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INNOVATION AND IMITATION ACROSS JURISDICTIONS

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Abstract

We consider cities which can increase the income of landowners by improving the quality of public services. The improvement can come from innovation or from imitation. We find that the level of innovation can be excessive.

1 Introduction

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] Whether decentralization promotes socially optimal policy innovations is controversial, however, once we take into account the externalities in the competition between state governments.

This paper models a dynamic game in which two cities compete for innovating better public services. To innovate, a city incurs the costs of a fixed amount. A city which is the first 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.

We show that when costs of innovation are very large, the Nash equilibrium has neither city innovate. In contrast, when innovation costs are not very large and imitation costs are sufficiently close to the innovation costs, the Nash equilibrium has both cities innovate. The economy-wide level of innovation is excessive. When imitation costs are far smaller than innovation costs, there exists an asymmetric pure strategy Nash equilibrium in which exactly one city innovates, and the other city imitates. Thus, the social optimum can be attained. However, besides such an asymmetric pure strategy Nash equilibrium, there is a symmetric Nash equilibrium with mixed strategies in which cities randomize the decision to innovate, leading to inefficient outcomes.

[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)).

2 Literature

2.1 Policy innovation and imitation

The idea that decentralized government can lead to political innovation is common. In the academic literature, Oates (1999) speaks of "laboratory federalism" and points out that the reform of welfare 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 when they 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 in Swiss cantons are interdependent, that is, whether the spending decisions of a canton are influenced by those of other cantons. The panel analysis provides evidence of the existence 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 the benefits to another state of adopting the same policy).

All these studies see the ease of imitation as exogenous, or even as costless. We, in contrast, consider a jurisdiction's choice of imitability.

2.2 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 provide compatibility between 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. The new product increases the utility of its users. But since products are network goods, the new product also benefits users of the old product, increasing the willingness to pay for the old product. Consequently, the producer of the old product may free-ride on the innovative efforts of another firm. The firm which does not innovate may even profit from the success of its rival.

3 Assumptions

We consider two cities, 1 and 2, indexed by i. Output increases with capital (H), 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

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

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

$$r_i = aK_i^{a-1} L_i^{1-a} G_i^b, \tag{2}$$

$$\pi_i = (1-a) K_i^a L_i^{-a} G_i^b. \tag{3}$$

We assume that the amount of land is the same in the two cities, and normalize it to 1; that is, $L_1 = L_2 = 1$. The endowment of capital in the economy is 1; a fraction k of it is in city 1, and a fraction $1-k$ is in city 2; that is, $K_1 = k$ and $K_2 = 1-k$. The distribution of capital k is determined so that r_i is equalized across the cities. From (2) such a distribution is

$$k = \frac{G_1^\beta}{G_1^\beta + G_2^\beta}, \tag{4}$$

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

$$\pi_i = (1-a) \left(\frac{G_i^\beta}{G_i^\beta + G_j^\beta} \right)^a G_1^b. \tag{5}$$

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 another city. We normalize the fixed quantity of public services to 1, and the quality of public services before improvement to 1. Thus $G_i = 1$ before city i improves the quality of its public services. We assume that the quality can be improved by g, so that $G_i = 1+g$ after city i improves its public services. Let aggregate income from land in each city when both cities provide bad public services be $\pi(0,0)$; the corresponding value when both cities provide good services is $\pi(1,1)$. Let $\pi(1,0)$ denote the income to land in a city which has good public services when the other city has bad services. And let $\pi(0,1)$ denote the income to land in one city when that city provides bad public services but the rival city provides good services. From (3), these can be expressed as

$$\pi(0,0) = (1-a)\left(\frac{1}{2}\right)^a, \tag{6}$$

$$\pi(1,1) = (1-a)\left(\frac{1}{2}\right)^a (1+g)^b, \tag{7}$$

$$\pi(1,0) = (1-a)\left(\frac{(1+g)^\beta}{(1+g)^\beta+1}\right)^a (1+g)^b, \tag{8}$$

and

$$\pi(0,1) = (1-a)\left(\frac{1}{(1+g)^\beta+1}\right)^a. \tag{9}$$

We can see that $\pi(0,1) < \pi(0,0) < \pi(1,1) < \pi(1,0)$.

Each of two cities can improve its public service to $G_i = 1+g$ by innovating or else by imitating. The fixed cost of innovation is F. A city can imitate an innovation made by another city at a fixed cost of M.

