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PROMOTING GROWTH: RENT-SEEKING AS A CAUSE OF FAILURE

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Promoting growth: rent-seeking as a cause of failure

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Почему усилия государства по стимулированию образования и фундаментальных исследований не всегда сказываются на динамике роста? Одно из возможных объяснений заключается в том, что обеспечивая поддержку НИОКР, государство зачастую создает блага, которые могут привлечь лоббистов и других соискателей ренты. Предложенная в данной работе теоретическая модель показывает, что при формировании государственной политики, касающейся новых разработок, требуется известная осторожность. Борьба за ренту может сорвать работу стимулирующих механизмов и тем самым ограничить возможности роста. Объем субсидий инноваторам должен быть поставлен в зависимость от технологического развития отрасли. В частности, не всегда стоит предлагать интенсивную поддержку новым отраслям на начальных стадиях их развития. Даже если развивающаяся отрасль проявляет возрастающую отдачу от масштаба, при которой данная стратегия представляется разумной, возможность непроизводительной борьбы за ренту может существенно обесценить все выгоды от такой защиты.

Ключевые слова: борьба за ренту, экономический рост

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Why government efforts to stimulate education and fundamental research turns out to be unrelated to the growth dynamics in some countries? One of possible explanations is that providing support for R\&D, the government often creates rents which may activate lobbying and other forms of rent-seeking activities. The proposed theoretical model shows that some caution is needed about policies concerning R\&D promotion. The possibility of rent-seeking makes some policies infeasible and thereby limits the growth opportunities. The amount of subsidies for innovators should correspond to the stage of technological development of the industry. In particular, under certain circumstances, it is not very good to offer intensive support for new industries at initial stages of their development. Even if the infant industry exhibits increasing returns to scale, in which case such strategy looks reasonable, the possibility of counterproductive rent-seeking may substantially depreciate the gains of early protection.

Key words: rent-seeking, economic growth

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1 Introduction

It is universally recognized that long-run economic growth is driven to a great extent by technological innovations and accumulation of human capital. At the same time, there is empirical evidence[1] that government efforts to stimulate these activities are not always related to the actual level of R&D activity[2] and the growth dynamics. Of course, low efficiency of growth promotion policies may be caused by many various factors, not only from the government side (generally, research is a risky activity). Nevertheless, proper choice of industrial policy concerning R&D is a necessary condition for successful stimulation of growth.

To what extent should the government try to influence private firms in their propensity to invest in research and development? As in the case of a more general question concerning the extent of any government intervention in the economic process, there are various opinions and arguments about this issue.

Advocates of intensive government regulation would notice that innovative activities usually exert externalities (spillovers): human and technological resources produced by one participant of the market positively affect the production possibilities of others through diffusion of technologies and dissemination of knowledge. Thus, social benefits of R&D are only partly taken into account by private agents. Appropriate government regulation might correct the incentives of producers by internalizing the spillover effect and thereby enhance growth.

Apart from the spillover effect, the government intervention may also be needed because of increasing returns in the R&D sector (see Romer, 1986). There are many various sources of increasing returns: threshold effects of human capital accumulation (Azariadis and Drazen, 1990), specific technology of innovation, start-up costs (Ciccone and Mat-

[1] For example, see Dagenais et al (1997) or Doremus et al (1995).

[2] In the current context, I mean by R&D (in a broad sense) not only developing new technologies but also training specialists, i. e., accumulating human capital. These two activities are different in their nature but similar in their impact on the performance of the economy.

suyama, 1996) or competition with established firms. In any case, increasing returns may generate an underdevelopment trap: firms with low initial level of technology and human capital do not exhibit sufficient incentives to invest in increasing their level and the corresponding industry stagnates or declines. The government could bring the economy out of the trap (or lower the risk of getting there) by offering intensive support or protection to new firms during their startup period until they can successfully compete with their rivals. Such motivation of the industrial policy is usually referred to as the *infant industry argument*.

Another market failure associated with R&D (important but not reflected in the present paper) is the monopoly power of the innovator. According to the Shumpeterian approach to endogenous economic growth (see the monograph by Aghion and Howitt (1998) for reference), after having invented a new technology, its author occupies a monopoly position for some time. The expected monopoly profits form the incentive to innovate but the unwillingness of the monopolist firm to spread its know-how among its rivals may slow down the development process. In this case, some government intervention is beneficial for the economy. Prudnichenko (2002) considers the issue of stimulating technology diffusion and shows that the government should compensate the innovator and open the free access to the new technology so as to make the industry competitive.

Thus, the process of innovation is accompanied with various market failures which need to be corrected by appropriate government intervention. On the other hand, there are serious arguments against too active intervention; these arguments refer to government failures. One of serious problems is rent-seeking. The government cannot keep full control over all its funds directed to the R&D sector because it is much less knowledgeable about the actual aims and costs of training and innovation projects than their managers are. The informational asymmetry results in rents which may become a tempted target for lobbyists and other rent-seekers. Thus, the government intervention may enhance not only growth-oriented innovative process but also influence activities. The incentives of producers become biased: carrying out R&D projects, they care not so much about efficiency as about their *signal* of high returns and need for support observed by the subsidizer.

There are many examples of such kind of influence activities: PR campaigns, lobbying, cheating and poor performance in R&D projects, carrying out unneeded projects and so on. In each case, the main objective of a rent-seeker is to convince those who provides the support that his project is very useful and important despite that it is very costly (he may choose a technology which is far from being optimal if it yields easy-to-show results).

It is not a new idea that rent-seeking activities are harmful for economic growth. Murphy et al (1993) showed that poor protection of property rights may lead the economy to a trap equilibrium with low growth and high level of redistributive activities. Ehrlich and Lui (1999) obtained a similar result for the case of bureaucratic corruption. However, unlike both papers, in the situation described above, the rent is created along with growth-promoting efforts, so it is not obvious, whether the total effect is negative or positive.

