innovate than are others. Walker (1969) finds that innovation is more common in states with higher per capita income, higher levels of education, and greater urbanization. But Gray (1973) argues that the characteristics of jurisdictions poorly predict diffusion of policy, diffusion being largely idiosyncratic.

Studying the post-World War II American occupation of Germany and German reunification after 1989, Jacoby (2001) concludes that imitation sparked innovation in both periods. Schaltegger (2004) examines whether spending decisions by one Swiss canton influence other cantons. The panel analysis provides evidence of budget spillovers among neighboring cantons. Boehmke and Witmer (2004) conduct an event-count study of Indian gaming. They consider diffusion as arising both from social learning (officials in one state learn from the actions of officials in neighboring states) and from economic competition (the actions in one state increase another state's benefits of adopting the same policy).

2.3 Industrial Organization

The idea that imitation reduces innovation resembles results with patents—the longer the patent the greater the incentive to innovate, but the lower the diffusion (or use) of the innovation.

In the literature on industrial organization, Baake and Boom (2001) consider firms' incentives to produce compatible products. The incentives to innovate rather than to imitate are studied by several authors. With a product-quality ladder, one firm may want another to innovate because it allows the second to innovate for the next stage (Scotchmer 1991). Glazer, Kannianen, and Mustonen (2006) consider duopolists who invest in R&D and, when successful, produce a new version of a product. They show that when products are network goods, the producer of the old product may free-ride on another firm's innovative efforts.

3 Assumptions

Consider a dynamic game in which two cities compete for innovating better public services. A city which innovates incurs a fixed cost. The first city to innovate can enjoy higher land rents until the other city catches up. The follower city can improve its public services by imitating the innovating city, thereby improving services at lower costs; this option discourages innovation. It is therefore unclear whether dynamic competition in a decentralized economy leads to the efficient level of innovation. The plausible socially optimal outcome has one city innovate and the other imitate. That is, innovation is socially valuable, but it is wasteful for both cities to incur the costs of innovations.

Index the two cities by i. Output in a city increases with its capital (K), land (L), and public services (G). Capital is mobile, land is immobile, and public services are a local public good in each city. The production function in city i is

$$Y_i = K_i^a L_i^{1-a} G_i^b,$$

where a and b are positive parameters. Let the price of capital in city i be r_i; the rental for land is π_i. The factor prices satisfy the marginal productivity conditions:

$$r_i = aK_i^{a-1} L_i^{1-a} G_i^b, \tag{1}$$

$$\pi_i = (1-a)K_i^a L_i^{-a} G_i^b. \tag{2}$$

Each city has one unit of land; that is, $L_1 = L_2 = 1$. The economy is endowed with one unit of capital; a fraction k of it is in city 1, and a fraction $1-k$ is in city 2; that is, $K_1 = k$ and $K_2 = 1-k$. Each city has a unit measure of land owners and a unit measure of capital owners. Land in each city is equally owned by residents of that city. Capital across all cities is equally owned by the total population; that is, the residents in each city own half the capital in their city, and half the capital in the other city. The owners are immobile between cities, while capital is mobile so that r_i is equalized across the cities. From (1) the distribution of capital k and equalized r_i are

$$k = \frac{G_1^\beta}{G_1^\beta + G_2^\beta},$$

$$r_A = r_B = a\left(G_1^\beta + G_2^\beta\right)^{1-a}, \tag{3}$$

where $\beta = \frac{b}{1-a}$. Payments for land are

$$\pi_i = (1-a)\left(\frac{G_i^\beta}{G_i^\beta + G_j^\beta}\right)^a G_1^b. \tag{4}$$

The quantity of public services is fixed, but the city can improve its quality from bad to good by innovating or by imitating the innovation made by another city. Normalize the fixed quantity of public services to 1, and normalize the quality of public services before improvement to 1. Thus before city i improves the quality of its public services, $G_i = 1$. A city which innovates can improve its public service to $G_i = 1 + g$. Innovation costs F. A city can imitate an innovation made by another city at a fixed cost of M. A city which imitates another city improves its public service to $G_i = 1+\gamma$, where $\gamma < g$. Transaction costs are sufficiently high so that in a decentralized solution the cities cannot make side payments to each other to achieve the efficient solution.