City i's objective function is

$$\max_{F_{it}\in\{0,F\},M_{it}\in\{0,M\}} \sum_{t=0}^{\infty} \delta^t(\pi_{it} - F_{it} - M_{it}), \pi_{i0} = \pi(0,0), \tag{10}$$

where δ is intertemporal discount factor, and π_{it} is the payment for land in city i in period t. The transitions in this function are as follows. Suppose first that both cities have bad services in period t, so that $G_{it} = 1$ and $\pi_{it} = \pi(0,0)$. Let the other city invest in innovation, incurring the fixed cost F in period t. Then if city i innovates in period t, then in period $t+1$ the income of land in that city is $\pi(1,1)$; if city i does not innovate, then the income of land will be $\pi(0,1)$. In contrast, suppose the other city does not invest in innovation. If city i innovates in period t, then in period $t+1$ the income of land in that city is $\pi(1,0)$; if city i does not innovate, then the income of land will be $\pi(0,0)$.

Suppose next that in period t city i had bad services, while the other city had good services. If city i innovates or imitates in period t, then the income of land in period $t+1$ is $\pi_{i,t+1}$=$\pi(1,1)$; otherwise the income to landowners in city i is $\pi(0,1)$.

If city i has good public services in period t ($\pi_{it} = \pi(1,0)$), and the other city neither innovates nor imitates, then the payments to land in the next period are $\pi(1,0)$; otherwise the payments are $\pi_{it+1} = \pi(1,1)$.

Lastly, if $\pi_{1t} = \pi_{2t} = \pi(1,1)$, then $\pi_{1,t+1} = \pi_{2,t+1} = \pi(1,1)$.

4 Social welfare

The socially optimal solution can take one of three forms: no city invests, both cities invest, one city invests and the other imitates.

Let W^{FF} denote social welfare when both cities invest. From (10),

$$\begin{aligned} W^{FF} &= 2\left(\pi(0,0) - F + \sum_{t=1}^{\infty} \delta^t \pi(1,1)\right) \\ &= 2\left(\pi(0,0) - F + \left(\frac{\delta}{1-\delta}\right)\pi(1,1)\right). \end{aligned} \tag{11}$$

Let W^{FM} denote social welfare when only one city invests in innovation in period 0 and another imitates in period 1; let W^0 denote social welfare when neither city invests. From (10), these are

$$\begin{aligned} W^{FM} &= \left(\pi(0,0) - F + \delta\pi(1,0) + \sum_{t=2}^{\infty} \delta^t \pi(1,1)\right) \\ &\quad + \left(\pi(0,0) + \delta(\pi(0,1) - M) + \sum_{t=2}^{\infty} \delta^t \pi(1,1)\right) \\ &= 2\left(\pi(0,0) + \left(\frac{\delta^2}{1-\delta}\right)\pi(1,1)\right) \\ &\quad + \delta(\pi(1,0) + \pi(0,1)) - F - \delta M, \end{aligned} \tag{12}$$

and

$$W^0 = 2\left(\sum_{t=0}^{\infty} \delta^t \pi(0,0)\right) = 2\left(\frac{1}{1-\delta}\right)\pi(0,0). \tag{13}$$

From (11), (12) and (13), we can see that the condition for W^{FF} to exceed W^0 is that

$$F \leq \left(\frac{\delta}{1-\delta}\right)(\pi(1,1) - \pi(0,0)). \tag{14}$$

W^{FM} exceeds W^0 if

$$F \leq -\delta M + 2\left(\frac{\delta}{1-\delta}\right)(\pi(1,1) - \pi(0,0)) + \delta(\pi(1,0) - \pi(1,1)) + \delta(\pi(0,1) - \pi(1,1)). \tag{15}$$

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

$$F \geq \delta M - \delta(\pi(1,0) - \pi(1,1)) - \delta(\pi(0,1) - \pi(1,1)). \tag{16}$$

We focus on the case where (15) and (16) hold. That is, we consider the economy where innovation is socially valuable, but where it is wasteful for both cities to incur the cost of innovating. Our question is whether the socially optimal situation is attained in decentralized economy.