Incentives of producers to innovate and to appropriate rents may be to some extent in line with each other but they become opposite as far as much resources are engaged in rent-seeking activity. The beneficial impact of subsidization of R&D is usually postponed for the future and spilled over many economic agents, so R&D is likely to exhibit *decreasing returns* from the private point of view. On the contrary, the induced rents are contested and appropriated immediately and seeking for a big rent may require not very high expenditures. Therefore, high subsidies along with low productivity of R&D can make rent-seeking activity very attractive. Under such circumstances, intensive growth-intended efforts of the government may not only fail to enhance research and development but even oppress them. In particular, the underdevelopment trap will get wider and the economy may get into it[3]. That is why this form of rent-seeking (seeking for subsidies) is especially harmful for economic growth. Although, lobbying may yield an additional source of information for the government, so it can be useful to some extent.

How real is the possibility of such inefficient outcome? Let us look at one example.

[3]Ehrlich and Lui (1999) draw the same conclusion for the case where the government intervention is not growth-affecting; in the present paper, a stronger result is obtained.

Doremus et al (1995) carried out an empirical investigation concerning the effectiveness of Research and Experimentation (R&E) tax credits which were enacted by US Congress in 1981. According to their estimations, for every dollar lost in tax revenue, the R&E tax credit produces a dollar increase in *reported* R&D spending, which seems to be a good result. However, they notice that this 1 : 1 sensitivity is considerably higher than the estimated overall sensitivity of R&D to changes in general costs (0.3–0.5 : 1). Such discrepancy may be thought of as a reflection of the existing gap between the reported (nominal) and the actual (effective) level of R&D or between purposely working off the credit and the efficient way of making innovations. Apart from that, surveys show[4] that privileges for innovators typically do not affect very much the propensity to innovate: many respondents said that they would carry out their R&D even if there were no government support. So, the efficiency of such growth promotion policy is questionable.

The above two arguments seem to impose contradictory requirements on possible actions of the government. The task of the policymaker is to design a policy adopting both arguments, i. e. suggest such growth promotion strategy that would not generate strong incentives to invest in earning subsidies rather than in R&D. In other words, subsidies and grants should be given to proper firms or organizations and spent on proper aims. This condition may significantly restrict the set of feasible policies and limit the opportunities of growth.

The paper is organized as follows. In section 2, the basic model of endogenous growth (without rent-seeking) is introduced. Section 3 shows how seeking for subsidies can affect the outcomes of growth promotion policies. In section 4, the optimal strategy of subsidization in the presence of rent-seeking is suggested. In section 5, the two-sector version of the model is considered and issues concerning rent-seeking versus infant industry argument are discussed. Finally, in section 6, concluding remarks are given.

[4]See Dagenais et al (1997) on analogous tax credits in Canada

2 Basic Model of Endogenous Growth

To analyze the issues reviewed above, I set up a model of rent-seeking behavior in the R&D sector. It is based on a model of endogenous growth which can be thought of as a simplification of one used by Azariasis and Drazen (1990). I am not going to represent in detail the process of innovation as Aghion and Tirole (1994) did: the model must be simple enough in order for rent-seeking effects to be incorporated. This basic model is introduced in the present section.

The economy consists of a large number of competitive firms (there are so many firms that the manager of each firm neglects the impact of his decision on the rest of the economy). Each firm lives for a single period and takes over a single short-term project. For the sake of simplicity, neither long-term projects, nor long-living firms are taken into consideration. In the beginning of the period, the firm inherits human and technological resources which have been developed in the economy up to that date. The period of existence of the firm consists of two stages[5]. At the first stage, the investment in R&D is made and at the second stage, the harvest of this investment is reaped. Then the period is over and the firm closes. It leaves its specialists and technologies for firms created in the subsequent period and the cycle is repeated. Thus, the spillover effect takes place just because the firm does not care about the level of human capital and technology that it leaves for inheritor firms. Such interpretation may look somewhat primitive but it is sufficient for the purposes of the present paper; other forms of the spillover effect are not likely to change the qualitative results.

Now let me describe the behavior of firms in more detail. As it has been already said, when a firm is created, it inherits the technological and human potential of the economy (this transfer may be sector-special) which determines its initial productivity. There is

[5]All considerations could be conducted in the framework of the overlapping generations model as in the paper by Azariasis and Drazen (1990). However, in the present paper, it seems to be only a complication, not bringing about any additional interesting insights. So, the periods of lives of the firms do not overlap here, they either coincide, or are disjunct.

also tradable input (labor, managerial skills and other non-durable resources) which can be employed by the firm[6]. Output produced by the firm is $xf(z)$, where x is the current productivity, z is the amount of input engaged in production and f is the production function which is assumed to satisfy the Inada conditions: f is increasing and strictly concave and the following equalities hold: $f(0) = 0$, $f'(0) = \infty$, $f'(\infty) = 0$. Output is sold in the global market, and the monetary units in model are chosen so, that its price is equal to 1.

At the first stage of the period, the manager of the firm can buy input in the market to use it for two activities: current production (z) and R&D activity (e) which increases the productivity from the initial level x to the second-stage level $\tilde{x}$. Namely, if e units of input have been used in R&D, then $\tilde{x} = xg(e)$, were g is an increasing strictly concave function such that $g(e)f(z)$ is concave in (e, z) and $g(0) = 1$ (provided that there is no depreciation of human and technological capital between the two stages; otherwise, $g(0) < 1$ would hold). At the second stage, input is employed for production only and the output is $\tilde{x}f(\tilde{z})$.

Suppose that w and $\tilde{w}$ are, respectively, the market prices of input at the first and the second stage. Assume also that R&D brings about no additional costs (only the opportunity cost of not engaging input in production is present) and there is no government regulation. Then the total profit of the firm is given by

$$\Pi = x\Big(f(z) + g(e)f(\tilde{z})\Big) - w(z + e) - \tilde{w}\tilde{z}, \tag{1}$$

where z and $\tilde{z}$ are the amounts of input engaged in production, respectively, at the first and the second stages

$$\begin{aligned} &w/x = f'(z); \\ &w/x = g'(e)f(\tilde{z}), \quad \text{if } e > 0; \\ &w/x \geq g'(0)f(\tilde{z}), \quad \text{if } e = 0; \\ &\tilde{w}/x = g(e)f'(\tilde{z}). \end{aligned} \tag{2}$$

[6]For the sake of simplicity, I do not consider the physical capital market in this model.