Let the rent on land in each city when both cities provide bad public services be $\pi(0,0)$; the return to capital is $r(0,0)$. The corresponding values when both cities innovate and provide good services are $\pi(1,1)$ and $r(0,0)$. Let $\pi(1,0)$ and $r(1,0)$ denote the payments to land and capital in a city which has good public services when the other city has bad services. And let $\pi(0,1)$ and $r(0,1)$ denote the payments to land and capital in one city when that city provides bad public services but the rival city provides good services. Let $\pi(1,\mu)$ and $r(1,\mu)$ denote the payments to land and capital in the city which innovates but is imitated by the other city; the corresponding values in the city which imitates are $\pi(\mu,1)$ and $r(\mu,1)$. Since capital is mobile, $r(1,0) = r(0,1)$ and $r(1,\mu) = r(\mu,1)$. From (3) and (4), express these as

$$\pi(0,0) = (1-a)\left(\frac{1}{2}\right)^a,$$

$$\pi(1,1) = (1-a)\left(\frac{1}{2}\right)^a (1+g)^b,$$

$$\pi(1,0) = (1-a)\left(\frac{(1+g)^\beta}{(1+g)^\beta+1}\right)^a (1+g)^b,$$

$$\pi(0,1) = (1-a)\left(\frac{1}{(1+g)^\beta+1}\right)^a,$$

$$\pi(1,\mu) = (1-a)\left(\frac{(1+g)^\beta}{(1+g)^\beta+(1+\gamma)^\beta}\right)^a (1+g)^b,$$

$$\pi(\mu,1) = (1-a)\left(\frac{(1+\gamma)^\beta}{(1+g)^\beta+(1+\gamma)^\beta}\right)^a (1+\gamma)^b,$$

$$r(0,0) = 2^{1-a}a,$$

$$r(1,1) = 2^{1-a}a(1+g)^b,$$

$$r(1,0) = r(0,1) = a\left((1+g)^\beta+1\right)^{1-a},$$

and

$$r(1,\mu) = r(\mu,1) = a\left((1+g)^\beta+(1+\gamma)^\beta\right)^{1-a}.$$

We can see that $\pi(0,1) < \pi(0,0) < \pi(1,1) < \pi(1,0)$ and $\pi(0,1) < \pi(\mu,1) < \pi(1,1) < \pi(1,\mu) < \pi(1,0)$. Also, $r(0,0) < r(1,0) = r(0,1) < r(1,\mu) = r(\mu,1) < r(1,1)$.

Consider an economy with three periods. Each city has bad services in period 1, so that $G_{i1} = 1$, $\pi_{i1} = \pi(0,0)$, and $r_{i1} = r(0,0)$. If city i innovates in period 1, incurring the fixed cost F in period 1, it has good public services in periods 2 and 3. Otherwise, it has bad public services in period 2. A city which did not innovate in period 1 can imitate in period 2 a city which did innovate in period 1; fresh innovation is infeasible in period 2. Imitation costs M; the quality of services in period 3 in the city which imitates is $G_i = 1 + \gamma$.

We shall consider two extreme cases of a city's objective. It can either maximize the return to landowners in the city, or alternatively it can maximize the return to capital owners in the city.

If city i maximizes the aggregate income of landowners in that city, its objective is to

$$\max_{I_{it} \in \{0,F,M\}} \sum_{t=1}^{3} \delta^t (\pi_{it} - I_{it}/2), \tag{5}$$

where δ is the intertemporal discount factor, π_{it} is the payment for land, $\pi_{i1} = \pi(0,0)$, and I_{it} is the investment by city i in period t. If instead city i maximizes the aggregate income of capital owners in that city, its objective is to

$$\max_{I_{it} \in \{0,F,M\}} \sum_{t=1}^{3} \delta^t (r_{it}/2 - I_{it}/2), \tag{6}$$

where $r_{i1} = r(0,0)$. We assume that in either case the tax to finance the costs for innovation or imitation is levied equally on both land owners and capital owners in each city.

4 Social welfare

The socially optimal solution, which maximizes aggregate welfare across the two cities, can take one of three forms: no city innovates, both cities innovate, one city innovates and the other imitates.

Let W^{FF} denote social welfare, the sum of the incomes of landowners and capital owners over all periods, when both cities innovate. From (5) and (6),

$$\begin{aligned} W^{FF} &= 2\left(\pi(0,0) + r(0,0)/2 - F\right) + 2\delta\left(\pi(1,1) + r(1,1)/2\right) \\ &\quad + 2\delta^2\left(\pi(1,1) + r(1,1)/2\right). \end{aligned} \tag{7}$$

Let W^{FM} denote social welfare when only one city innovates in period 1, whereas the other city imitates in period 2; let W^0 denote social welfare when neither city innovates. From (5), these are

$$\begin{aligned} W^{FM} &= \left(\pi(0,0) + r(0,0)/2 - F\right) + \delta\left(\pi(1,0) + r(1,0)/2\right) \\ &\quad + \delta^2\left(\pi(1,\mu) + r(1,\mu)/2\right) \\ &\quad + \left(\pi(0,0) + r(0,0)/2\right) + \delta\left(\pi(0,1) + r(0,1)/2 - M\right) \\ &\quad + \delta^2\left(\pi(\mu,1) + r(\mu,1)/2\right), \end{aligned} \tag{8}$$

and

$$W^0 = 2\left(\pi(0,0) + r(0,0)/2\right) + 2\delta\left(\pi(0,0) + r(0,0)/2\right) + 2\delta^2\left(\pi(0,0) + r(0,0)/2\right). \tag{9}$$