5 Nash equilibrium

Each city chooses a sequence of F_{it} and M_{it} to maximize (10) given the strategy of the rival city. We consider Markov strategies, where a city's decision depends only on the current state variable. This economy has three possible states: both cities provide good services (with a payoff denoted by $B(1,1)$); one city provides good services while the other provides bad services; and both cities provide bad services (with a payoff denoted by $B(0,0)$). We let $B(1,0)$ denote the maximized benefits to a city with good services when the other city has bad services; $B(0,1)$ represents the opposite case. That is, $B(1,1)$ is the solution of (10) with $\pi_{i0} = \pi(1,1)$ instead of $\pi_{i0} = \pi(0,0)$. Similarly, $B(1,0)$ is the solution of (10) with $\pi_{i0} = \pi(1,0)$; and $B(0,1)$ is the solution with $\pi_{i0} = \pi(0,1)$.

To determine the subgame-perfect Nash equilibrium, we first consider the game between cities which already have good services. We then consider the equilibrium when only one city provides good service. Lastly, we will consider the equilibrium when initially both cities had bad services.

When both cities have good public services, they can not improve them. Thus cities invest neither in innovation nor imitation, and $B(1,1)$ becomes

$$B(1,1) = \sum_{t=0}^{\infty} \delta^t \pi(1,1) = \left(\frac{1}{1-\delta}\right) \pi(1,1). \tag{17}$$

Next, we consider the case where only one city provides good services. The problem facing the city with the bad services is

$$\max[\pi(0,1) + \delta B(0,1), \pi(0,1) - M + \delta B(1,1), \pi(0,1) - F + \delta B(1,1)] = B(0,1) \tag{18}$$

It chooses to imitate if

$$M \leq F, \tag{19}$$

and

$$\left(\frac{\delta}{1-\delta}\right) (\pi(1,1) - \pi(0,1)) \geq M. \tag{20}$$

In this case, with (17) its benefits are

$$B(0,1) = \pi(0,1) - M + \delta B(1,1) = \pi(0,1) - M + \left(\frac{\delta}{1-\delta}\right) \pi(1,1). \tag{21}$$

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

$$B(1,0) = \max[\pi(1,0) + \delta B(1,1), \pi(1,0) - F + \delta B(1,1)]. \tag{22}$$

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

$$B(1,0) = \pi(1,0) + \left(\frac{\delta}{1-\delta}\right) \pi(1,1). \tag{23}$$

Therefore, if (20) holds, the Nash equilibrium has the city with worse services imitate, and has the city with better services do nothing. Their benefits are (21) and (23).[2]

With (17), (21) and (23) in hand, we can turn to the original problem (10), where both cities initially had bad public services. Given that the rival city innovates, a city's optimization problem is to

$$\max[\pi(0,0) - F + \delta B(1,1), \pi(0,0) + \delta B(0,1)] \equiv B(0,0). \tag{24}$$

The city innovates if

$$F \leq \delta M + \delta(\pi(1,1) - \pi(0,1)). \tag{25}$$

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

$$\max[\pi(0,0) - F + \delta B(1,0), \pi(0,0) + \delta B(0,0)] = B(0,0). \tag{26}$$

The city innovates if

$$F \leq \left(\frac{\delta}{1-\delta}\right)(\pi(1,1) - \pi(0,0)) + \delta(\pi(1,0) - \pi(1,1)). \tag{27}$$

Three equilibrium patterns are possible, depending on whether (25) and (27) hold:[3]

1. Equation (27) holds and (25) does not hold. Then the Nash equilibrium has only one city innovate. The benefits to the city that innovates (say city 1) are

$$B_1(0,0) = \pi(0,0) + \delta\pi(1,0) + \left(\frac{\delta^2}{1-\delta}\right)\pi(1,1) - F. \tag{28}$$

   The benefits to the city that does not innovate are

$$B_2(0,0) = \pi(0,0) + \delta\pi(0,1) + \left(\frac{\delta^2}{1-\delta}\right)\pi(1,1) - \delta M. \tag{29}$$

2. Equations (25) and (27) both hold. Then both cities invest in innovation. The benefits are

$$B(0,0) = \pi(0,0) - F + \left(\frac{\delta}{1-\delta}\right)\pi(1,1). \tag{30}$$

3. Neither (25) nor (27) holds. Then neither city innovates. The benefits to each are

$$B(0,0) = \left(\frac{1}{1-\delta}\right)\pi(0,0). \tag{31}$$

[2] Equation (19) is plausible. The set of (F, M) which satisfies (20) includes the one which satisfies (15) and (16).

[3] In a fourth case, (25) holds and (27) does not hold. Such F and M, however, are not included in the set which satisfies (15) and (16).