From now on, assume that the economy consists of just one sector in which firms are identical[7] and that the supply of input is absolutely inelastic. Without loss of generality, I chose the units of input and output so that the average amount of input in the economy is 1 and $f(1) = 1$. The equilibrium level of R&D activity $\underline{e}$ in the unregulated economy is then given by

$$\underline{e} = \begin{cases} \text{the solution to } f'(1-e) = g'(e), & \text{if } f'(1) < g'(0); \\ 0, & \text{otherwise.} \end{cases} \tag{3}$$

The amount of input engaged in production at each stage is, respectively, $z = 1 - e$ and $\tilde{z} = 1$.

Let us look at the growth dynamics of the unregulated economy. When some firms are closed and other are created, the human and technological resources accumulated by the former firms can be inherited by the new ones. However, losses are inevitable here: skills and technologies used in one project cannot be freely adapted to another. Technology obsolescence and human capital depreciation are sources of additional losses. Thereby, I assume that each new firm is initially endowed with share $\delta \in [0, 1]$ of the average productivity accumulated in the economy by the end of the previous period. Thus the next period productivity x_{+1} is given by

$$x_{+1} = \delta x g(e), \tag{4}$$

where x is the current productivity. The productivity remains the same after one period, if $e = e^*$, where $e^* = g^{-1}(1/\delta)$. If $e < e^*$, then the productivity falls and if $e > e^*$, then it rises during the period.

Thus, as follows from (3) and (4), the unregulated economy will grow, if $\underline{e} > e^*$ and fall, if $\underline{e} < e^*$. The growth factor[8] is equal to $\underline{\gamma} = \delta g(\underline{e})$. This $\underline{\gamma}$ may be thought of as a natural growth factor of the economy.

[7] In section 5, a model with two sectors will be studied.

[8] For the sake of convenience, I use here the growth factor instead of the growth rate which is less by unity.

Now I am going to introduce the government intervention. As it has been already noted, when investing in R&D, a firm exerts an externality because it (slightly) increases the productivity of the inheritor firms, though does not appropriate their profits. Thus, a market failure takes place, so the government regulation might be socially desirable. One of natural ways to internalize the externality is to introduce R&D subsidies. Here I do not specify how this item of the government expenditures is financed; the discussion of this issue is postponed for section 4. So far, let us just assume that the government gives firms subsidies for free.

Let S be the amount of subsidy received by the firm. In order for subsidies to be growth-stimulating, it is necessary to make S depending on innovation activity. From the viewpoint of the firm, the most general non-linear subsidizing scheme can be given by any non-decreasing function $S = S(e)$. To compare various schemes, let us consider some parametric family of functions $\{S_\theta(\cdot) \mid \theta \in [0, \theta_{\max}]\}$, such that $S_\theta(e) - S_{\theta'}(e)$ is non-decreasing in e for $\theta > \theta'$; θ corresponds to the higher extent of government intervention in the economy than θ' does.

Consider some examples subsidizing schemes:

1. **Compensation of some fraction of costs:** $S(e) = \sigma we$, where $\sigma \in [0, 1)$. Thus, the firm has to cover only some part of its R&D expenditures.

2. **Subsidies per unit of input:** $S(e) = se$, i. e. the price of input engaged in R&D is discounted by s comparing to the market level.

3. **Proportional scheme of distribution:** the government sets the average (or, equivalently, total) amount of subsidies S which is then distributed among firms proportionally to their spendings on R&D: $S_i = \dfrac{e_i}{e} S$, where i is the firm's name, e the average of e_i over all i. Thus, firms are involved in a game. The Nash equilibrium of this game is unique and such that all e_i are the same and $S_i = S$. Note that such a scheme is widely used iv various models of rent-seeking behavior[9]

[9]Generally, distribution schemes are not necessarily proportional. Arbitrary distribution schemes in

4. **Threshold subsidy:** the firm earns fixed amount S, if its level of R&D activity e exceeds or is equal to some threshold value d.

The first three ways of subsidization result in linear correspondence between e and S. Clearly, they are equivalent to each other if $\sigma we = se = S$. Thus, the linear subsidy can be determined by setting any of σ, s or S.

The level of R&D activity e_0 (subscript 0 means that there is no rent-seeking so far) under the subsidization scheme $S(\cdot)$ can be found as the solution to

$$xg(e) + S(e) - we \to \max_e . \tag{5}$$

If S is differentiable around e_0 and $e_0 > 0$, then the following first-order condition must hold in equilibrium:

$$f'(1 - e_0) = g'(e_0) + \frac{S'(e_0)}{x}. \tag{6}$$

If $S = S_\theta$, then, as follows from (6), $e_0(\theta)$ is an increasing function of θ, the intensity of government intervention (x being constant).

In particular, under linear subsidy which compensates fraction σ of R&D costs, the equilibrium value of e is given by

$$e = e_0(\sigma) = \begin{cases} \text{the solution to } f'(1-e) = \dfrac{g'(e)}{1-\sigma}, & \text{if } f'(1) < \dfrac{g'(0)}{1-\sigma}; \\ 0, & \text{otherwise} \end{cases} \tag{7}$$

It is easy to see that $e_0(0) = \underline{e}$ and $e_0(\sigma)$ is increasing in σ. In particular, when the proportional distribution scheme is used (see example 3) and S, the average amount of subsidies, is fixed at some level, the impact of subsidies on R&D gets weaker as the productivity gets higher.