Equations (7), (8) and (9), imply that W^{FF} exceeds W^0 if

$$F \leq \delta(1+\delta)(\pi(1,1) - \pi(0,0)) + \delta(1+\delta)(r(1,1) - r(0,0)). \tag{10}$$

Similarly, W^{FM} exceeds W^0 if

$$\begin{aligned} F \leq & -\delta M + \delta(\pi(1,0) - \pi(0,0)) + \delta^2(\pi(1,\mu) - \pi(0,0)) \\ & - \delta(\pi(0,0) - \pi(0,1)) - \delta^2(\pi(0,0) - \pi(\mu,1)) \\ & + \delta(r(1,0) - r(0,0)) + \delta^2(r(1,\mu) - r(0,0)). \end{aligned} \tag{11}$$

And W^{FM} exceeds W^{FF} if

$$\begin{aligned} F \geq & \ \delta M + \delta(\pi(1,1) - \pi(0,1)) + \delta^2(\pi(1,1) - \pi(\mu,1)) \\ & - \delta(\pi(1,0) - \pi(1,1)) - \delta^2(\pi(1,\mu) - \pi(1,1)) \\ & + \delta(r(1,1) - r(1,0)) + \delta^2(r(1,1) - r(1,\mu)). \end{aligned} \tag{12}$$

Figure 1 shows the areas which satisfy (7), (8), and (9). We focus on the outcomes when (11) and (12) hold; that is, the values of F and M lie in the triangle enclosed by the borders of (11) and (12), and the vertical axis. Though innovation is socially valuable, it will often prove wasteful for both cities to incur the cost of innovating. Instead, at the socially optimal outcome one city innovates in period 1 and the other imitates in period 2. One question we address is whether a decentralized economy attains the socially optimal solution.

5 Nash equilibrium

5.1 A city maximizing the income of landowners

We consider first each city maximizing land rents, or maximizing (5), given the strategy of the rival city. Let B_t denote the maximized benefits to a city from period t on. The maximized benefits are functions of the qualities of public services in the two cities in the starting period t. In periods 2 and 3, this economy has the following possible states: both cities provide good services (with a payoff denoted by $B_t(1,1)$); one city provides good services while the other provides bad services; and both cities provide bad services (with a payoff denoted by $B_t(0,0)$). Let $B_t(1,0)$ denote the maximized benefits to a city with good services when the other city has bad services; $B_t(0,1)$ represents the opposite case. In period 3, a possible outcome is that one city provides good services while the other imitated it in period 2; the imitating city then provides public services with quality $G_i = 1+\gamma$. Let $B_3(1,\mu)$ denote the maximized benefits to a city with better services; $B_3(\mu,1)$ is the maximized benefit to the city that imitated the other city. The maximized benefit in period 3, B_3, is π_{i3}.

In period 1, both cities provide bad public services. Let $B_1(0,0)$ solve (5) with $\pi_{i0} = \pi(0,0)$.

To determine the subgame-perfect Nash equilibrium, consider first the game between cities in period 2. Suppose both cities provide good public services in period 2. Then $B_2(1,1)$ becomes

$$B_2(1,1) = \pi(1,1) + \delta\pi(1,1). \tag{13}$$

Suppose next that only one city provides good services. The problem facing the city with the bad services is to

$$\max[\pi(0,1) + \delta B_3(0,1), \pi(0,1) - M/2 + \delta B_3(\mu,1), \\ \pi(0,1) - F/2 + \delta B_3(1,1)] = B_2(0,1).$$

It chooses to imitate if

$$M + 2\delta(\pi(1,1) - \pi(\mu,1)) \leq F, \tag{14}$$

and

$$2\delta(\pi(\mu,1) - \pi(0,1)) \geq M. \tag{15}$$

Its benefits are then

$$B_2(0,1) = \pi(0,1) - M/2 + \delta B_3(\mu,1) = \pi(0,1) - M/2 + \delta\pi(\mu,1). \tag{16}$$

Given that the city with initially bad services imitates the city with good services, the benefits to the city with good services are

$$\max[\pi(1,0) + \delta B_3(1,\mu), \pi(1,0) - F/2 + \delta B_3(1,\mu)] = B_2(1,0). \tag{17}$$