In case 1, $B_1(0,0) + B_2(0,0) = W^{FM}$ and the social optimum is attained. In cases 2 and 3, however, the social optimum is not attained. In case 2, innovation is excessive. In case 3, in contrast, no city innovates.

To see the results intuitively, suppose first that the costs of innovation F are so small that equation (27) holds. If city A innovates while city B imitates, then city B enjoys lower land rents in the next period, but enjoys a lower cost of improving public services. If the imitation costs M are too small to satisfy (25), the city will not innovate in the current period but will instead imitate in the next period. However, the closer the imitation costs are to the innovation costs, the less attractive is imitation. If the imitation costs are so close to the innovation costs that M satisfies (25), the city will innovate. The gain to a city of switching from imitation in the next period to innovation in the current period is non-negative, but smaller than the loss of the rival city. In particular, when M and F make (25) an equality, the gain is zero (imitation and innovation are indifferent for that city). Therefore, the sum of benefits for the two cities is smaller when both cities innovate then when one city innovates and the other imitates. The equilibrium level of innovation is excessive.

Suppose next that the costs of innovation F are too large for (27) to hold. If city A innovates and city B imitates, city A enjoys large benefits in the current period, but city B incurs low costs in the following period to adopt good public services. The larger are the innovation costs, the less attractive is innovation, given that the rival does not innovate in the current period. In equilibrium, no city may innovate.

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

Given that the rival city innovates with probability of ϕ_j, a city's optimization problem is

$$\begin{aligned} B_i(0,0) = \max\nolimits_{\phi_i \in [0,1]}[&\pi(0,0) - F + \delta\phi_j B(1,1) + (1-\phi_j)B(1,0), \\ &\pi(0,0) + \delta\phi_j B(0,1) + (1-\phi_j)B(0,0)], \end{aligned} \tag{32}$$

and thus

$$\begin{aligned} &\text{if} - F + \delta\phi_j B(1,1) + (1-\phi_j)B(1,0) > \delta\phi_j B(0,1) + (1-\phi_j)B(0,0) \\ &\text{then} \phi_i = 1, \end{aligned} \tag{33}$$

$$\begin{aligned} &\text{if} - F + \delta\phi_j B(1,1) + (1-\phi_j)B(1,0) = \delta\phi_j B(0,1) + (1-\phi_j)B(0,0) \\ &\text{then} \phi_i \text{can take any value in } [0,1], \end{aligned} \tag{34}$$

$$\begin{aligned} &\text{if} - F + \delta\phi_j B(1,1) + (1-\phi_j)B(1,0) < \delta\phi_j B(0,1) + (1-\phi_j)B(0,0) \\ &\text{then} \phi_i = 0. \end{aligned} \tag{35}$$

If ϕ_j satisfies (37) in the range of $\phi_j \in [0,1]$, then $\phi_i = \phi_j = \phi$ is a symmetric Nash equilibrium in mixed strategies, and the benefits of the cities are

$$B(0,0) = \pi(0,0) - F + \delta\phi B(1,1) + (1-\phi)B(1,0). \tag{36}$$

Therefore, we can determine whether this economy has a symmetric mixed strategy Nash equilibrium by checking whether the ϕ that satisfies (36) and (37) lies in [0, 1]. With (17), (21), (23), (36) and (37) we have

$$\begin{aligned}-F + \pi(0,0)\delta\left(\phi + (1-\phi)\left(\frac{\delta}{1-\delta+\phi\delta}\right)\right) - \pi(0,1)\delta\left(\frac{\phi}{1-\delta+\phi\delta}\right) \\ +\pi(1,0)\delta(1-\phi) - \pi(0,0)\delta\left(\frac{1-\phi}{1-\delta+\phi\delta}\right) + \delta\left(\frac{\phi}{1-\delta+\phi\delta}\right) = 0.\end{aligned} \tag{37}$$

Let $f(\phi)$ denote the left hand side of (37). To obtain ϕ explicitly by solving (37) is difficult, 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 (27), and the condition $f(1) \leq 0$ is the inverse of (25). Hence, we can see that if (27) holds and (25) 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.