Note that in the framework described above (under no threat of rent-seeking and free government funds), the government can reach any possible $e \in (\underline{e}, 1)$ as the equilibrium

the rent-seeking context were studied and modeled by the author (see Tonis 1998).

level of R&D activity under a proper subsidizing scheme. As will be seen from the subsequent sections, this will not always be the case if firms can struggle for subsidies.

3 Lobbying R&D Subsidies in One-Sector Model

Now I am going to incorporate rent-seeking into the basic model presented above[10]. This section is aimed to show that too intensive efforts to stimulate innovations at early stages of development may be harmful for economic growth.

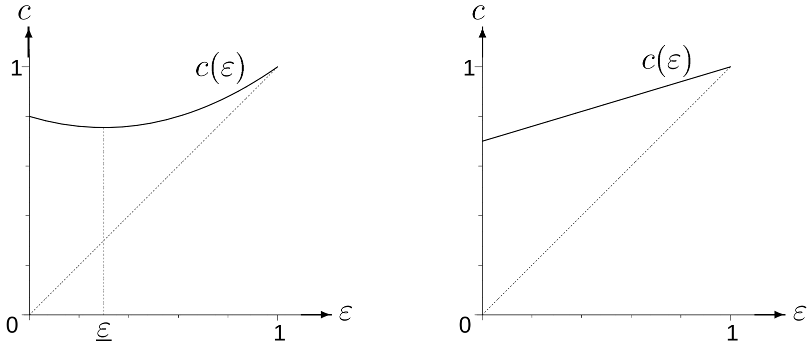
Suppose that along with R&D, producers can be engaged in a special activity which helps them receive government subsidies. Technically, the manager of a firm is able to convince the government (using PR, lobbying, cheating etc) that he needs the subsidy for d units of input whereas actually he is going to invest in R&D $e = \varepsilon d$ units, where $\varepsilon \in [0, 1]$ is the "honesty rate". Of course, this influence activity is costly: the manager has to spend some resources on the above-mentioned actions; the fear of punishment for misrepresenting the actual R&D efforts should also be mentioned among the costs of rent-seeking. Here I assume that in order to invest $e = \varepsilon d$ in R&D and declare d to the government (and thereby get the subsidy for level of activity d), the manager needs $C(e, d) = dc(\varepsilon)$ actual units of input. Function $c(\varepsilon)$ determines the technology of rent-seeking (actually, $(c(\varepsilon) - \varepsilon)d$ is the net cost function of rent-seeking); it is assumed to be convex and such that $\varepsilon \leq c(\varepsilon) \leq 1$ (in particular, $c(1) = 1$)[11].

Thus, the rent-seeking technology exhibits constant returns to scale, i. e. if both the declared and the actual investment in R&D are, say, doubled, the required amount of input is doubled too[12]. Function $c(\cdot)$ represents the lobbying strength of firms.

[10] In my previous paper (Tonis, 2002), I considered seeking for subsidies and privileges within the framework of static oligopoly. The present work may be thought of as an extension of some of those results to the endogenous growth environment.

[11] Alternatively, the technology of rent-seeking can be determined by gross cost function $C(e, d)$, which is defined for all (e, d) such that $e \leq d$. Function $C(e, d)$ must be non-negative, convex, homogeneous of degree 1 and such that $e \leq C(e, d) \leq d$.

[12] If rent-seeking yields decreasing returns, the results may substantially differ from what is obtained



a) Soft rent-seeking b) Hard rent-seeking

Figure 1. Per-unit cost function of rent-seeking $c(\varepsilon)$.

Let us denote

$$\underline{\varepsilon} = \arg \min_{\varepsilon \in [0,1]} c(\varepsilon)$$

(if there are many values of ε yielding minimum to $c(\varepsilon)$, then $\underline{\varepsilon}$ is taken to be the highest of them). Obviously, values $\varepsilon < \underline{\varepsilon}$ cannot be realized in equilibrium because raising ε would both lower the cost and increase the second-stage productivity. Thus, the reasonable interval for ε is $[\underline{\varepsilon}, 1]$; $\varepsilon = \underline{\varepsilon}$ is associated with the maximal level of influential activity and $\varepsilon = 1$ corresponds to the case of no rent-seeking.

The graph of per-unit cost function $c(\varepsilon)$ may have various shape (see Figure 1). Its slope may be rapidly decreasing, as ε falls, in which case $\underline{\varepsilon}$ is likely to be high, as in Figure 1a. It turns out that in this case, rent-seeking is to a great extent accompanied by the productive use of the subsidy: e must always constitute a substantial percentage of d. In other words, rent-seeking and R&D turn out to be strategic complements (at least, for high ε), so rent-seeking may be admissible (though, not desirable) in this case[13]. This case will be referred to as *soft* rent-seeking. On the contrary, let us say that *hard* or *counterproductive* rent-seeking is present if d and e are negatively dependent whenever $e < d$. This situation is typical for slowly changing $c'(\varepsilon)$ and low $\underline{\varepsilon}$. Hard rent-seeking is a

in this paper. In particular, high subsidies not necessarily lead to the leakage of resources from R&D to rent-seeking.

[13]There is another interpretation of such shape of cost function: lobbies provide the government with not very distorted information about their incentives.

strategic substitute to R&D (and any productive activity at all) and must be minimized by a benevolent government. The most counterproductive rent-seeking technology is linear in ε (see Figure 1b).

If everything else is the same as in section 2, then the profit of the representative firm can be written as

$$\Pi = x\Big(f(z) + g(e)f(\tilde{z})\Big) - w\Big(z + c(\varepsilon)d\Big) - \tilde{w}\tilde{z} + S(d), \tag{8}$$

and the balance condition in the input market takes the form:

$$z + dc(\varepsilon) = 1. \tag{9}$$

Thus, the amount of subsidy is determined based on d rather than e ($d = e$ under no rent-seeking). Note that if the support of R&D is carried out by compensating some fraction σ of the declared expenditures, then all subsidies cannot be paid in the case of too large σ. Indeed, if there were $\sigma \geq \underline{c} = c(\underline{\varepsilon})$, then producers could earn arbitrarily high profits by choosing $\varepsilon = \underline{\varepsilon}$ and very large d, i. e. they would exhibit infinite demand for subsidies. Thus, the set of feasible σ is restricted by $\sigma < \underline{c}$.