The city's optimal strategy is to do nothing, generating benefits

$$B_2(1,0) = \pi(1,0) + \delta\pi(1,\mu). \tag{18}$$

Therefore, if (15) holds, the Nash equilibrium has the city with worse services imitate. Their benefits are (16) and (18).[2]

With (13), (16) and (18) in hand, we can turn to the original problem, (5), where initially both cities have bad public services. Given that the rival city innovates, a city's optimization problem is to

$$\max[\pi(0,0) - F/2 + \delta B_2(1,1), \pi(0,0) + \delta B_2(0,1)]B_1(0,0). \tag{19}$$

The city innovates if

$$F \leq \delta M + 2\delta(\pi(1,1) - \pi(0,1)) + 2\delta^2(\pi(1,1) - \pi(\mu,1)). \tag{20}$$

In contrast, when the rival city does not innovate, a city's problem becomes

$$\max[\pi(0,0) - F/2 + \delta B_2(1,0), \pi(0,0) + \delta B_2(0,0)] = B_1(0,0).$$

[2]Equation (14) is plausible. The set of (F, M) which satisfies (15) includes the set which satisfies (11) and (12).

The city innovates if

$$F \leq 2\delta(\pi(1,0) - \pi(0,0)) + 2\delta^2(\pi(1,\mu) - \pi(0,0)). \tag{21}$$

Three equilibrium patterns are possible, depending on whether (20) and (21) hold:[3]

1. Equation (21) holds and (20) does not hold. Then the Nash equilibrium has only one city innovate. The benefits to the city that innovates (say city 1) are
$$\pi(0,0) - F/2 + \delta\pi(1,0) + \delta^2\pi(1,\mu).$$
The benefits to the city that does not innovate are
$$\pi(0,0) + \delta\pi(0,1) - \delta M/2 + \delta^2\pi(\mu,1).$$

2. Equations (20) and (21) both hold. Then both cities innovate. The benefits are
$$\pi(0,0) - F/2 + \delta\pi(1,1) + \delta^2\pi(1,1).$$

3. Neither (20) nor (21) holds. Then neither city innovates. The benefits to each are
$$\pi(0,0) + \delta\pi(0,0) + \delta^2\pi(0,0).$$

In case 1, the social optimum is attained. In cases 2 and 3, however, the social optimum is not attained. In case 2 too many cities innovate. In case 3 no city innovates.[4]

Figure 2 shows the areas in which each of the three cases holds. We can see that innovation tends to be excessive. If city A innovates while city B imitates, then city B has lower land rents, but enjoys a lower cost of improving public services. If the imitation costs M are too small to satisfy (20), the city will not innovate in the current period but will instead imitate in the next period. The closer the imitation costs to the innovation costs, however, the less attractive is imitation.

If the imitation costs are so close to the innovation costs as to make M satisfy (20), the city will innovate. The gain to the landowners in city B of switching from imitation in the next period to innovation in the current period

[3] In a fourth case, (20) holds and (21) does not hold. Such F and M, however, are excluded in the set which satisfies (11) and (12).

[4] Among $B_2(1,1)$, $B_2(1,0)$, $B_2(0,1)$ and $B_2(0,0)$ in the optimization problem equations, we obtained the first three as (13), (16) and (18); we have yet to analyze $B_2(0,0)$. In obtaining conditions (20) and (21) we assumed that $B_2(0,0) = \pi(0,0) + \delta\pi(0,0)$. We can see that when both cities have bad public services in period 2 and F is sufficiently large to satisfy $F \geq \delta M + 2\delta(\pi(1,0) - \pi(0,0))$, they do not innovate; both innovate if F is so small that $F \leq \delta M + 2\delta(\pi(1,1) - \pi(0,1))$. Thus we must check that $F \geq \delta M + 2\delta(\pi(1,0) - \pi(0,0))$ for each of the three cases. In cases 1 and 3, the inequality holds. In case 2, however, the inequality does not necessarily hold, and F may be less than $\delta M + 2\delta(\pi(1,1) - \pi(0,1))$. With F so small as in case 2, however, both cities will innovate in period 1. That is, both face the problem (19), in which there is no $B_2(0,0)$.

is non-negative, but smaller than the loss of the landowners in the rival city. In particular, when M and F make (20) an equality, the gain is zero (that city is indifferent between imitation and innovation). Therefore, the sum of benefits for the landowners in the two cities is smaller when both cities innovate than when one city innovates and the other imitates. In equilibrium, too many cities innovate. In addition, a switch from imitation in the next period to innovation in the current period by city B harms owners of capital. City B can prevent capital outflow by such a switch. Capital owners in city B, however, gain less than landowners. The reason is that capital mobility makes the price of capital less sensitive to the gap in the quality of public services than is the price of land. If only city A innovates, capital in city B moves to city A, and thus capital owners in city B could also enjoy the higher quality of the public services in city A. Therefore, even when F is sufficiently small to satisfy (20), it can exceed the benefits to capital owners of increased returns of switching from imitation to innovation. That in turn implies that if a city maximizes returns to landowners, too many cities may innovate.