The social welfare attained in a mixed strategy Nash equilibrium is

$$\begin{aligned}2B(0,0) = 2\phi^2[\pi(0,0) - F + \delta B(1,1)] + 2\phi(1-\phi)[\pi(0,0) - F + \delta B(1,0)] \\ + 2(1-\phi)\phi[\pi(0,0) - F + \delta B(0,1)] + 2(1-\phi)^2[\pi(0,0) + \delta B(0,0)].\end{aligned} \tag{38}$$

Rearranging it by using (11), (12), (13), (17), (23) and (21) yields

$$\begin{aligned}2B(0,0) &= \left(\frac{\phi^2}{1-\delta(1-\phi)^2}\right)W^{FF} + \left(\frac{2\phi(1-\phi)}{1-\delta(1-\phi)^2}\right)W^{FM} + \left(\frac{(1-\phi)^2}{1-\delta(1-\phi)^2}\right)\pi(0,0) \\ &= \left(\frac{\phi^2}{1-\delta(1-\phi)^2}\right)W^{FF} + \left(\frac{2\phi(1-\phi)}{1-\delta(1-\phi)^2}\right)W^{FM} + \left(\frac{(1-\delta)(1-\phi)^2}{1-\delta(1-\phi)^2}\right)W^0.\end{aligned} \tag{39}$$

The social welfare $2B(0,0)$ is strictly smaller than W^{FM}, since in (39) the sum of the coefficients of W^{FF}, W^{FM} and W^O is unity, 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 of ϕ^2 excessive innovation takes place; with probability of $(1-\phi)^2$ no city innovates.

6 Endogenous imitability choice

So far we supposed that an innovating city had no influence on whether the other city will imitate. Sometimes, however, an innovator can make imitation costly: it can hide information about its form of innovation, it can adopt an innovation which relies on some specialized resources, and so on. This section accordingly extends the analysis by making imitability a strategic choice. We let F_N denote the fixed cost of an innovation that cannot be imitated. Also, we let $B(N, 0)$ denote the maximized benefits to a city with good public services which cannot be imitated when the other city has bad services; $B(0, N)$ represents the opposite case. As before, the cost of an innovation which can be imitated is F.

When the rival city has good public services which cannot be imitated, a city incurs F or F_N to catch up. However, if

$$\left(\frac{\delta}{1-\delta}\right)(\pi(1,1) - \pi(0,1)) \leq F, \tag{40}$$

the city will not innovate, and the benefits of the cities are

$$B(0, N) = \left(\frac{1}{1-\delta}\right)\pi(0,1), \tag{41}$$

$$B(N, 0) = \left(\frac{1}{1-\delta}\right)\pi(1,0). \tag{42}$$

The gap in public services between cities will not be reduced over time. In contrast, If F is small so that (40) never holds, $B(N, 0) = B(1, 0)$. A city would not choose to spend F_N instead of F to make it impossible for the other city to imitate, and the analysis in the last section holds. In this sections w focus on the more interesting case where (40) holds.

When both cities initially had bad public services, and the rival city adopts an innovation that cannot be imitated, a city's optimization problem is to

$$B(0,0) = \max[\pi(0,0) - F_N + \delta B(1,1), \pi(0,0) - F + \delta B(1,1), \pi(0,0) + \delta B(0,N)]. \tag{43}$$

If (40) holds, the city never innovates. Otherwise, the city innovates, incurring a cost of F rather than of F. When the rival city does not innovate, a city's problem becomes

$$B(0,0) = \max[\pi(0,0) - F_N + \delta B(N,0), \pi(0,0) - F + \delta B(1,0), \pi(0,0) + \delta B(0,0)]. \tag{44}$$

The city will adopt an innovation that cannot be imitated, at a cost of F_N, if

$$F_N - F \leq \delta\left(\frac{\delta}{1-\delta}\right)(\pi(1,0) - \pi(1,1)), \tag{45}$$

and

$$F_N \leq \left(\frac{\delta}{1-\delta}\right)(\pi(1,0) - \pi(0,0)). \tag{46}$$

Then, if F_N and F satisfy (40), (45) and (46), the Nash equilibrium has one city adopt an innovation that cannot be imitated, and the other city never improves its public services.[4]

Given that the rival city will have or already has better public services and it cannot be imitated, a city must incur at least F to improve its services. If, however, F is very large, the city prefers not to improve its public services. The city with the better public services enjoys higher land rents in perpetuity. When both cities have bad public services, given that the rival city never innovates, a city will incur F_N to enjoy such perpetually higher rents, if F_N is larger than F but is not extremely so. Hence, under very large F and F_N slightly larger than F, the Nash equilibrium has one city adopt an innovation that cannot be imitated, and the other city never improves its public services.