Now let us study the equilibrium behavior of a firm which can be involved in seeking for subsidies. The following proposition shows how the equilibrium of the symmetric model depends on the intensity of government intervention (represented by θ).

Proposition 1 *The equilibrium in the one-sector model with identical firms always exists, is unique and has the following properties:*

1. *For relatively low level of subsidy θ, there is no rent-seeking in equilibrium ($\varepsilon(\theta) = 1$); for higher θ, there is some rent-seeking; the higher θ, the lower the honesty rate $\varepsilon(\theta)$.*

2. *The declared level of investment in R&D $d(\theta)$ is increasing in θ.*

3. *The actual level of investment in R&D is non-monotone in θ: if the subsidy is too high, its impact on e is negative (see Figure 2).*

Proof Suppose that function $S(\cdot) = S_\theta(\cdot)$ is differentiable in some neighborhood of the equilibrium value of e (actually, this assumption brings about no loss of generality). Suppose also that that there is some rent-seeking in equilibrium, i. e. $\varepsilon < 1$ (the opposite case was considered in the previous section, with the equilibrium conditions given by (7)). Then the equilibrium values of the variables $\varepsilon = \varepsilon_R(\theta)$ and $d = d_R(\theta)$ are determined by the following system of two equations:

$$f'(1 - dc(\varepsilon))c'(\varepsilon) = g'(\varepsilon d); \tag{10}$$

$$S'_\theta(d) = xf'(1 - dc(\varepsilon))\Big(c(\varepsilon) - \varepsilon c'(\varepsilon)\Big); \tag{11}$$

Equation (10) determines the relationship between ε and d in equilibrium. This equation does not depend on the subsidizing scheme, so it can be applied to any way of promoting R&D. Therefore, ε is a function of d in the case of interior equilibrium: $\varepsilon = \varepsilon(d)$; it is easy to show that $\varepsilon(d)$ is decreasing in d. The second equation (11) determines the correspondence between θ and d (provided that $\varepsilon = \varepsilon(d)$); due to our assumptions, $d = d_R(\theta)$ is increasing in θ.

Let us start with the existence and uniqueness. Suppose that $f'(1)c'(1) > g'(0)$. Then there is $\breve{\varepsilon} \in (\underline{\varepsilon}, 1)$ such that $f'(1)c'(\breve{\varepsilon}) = g'(0)$. Let us consider $\breve{\theta} = d_R^{-1}(\varepsilon^{-1}(\breve{\varepsilon}))$. If $\theta \leq \breve{\theta}$, then there is neither rent-seeking, nor innovation in equilibrium; for $\theta > \breve{\theta}$, the equilibrium is interior ($\varepsilon > 0$, $d > 0$) and is described by (10)–(11).

If, on the contrary, $f'(1)c'(1) \leq g'(0)$, then the threshold level of θ is given by $\breve{\theta} = d_R^{-1}(\breve{d})$, where $\breve{d}$ is the solution to the equation $f'(1 - \breve{d})c'(1) = g'(\breve{d})$ (it exists and is unique; it is natural to put $\varepsilon(d) = 1$ for $d < \breve{d}$). If $\theta \leq \breve{\theta}$, then there is no rent-seeking and the equilibrium is given by (6); otherwise, it is determined by (10)–(11).

The complete characterization of equilibrium $(\varepsilon(\theta), d(\theta))$ is given by

$$\begin{aligned} \varepsilon(\theta) &= \begin{cases} 1, & \text{if } \theta \leq \breve{\theta}; \\ \varepsilon_R(\theta) & \text{otherwise;} \end{cases} \\ d(\theta) &= \begin{cases} e_0(\theta), & \text{if } \theta \leq \breve{\theta}; \\ d_R(\theta) & \text{otherwise.} \end{cases} \end{aligned} \tag{12}$$

Thus, in any case, the equilibrium exists, is unique and is interior for $\theta > \breve{\theta}$. In the latter case, $d(\theta)$ is always increasing in θ, so the subsidizing schemes could be parameterized by d instead of θ. Since $\varepsilon(d)$ is decreasing in d, then $\varepsilon(\theta)$ is decreasing in θ for $\theta > \breve{\theta}$. Since $e(\theta) = \varepsilon(\theta)d(\theta)$ is the product of decreasing and increasing function, $e(\theta)$ can be non-monotone in θ. In the case of interior equilibrium, the first derivative of e in θ is given by

$$\frac{de}{d\theta} = \frac{dc'(\varepsilon)f''(z)\big(c(\varepsilon) - \varepsilon c'(\varepsilon)\big) + \varepsilon f'(z)c''(\varepsilon)}{Q}, \tag{13}$$

where Q is some positive function.

If $\theta \leq \breve{\theta}$, then $e(\theta)$ coincides with $d(\theta)$ and thus is increasing in θ. On the other hand, if θ is so high that $\varepsilon(\theta)$ approaches to $\underline{\varepsilon}$, then $c'(\varepsilon)$ and $1/f'(z)$ are small, so

$$c'(\varepsilon)f'(z) \to g'(\underline{\varepsilon}/\underline{c}) \text{ for } \varepsilon \to \underline{\varepsilon}. \tag{14}$$

Therefore, when $\varepsilon \to \underline{\varepsilon}$, $z \to 0$ and

$$f''(z)c'(\varepsilon) \sim g'(\underline{\varepsilon}/\underline{c})\frac{f''(z)}{f'(z)} = g'(\underline{\varepsilon}/\underline{c})\frac{d}{dz}(\ln f'(z)) \to -\infty. \tag{15}$$

Hence, the right-hand side of (13) is negative for high θ, i. e. $e(\theta)$ is decreasing in θ. Thereby, the non-monotonicity of $e(\theta)$ is proved. $\square$