In case 1 a Nash equilibrium has pure strategies, but the solution is asymmetric. We discuss below whether there exists a symmetric Nash equilibrium with mixed strategies.

Suppose that in period 1 the rival city innovates with probability ϕ_j. Then a city's optimization problem is to

$$\begin{aligned}\max_{\phi_i\in[0,1]}&[\phi_i\{\pi(0,0)-F/2+\delta\phi_j B_2(1,1)+\delta(1-\phi_j)B_2(1,0)\},\\ &+(1-\phi_i)\{\pi(0,0)+\delta\phi_j B_2(0,1)+\delta(1-\phi_j)B_2(0,0)\}].\end{aligned}$$

The solution is

$$\text{if} -F/2+\delta\phi_j B_2(1,1)+\delta(1-\phi_j)B_2(1,0) > \delta\phi_j B_2(0,1)+\delta(1-\phi_j)B_2(0,0)$$
$$\text{then}\ \ \phi_i = 1,$$

$$\text{if} -F/2+\delta\phi_j B_2(1,1)+\delta(1-\phi_j)B_2(1,0) = \delta\phi_j B_2(0,1)+\delta(1-\phi_j)B_2(0,0)$$
$$\text{then}\ \ \phi_i\ \ \text{can take any value in } [0,1],$$

$$\text{if} -F/2+\delta\phi_j B_2(1,1)+\delta(1-\phi_j)B_2(1,0) < \delta\phi_j B_2(0,1)+\delta(1-\phi_j)B_2(0,0)$$
$$\text{then}\ \ \phi_i = 0.$$

If ϕ_j satisfies (5.1) in the range of $\phi_j \in [0,1]$, then $\phi_i = \phi_j = \phi$ is a symmetric Nash equilibrium in mixed strategies. The benefits to a city are

$$B_1(0,0) = \pi(0,0) - F/2 + \delta\phi B_2(1,1) + \delta(1-\phi)B_2(1,0). \tag{22}$$

Thus, this economy has a symmetric Nash equilibrium with mixed strategies if the ϕ that satisfies (22) and (5.1) lies in [0, 1]. With (13), (16), (18), (22), and (5.1) we have

$$\begin{aligned}&-F/2+\phi\delta(1+\delta)\pi(1,1)+(1-\phi)\delta(\pi(1,0)+\delta\pi(1,\mu))\\ &\quad-\phi\delta(\pi(0,1)-M/2+\delta\pi(\mu,1))-(1-\phi)\delta(1+\delta)\pi(0,0)=0.\end{aligned} \tag{23}$$

Let $f(\phi)$ denote the left-hand side of (23). It is difficult to obtain ϕ explicitly by solving (23), yet we can see that $\phi \in [0,1]$ if either $f(0) \leq 0$ and $f(1) \geq 0$, or if $f(0) \geq 0$ and $f(1) \leq 0$. The condition $f(0) \geq 0$ is the same as (21), and the condition $f(1) \leq 0$ is the inverse of (20). Hence, if (21) holds and (20) does not hold, two types of equilibria can arise. One equilibrium has asymmetric pure strategies: one city innovates and the other does not. Another equilibrium has symmetric mixed strategies: each city innovates with positive probability.

Social welfare in a mixed-strategy Nash equilibrium is

$$\phi^2 W^{FF} + 2\phi(1-\phi)W^{FM} + (1-\phi)^2 W^0. \tag{24}$$

This value is strictly smaller than W^{FM}, since in (24) the sum of the coefficients of W^{FF}, W^{FM} and W^O is 1, and W^{FM} is the largest of the three. That is, in contrast to the Nash equilibrium with asymmetric pure strategies, in a Nash equilibrium with symmetric mixed strategies, the social optimum W^{FM} cannot be attained. The socially optimal solution has one city innovate and the other imitate. In a mixed strategy Nash equilibrium, however, this solution appears only with probability $2\phi(1-\phi) < 1$. With probability ϕ^2, too many cities innovate; with probability $(1-\phi)^2$ no city innovates.

5.2 A city maximizing the income of capital owners

Consider next the equilibrium when each city maximizes the income of capital owners, or maximizes (6), given the rival city's strategy.

Let V_t denote the maximized benefits to a city from period t on, which are functions of the qualities of public services in the two cities in the starting period t.