[4]When F_N and F satisfy these conditions, F is necessarily in the case 3 in the last section. Such a set is not empty, but very limited. There are other patterns of pure strategy Nash equilibria. However, the condition under which each pattern emerges is the same as we saw in the last section, except that in a partial set of the case 3 in the last section there may emerge the Nash equilibrium we discuss here.

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7 Notation

F Fixed cost of innovating

M_i Amount city i spends on imitative ability

ϕ_i Probability that city i invests in innovation

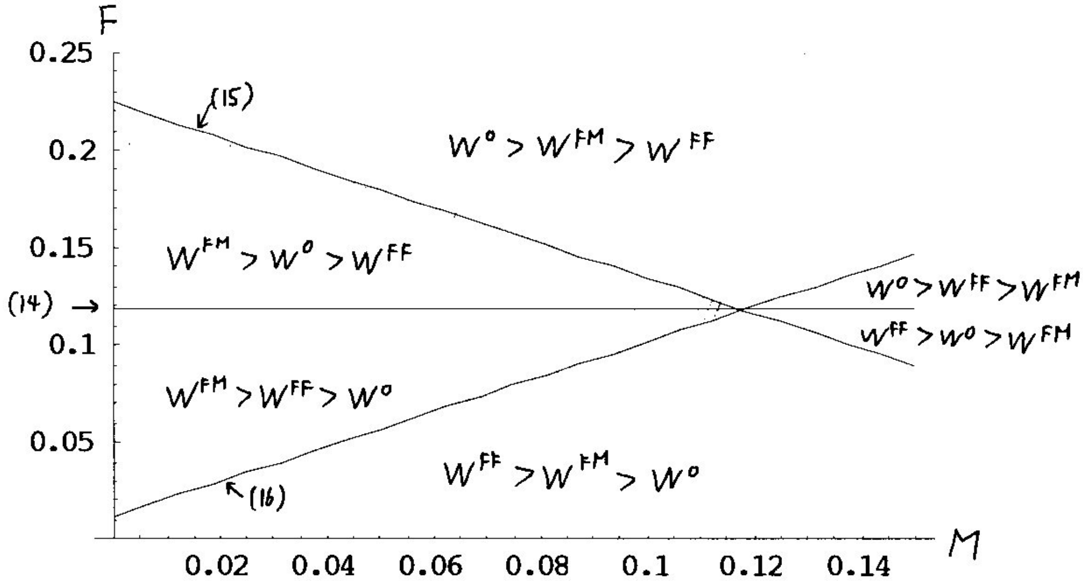

Figure1 (i)

(M, F) under which innovation is socially valuable, but it is wasteful for both cities to incur the cost of innovating.

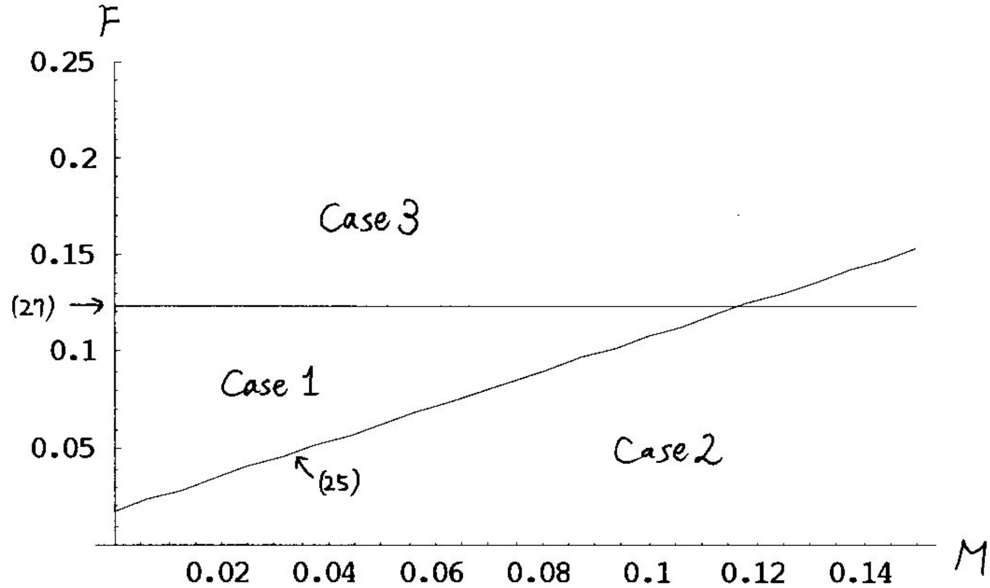

Figure1 (ii)

Three Nash equilibrium patterns.