Proposition 1 shows that the government faces a tradeoff when choosing its subsidization strategy: high subsidies are expected to promote growth but they also enhance the rent-seeking behavior. An important result is that for high subsidies, the second effect

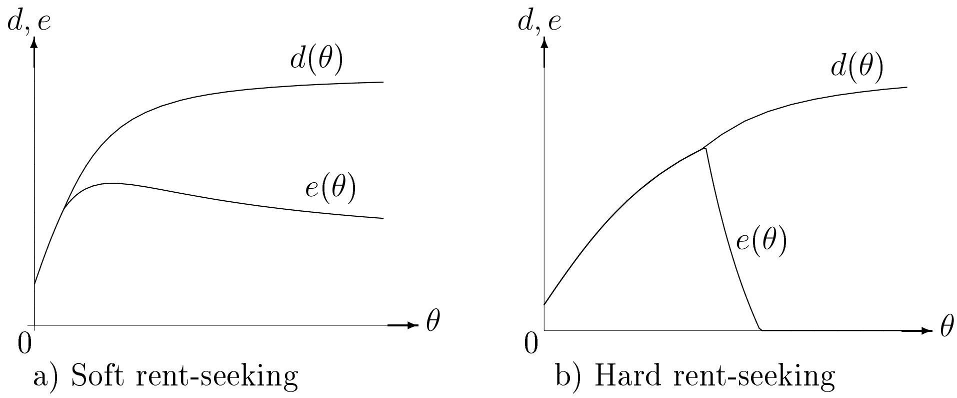


Figure 2. Declared and actual investment in R&D under various subsidies.

overweigh the first one and the total effect is opposite to what was intended. Therefore, rent-seeking restricts the speed of growth that can be reached by subsidies: the maximal feasible growth factor $\bar{\gamma}$ corresponds to the maximal level of investment in R&D $\bar{e} = \bar{\varepsilon}\bar{d}$, which can be determined by solving for (ε, d) the following system of two equations[14]:

$$f'(1-d)c'(\varepsilon) = g'(\varepsilon d); \tag{16}$$

$$\varepsilon f'(z)c''(\varepsilon) = -dc'(\varepsilon)f''(z)\Big(c(\varepsilon) - \varepsilon c'(\varepsilon)\Big). \tag{17}$$

If system (16)–(17) has no solution with $\varepsilon < 1$, then the maximal level of e is realized under no rent-seeking. In particular, this is so in the case of extremely hard rent-seeking where the cost function is linear: indeed, if $c''(\varepsilon) = 0$, then the right-hand side of (17) always overweighs the left-hand side. Thus, $\varepsilon < 1$ necessarily implies that $\frac{de}{d\theta} < 0$ in this case (see Figure 2b). This is just the above-announced strategic substitution effect between rent-seeking and R&D.

In the special case of linear subsidies, the relationship between the share of compensated costs σ and equilibrium values of ε and d (see (11)) takes a very simple form:

$$\sigma = \begin{cases} c(\varepsilon) - \varepsilon c'(\varepsilon), & \text{if } \underline{\varepsilon} < \varepsilon < 1; \\ 1 - \dfrac{g'(d)}{f'(1-dc(\varepsilon))}, & \text{if } \varepsilon = 1 \end{cases} \tag{18}$$

[14]Without additional assumptions concerning the third derivatives, the uniqueness of the solution to (16)–(17) cannot be guaranteed.

As in the general setting, σ is non-increasing in ε and increasing in d. As σ goes from 0 to $\underline{c}$, pair (ε, d) takes all possible values that can be realized by any (generally, non-linear) subsidization scheme. Thus, linear subsidies constitute a complete set of policy instruments in the symmetric model.

Another corollary from proposition 1 concerns the dependence of rent-seeking activity on the level of technological development. The influence activity is more attractive under lack of production opportunities. This effect is crucial for the growth dynamics:

Proposition 2 *Under a fixed (independent of the current stage of technological development) subsidizing scheme $S(\cdot)$, rent-seeking may lead to an underdevelopment trap: more developed economies experience steady growth (or, at least, maintain their level of productivity), whereas less developed ones plunge into recession. Increasing the subsidy benefits those economies which are anyway in a good position but, at the same time, widens the zone of attraction of the trap.*

Proof Suppose that $\underline{\varepsilon} < e^* < \bar{e}$. Let d^* be the lowest solution to the equation $d\,\varepsilon(d) = e^*$ (at least, one solution does exist), $\varepsilon^* = \varepsilon(d^*)$ and

$$x^* = \frac{S'(d^*)}{f'(1 - d^*c(\varepsilon^*))(c(\varepsilon^*) - \varepsilon^* c'(\varepsilon^*))}.$$

If $x < x^*$, then $x_{+1} < x < x^*$ and it is clear that having started from a low level of development (lower than x^*), the economy will proceed along a declining trajectory (at least, until the government policy changes). On the other hand, if x is slightly higher than x^*, so that $e > e^*$, then the economy will grow for some time. If $\underline{e} > e^*$, then this growth will be permanent. Otherwise, there is a stable stationary level of development $x^{*}*$ to which the trajectory will converge. In any case, the economy will not get to the zone of trap where $x < x^*$. The evolution of the economy over time $x(t)$ depending on the initial level of development $x(0)$ is depicted in Figure 3.