As in section 5.1, we first consider the game between cities in period 2. If both cities provide good public services in period 2, the cities cannot further improve public services. Thus $V_2(1,1)$ becomes

$$V_2(1,1) = r(1,1)/2 + \delta r(1,1)/2. \tag{25}$$

Consider next the equilibrium when each city maximizes (6) given that only one city initially provides good services. The problem facing the city with the bad services is to

$$\begin{aligned}&\max[r(0,1)/2 + \delta V_3(0,1), r(0,1)/2 - M/2 + \delta V_3(\mu,1),\\ &\quad r(0,1)/2 - F/2 + \delta V_3(1,1)] = V_2(0,1).\end{aligned}$$

It chooses to imitate if

$$M + \delta(r(1,1) - r(\mu,1)) \leq F, \tag{26}$$

and

$$\delta(r(\mu,1) - r(0,1)) \geq M. \tag{27}$$

Its benefits are then

$$V_2(0,1) = r(0,1)/2 - M/2 + \delta V_3(\mu,1) = r(0,1)/2 - M/2 + \delta r(\mu,1)/2. \tag{28}$$

Given that the city with initially bad services imitates the city with good services, the city with good services has benefits

$$V_2(1,0) = r(1,0)/2 + \delta r(1,\mu)/2. \tag{29}$$

Therefore, if (27) holds, the Nash equilibrium has the city with worse services imitate. Their benefits are (28) and (29). The set of (F, M) which satisfies (26) includes the one which satisfies (11) and (12). However, (27) does not necessarily hold. In this sub-section, we suppose (27) holds; in the Appendix we suppose it does not.

With (25), (28) and (29) in hand, we can turn to the original problem (6). Given that the rival city innovates, a city's optimization problem is to maximize

$$[r(0,0)/2 - F/2 + \delta V_2(1,1), r(0,0)/2 + \delta V_2(0,1)]. \tag{30}$$

The city innovates if

$$F \leq \delta M + \delta(r(1,1) - r(0,1)) + \delta^2(r(1,1) - r(\mu,1)). \tag{31}$$

In contrast, when the rival city does not innovate, a city's problem becomes to maximize

$$[r(0,0)/2 - F/2 + \delta V_2(1,0), r(0,0)/2 + \delta V_2(0,0)]. \tag{32}$$

The city innovates if

$$F \leq \delta(r(1,0) - r(0,0)) + \delta^2(r(1,\mu) - r(0,0)). \tag{33}$$

Three equilibrium patterns are possible, depending on whether (20) and (21) hold:

1. Equation (33) holds and (31) does not hold. Then the Nash equilibrium has only one city innovate. The benefits to the city that innovates (say city 1) are
$$r(0,0)/2 - F/2 + \delta r(1,0)/2 + \delta^2 \pi(1,\mu)/2.$$
The benefits to the city that does not innovate are
$$r(0,0)/2 + \delta r(0,1)/2 - \delta M/2 + \delta^2 r(\mu,1)/2.$$
2. Equations (31) and (33) both hold. Then both cities innovate. The benefits are
$$r(0,0)/2 - F/2 + \delta r(1,1)/2 + \delta^2 r(1,1).$$
3. Neither (31) nor (33) holds. Then neither city innovates. The benefits to each are
$$r(0,0)/2 + \delta r(0,0)/2 + \delta^2 r(0,0)/2.$$

In case 1, the social optimum is attained. In cases 2 and 3 the social optimum is not attained. In case 2, too many cities innovate. In case 3, in contrast, no city innovates.

Figure 3 shows the areas in which each of the cases holds. We see that when the socially optimal outcome has one city innovate and the other imitate, in equilibrium innovation hardly takes place. The price of capital in one city rises following an innovation in that city, but not by as much as the land rent rises. Furthermore, an innovation in one city can raise the price of capital and lower the price of land in the other city. Therefore, a city which maximizes the income of capital owners has smaller incentive to innovate than a city which maximizes the income of landowners.

6 Redistributive policy by federal government

As seen in section 5.1, which discussed cities maximizing the incomes of land owners, too many cities may innovate. We consider here how the central government redistributive policies affect the results. Let $\tilde{\pi}$ denote returns after redistribution:

$$\tilde{\pi}(1,\mu) = \lambda\pi(1,\mu) + (1-\lambda)\pi(\mu,1),$$

$$\tilde{\pi}(\mu,1) = (1-\lambda)\pi(1,\mu) + \lambda\pi(\mu,1),$$

where λ represents the degree of redistribution: $\lambda = 1$ represents no redistribution and $\lambda = 1/2$ represents extreme redistribution such that the returns are equalized.