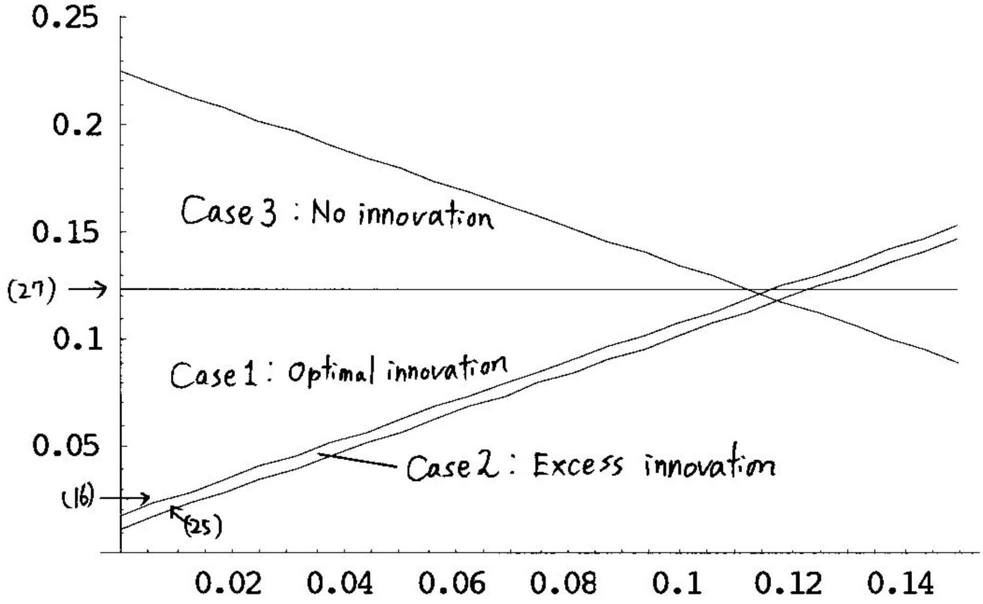

Figure1 (iii)

Nash equilibrium and social welfare

($a = 0.5$, $b = 0.2$, $\delta = 0.9$, $g = 0.2$)

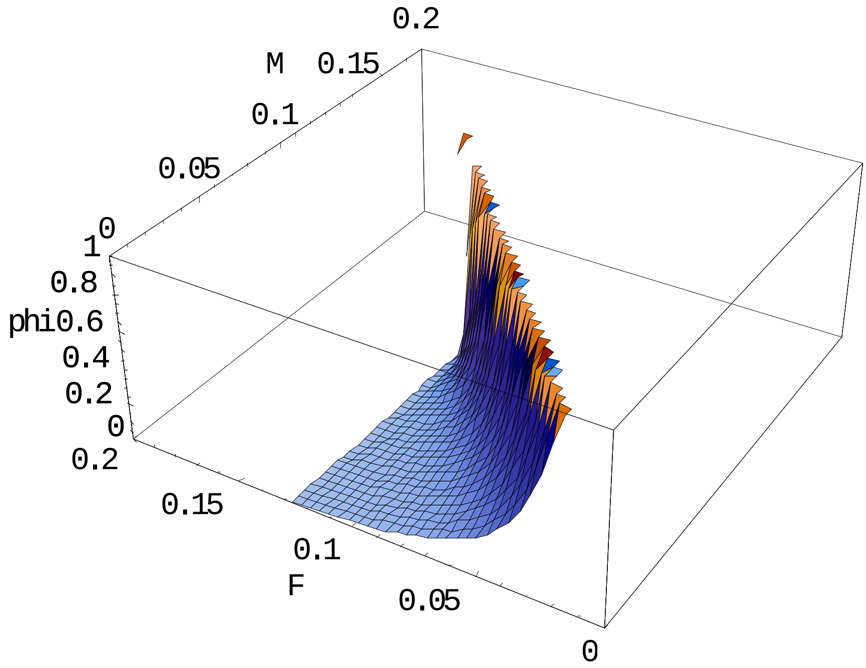

Figure 2

ϕ of mixed strategy Nash equilibrium on (M, F) of case 1