If $\bar{e} < e^*$, then the declining evolution starts from any initial state. Rent-seeking completely prevents the subsidy from working properly and the size of the trap is infinite

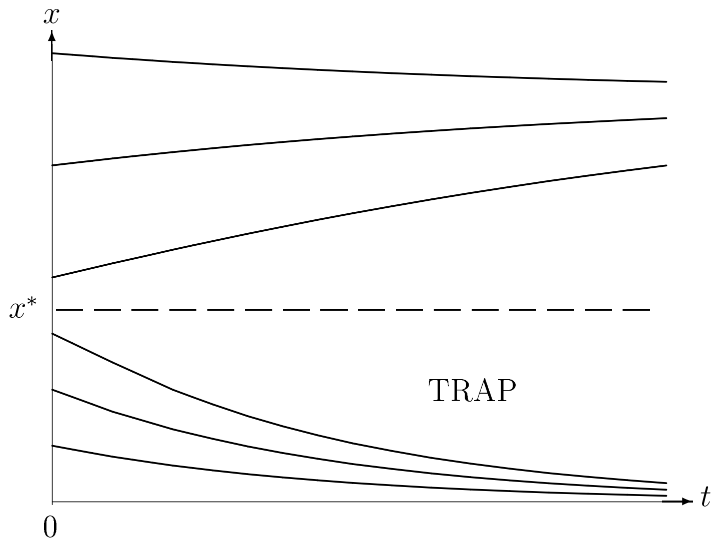


Figure 3. Evolution of the economy under fixed $S(\cdot)$.

in this case.

If θ increases, then both x^* and x^{**} rise too (see Figure 4). Thus, the high-development equilibrium gets even higher but the zone of attraction of the bad equilibrium becomes wider. $\square$

Note. Proposition 2 is actually applicable not only for the case of fixed $S(\cdot)$ but also for any subsidization strategy with the negative dependence between x and $\dfrac{S(e)}{x}$ (for example, this is the case when the total amount of subsidies is fixed and allocated according to the proportional distribution scheme). Note that using such kind of strategies is suggested by the infant industry argument. Proposition 2 says that following this policy can be dangerous in the presence of rent-seeking.

The reason why the trap occurs is very clear: from the firm's point of view, the innovative activity exhibits decreasing returns to scale whereas seeking for subsidies exhibits constant returns to scale. Hence, under decreasing $\dfrac{S(e)}{x}$, the latter activity is more preferable for agents in less developed economies which results in their higher propensity to redistribute rents and lower investment in productivity.

Note that fixed share of compensated cost σ does not create a trap if σ is properly

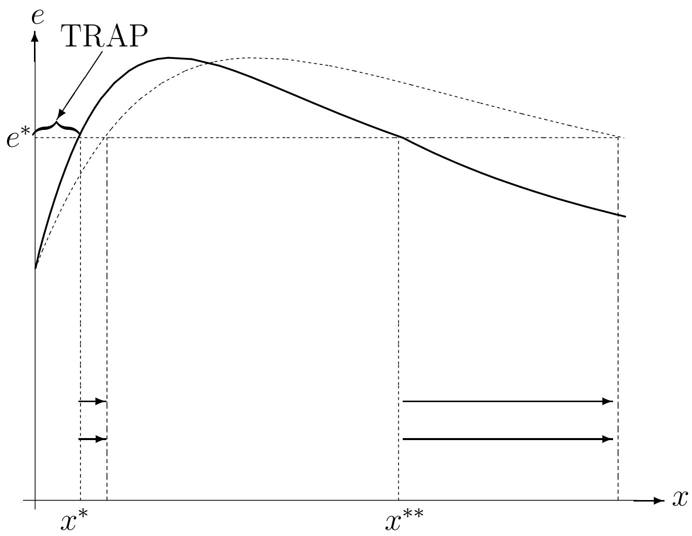


Figure 4. R&D activity as a function of x: the effect of raising subsidy.

chosen. The reason is that the actual level of subsidy is conditioned on the stage of development in this case because it is proportional to the market price of input.

Example. Let $f(z) = \sqrt{z}$, $g(e) = \sqrt{1+\alpha e}$ and the government compensates fraction σ of R&D costs. Then, according to (7), $e_0(\sigma)$ is given by

$$\max\left(\frac{\alpha^2 - (1-\sigma)^2}{\alpha\left(\alpha + (1-\sigma)^2\right)}, 0\right)$$

In particular, $e_0(0) = \max(1 - 1/\alpha, 0)$. Thus, under no government intervention, the level of R&D activity is positive, if $\alpha > 1$. The steady-state level of e is $e^* = \dfrac{1/\delta^2 - 1}{\alpha}$; the natural growth factor is $\underline{\gamma} = \delta\sqrt{\alpha}$, i. e., the economy is predisposed to growth, if $\alpha\delta^2 \geq 1$.

Now suppose that rent-seeking is possible and its per-unit cost function is $c(\varepsilon)$. Then the equilibrium is given by

$$d = \begin{cases} e_0(\sigma), & \text{if } \sigma \leq 1 - c'(1); \\ \dfrac{\alpha^2 - c'(\varepsilon)^2}{\alpha\left(\varepsilon c'(\varepsilon)^2 + \alpha c(\varepsilon)\right)}, & \text{if } \sigma > 1 - c'(1), \end{cases} \tag{19}$$

where ε is a function of σ determined by (18). As follows from (19), there is negative dependence between ε and d. Let us parameterize the interior equilibrium by ε. Then the level of R&D activity e is $e(\varepsilon) = \varepsilon d(\varepsilon)$, where $d(\varepsilon)$ is given by (19). If $c''(\varepsilon)$ does not decrease too fast, then $e(\varepsilon)$ is increasing in ε over $\varepsilon \in [\underline{\varepsilon}, 1]$ if and only if the following inequality holds:

$$(1 - c'(1))(\alpha^2 - c'(1)^2) \geq 2(1 + \alpha)c'(1)c''(1). \tag{20}$$

Thus, rent-seeking is counterproductive under high α (i. e. under high returns to innovative activities) or low $c'(1)$ (when rent dissipation is too severe), or too slowly increasing $c'(\varepsilon)$. Otherwise, low subsidies positively affect the growth dynamics, in spite of influence activities, so this is the case of soft rent-seeking.

4 Optimal Subsidization Policy

In the previous section, the behavior of firms was studied under a given subsidization strategy. Now I am going to discuss the issue of choosing the optimal strategy. Here the government is assumed to be benevolent (which might be to stretch a point). Of course, the choice of the government depends on its optimality criterion and budget constraint.