Given such a redistributive policy, (20) and (21) become

$$F \le \delta M - \left(\frac{\delta^2}{1-\delta}\right)((1-\lambda)\pi(1,\mu)+\lambda\pi(\mu,1)) - \delta\pi(0,1) + \left(\frac{\delta}{1-\delta}\right)\pi(1,1). \quad (34)$$

$$F \le \left(\frac{\delta^2}{1-\delta}\right)(\lambda\pi(1,\mu) + (1-\lambda)\pi(\mu,1)) + \delta\pi(1,0) - \left(\frac{\delta}{1-\delta}\right)\pi(0,0). \quad (35)$$

When equation (35) holds and (34) does not, only one city innovates. Conditions (34) and (35) imply that increased redistribution reduces innovation. Thus, when F is sufficiently small and so too many cities innovate, redistributive policy will lead to the social optimum.

7 Conclusion

Competition across cities is often seen as a "race to the bottom," with each city fearing that high taxes will drive capital to other cities. Our analysis looked at the opposite effect: a city can attract capital by providing better services than its neighbor does. One reason for the difference in the results is that much of the literature on tax competition supposes that tax revenue is used for redistribution from the rich (or from capital owners) to the poor. We instead see tax revenue as used to improve services which increase the productivity of capital. Some such policies, such as education, may even appear to be redistributive. Our second contribution to the large literature on tax competition is to compare outcomes when a city aims to maximize returns to landowners to outcomes when a city aims to maximize returns to landowners. Both cases generate externalities across cities. In maximizing returns to local owners of capital, the city ignores how its policies will raise the returns to capital earned by residents of the other city. In maximizing returns to local landowners, the city ignores how its policies will reduce the returns earned by landowners in the other city. These externalities work in opposite directions, with the cities induced to spend either too little or too much on improving services.

8 Appendix

Consider the solution when (27) does not hold, and thus the city with worse services does not imitate in period 2. Then $V_2(1,0)$ and $V_2(0,1)$ are not (28) and (29) but are the following:

$$V_2(0,1) = r(0,1)/2 + \delta V_3(0,1) = r(0,1)/2 + \delta r(0,1)/2. \tag{36}$$

Given that the city with initially bad services imitates the city with good services, the benefits to the city with good services are

$$V_2(1,0) = r(1,0)/2 + \delta r(1,0)/2. \tag{37}$$

A city's optimization problem given that the rival city innovates in period 1 is the same as (30). Since, however, $V_2(1,0)$ and $V_2(0,1)$ are (36) and (37), the condition under which the city innovates becomes

$$F \leq \delta(1+\delta)(r(1,1) - r(0,1)). \tag{38}$$

A city's optimization problem given that the rival city does not innovate in period 1 is the same as (32), but the condition under which the city innovates is

$$F \leq \delta(1+\delta)(r(1,0) - r(0,0)). \tag{39}$$

If equation (39) holds and (38) does not hold, the Nash equilibrium has only one city innovate. The other city will not imitate in period 2. If equation (38) and (39) both hold, both cities innovate. If neither (38) nor (39) holds, then neither city innovates. In any case, the social optimum is never attained.

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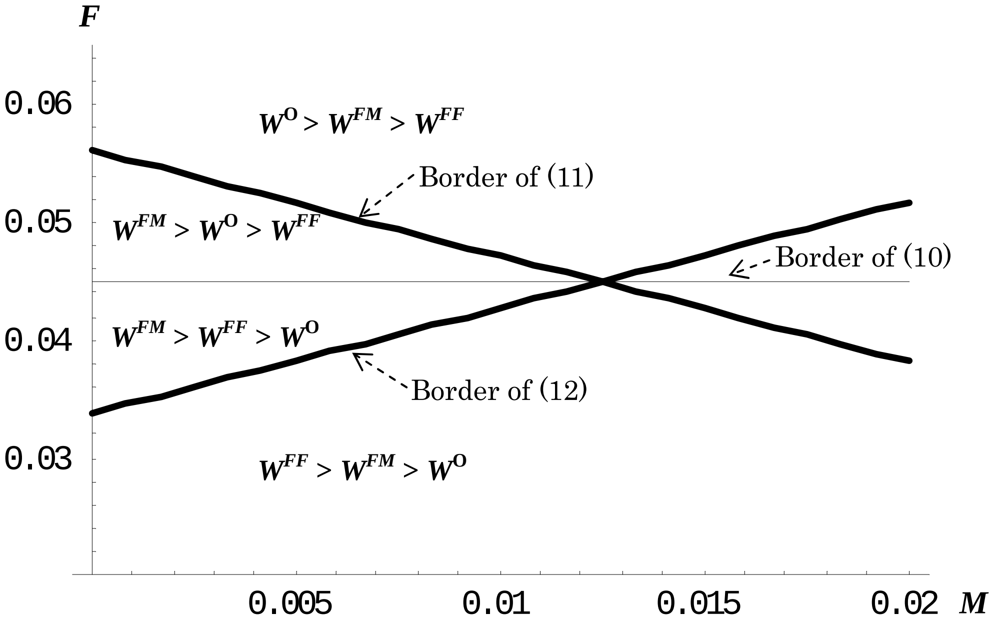

Figure 1

The sizes of F and M and the order of W^{FF}, W^{FM} and W^{O}.

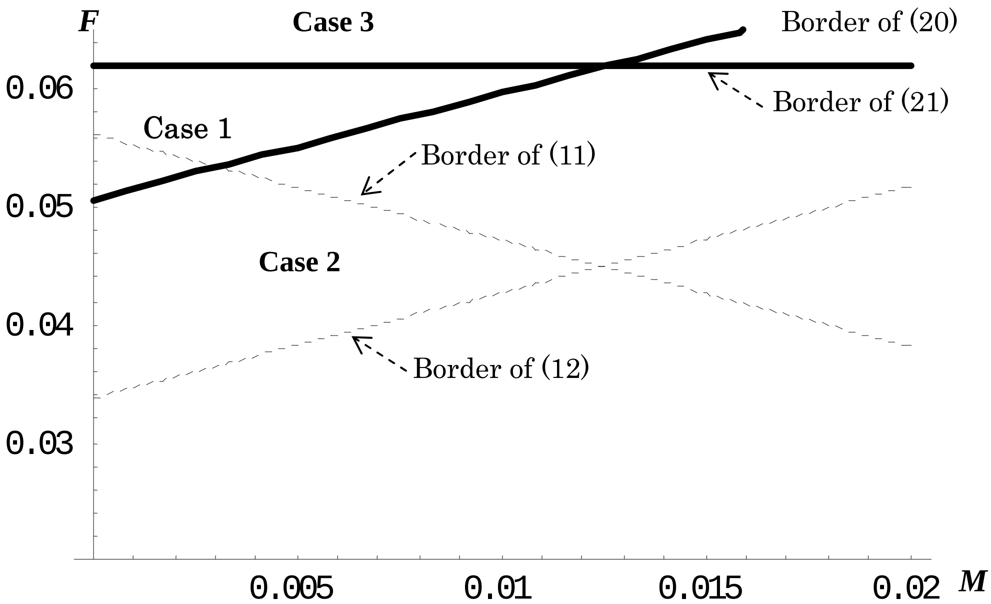

Figure 2
The sizes of F and M and three equilibrium patterns of the game where a city is maximizing the income of landowners.

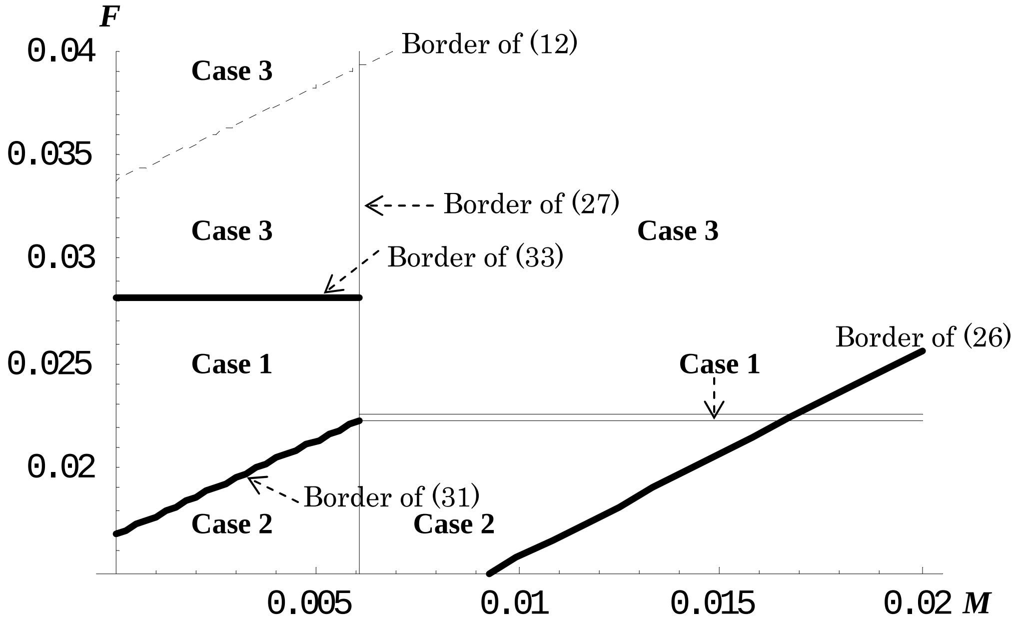

Figure 3

The sizes of F and M and three equilibrium patterns of the game where a city is maximizing the income of capital owners.