Let us forget for a while about the budget constraint and suppose that the government is free to spend any amount of money if needed. The most natural long-run criterion for the model presented above is the present discounted value of GDP:

$$\sum_{t=0}^{\infty} \rho^t y(x_t, z_t, e_t), \tag{21}$$

where x_t is the productivity at the beginning of period t, z_t and e_t are the amounts of input engaged, respectively, in production and R&D in period t, $\rho \in [0, 1]$ is the discount factor and $y(x, z, e)$ is the output function:

$$y(x, z, e) = x(f(z) + g(e)). \tag{22}$$

Of course, x_t, z_t and e_t are not independent variables, they are subject to the equilibrium conditions discussed in the previous section.

Let us derive the optimality conditions using the Bellman's approach. According to this approach, function $V(x)$, the maximal value of (21) as a function of the initial level of development $x = x_0$, satisfies the Bellman equation:

$$V(x) = \max_{\sigma}\Big(y(x, z, e) + \rho V(\delta x g(e))\Big). \tag{23}$$

It is natural to assume that the value function $V(x)$ in (23) is linear: $V(x) = Ax$. Then the policy optimization problem can be reduced to the following simple form:

$$f(1 - dc(\varepsilon(d))) + Bg(\varepsilon(d)d) \to \max_{d}, \tag{24}$$

where $d \in [\underline{e},\ 1/\underline{c}]$, $B = 1 + \rho\,\delta A$ and $\varepsilon(d)$ is determined by

$$\varepsilon(d) = \begin{cases} \text{the solution to } f'(1 - dc(\varepsilon))c'(\varepsilon) = g'(\varepsilon d), & \text{if } f'(1-d)c'(1) > g'(d); \\ 1 & \text{в otherwise.} \end{cases} \tag{25}$$

Note that the control variable in (24) is d rather than θ. If d is given, $\varepsilon = \varepsilon(d)$ can be found, whence the policy variable θ can be obtained using (11).

Thus, the optimal subsidization strategy must be such that d be constant over time. Let $\hat{d}$ be the optimal value of d which maximizes (24), $\hat{\varepsilon} = \varepsilon(\hat{d})$ and $\hat{e} = \hat{\varepsilon}\hat{d}$. Then (23) yields

$$V(x) = (f(\hat{z}) + Bg(\hat{e}))x = \frac{B-1}{\rho\delta}x. \tag{26}$$

Equation (26) proves the truth of the assumption about the linear form of $V(x)$ and allows to find B:

$$B = \frac{1 + \rho\delta f(\hat{z})}{1 - \rho\delta g(\hat{e})}. \tag{27}$$

If $\rho\delta g(\hat{e}) \geq 1$, then the series in (21) diverges, i. e. B is infinite. This implies that if $\rho\delta g(\bar{e}) \geq 1$ (where $\bar{e}$ is determined by (16)–(17)), then the optimal strategy is to maximize growth, i. e. such that $\hat{e} = \bar{e}$. Otherwise, B is finite and can be determined by (27).

If there is no rent-seeking in optimum (i. e., $\hat{d} \leq \breve{d}$, where $\breve{d}$ is the solution to $f'(1-d)c'(1) = g'(d)$), then the only real difference between the objective function of the government and an unsubsidized firm is in B: the government counts the effect of the innovative activity with a higher weight than the firm does. The optimality condition determining $\hat{d}$ in this case takes the form[15]

$$f'(1-d) = Bg'(d) \tag{28}$$

and the optimal subsidy $\hat{\sigma}$ is

$$\hat{\sigma} = (B-1)g'(\hat{d}). \tag{29}$$

A different situation occurs if some rent-seeking is allowed in optimum ($\hat{d} > \breve{d}$). Then the government's ability to fight a market failure (the spillover effect captured by B) is restricted by a government failure (rent-seeking which results in rent dissipation). Now $\hat{d}$ can be found from the following optimality condition:

$$\Big(c(\hat{\varepsilon}) - \hat{\varepsilon}c'(\hat{\varepsilon})\Big)\Big(Bf''(\hat{z})c'(\hat{\varepsilon})^2 + g''(\hat{e})\Big)\hat{d} = f'(\hat{z})c''(\hat{\varepsilon})\Big(c(\hat{\varepsilon}) - B\hat{\varepsilon}c'(\hat{\varepsilon})\Big). \tag{30}$$

Formulas (30)–(31) are valid (there is indeed some rent-seeking in the optimum), if (30) is solvable for d. That can be the case only for large B (at least, for $B > 1/c'(1)$). Otherwise, $\hat{\varepsilon} = 0$ and formulas (28)–(29) are applicable.

As far as the optimal pair $(\hat{\varepsilon}, \hat{d})$ is known, it is easy to suggest a subsidizing scheme which implements this outcome. For example, the share of compensated costs $\hat{\sigma}$ is given by

$$\hat{\sigma} = \begin{cases} 1 - 1/B, & \text{if } d \leq \breve{d}; \\ c(\hat{\varepsilon}) - \hat{\varepsilon}c'(\hat{\varepsilon}), & \text{if } d > \breve{d}. \end{cases} \tag{31}$$

It is easy to show that the optimal compensation rate $\hat{\sigma}$ positively depends on δ and ρ and rises from 0 to $\bar{\sigma}$ as $\rho\delta$ increases ($\bar{\sigma}$ is the growth-maximizing compensation rate, such

[15] If this equation is unsolvable, then it is suboptimal to stop the collapse of the economy: $e = 0$ is the optimal long-run level of R&D. Perhaps, the social discount factor δ is too small in this case.

that $e(\bar{\sigma}) = \bar{e}$). In particular, in the case of hard rent-seeking, $\hat{\sigma} \leq \bar{\sigma} = \breve{\sigma}$, so $\varepsilon = 1$ always holds in optimum.

The corresponding s and S (as parameters of the proportional subsidizing scheme) are, respectively, $\hat{s} = xf'(\hat{z})$ and $\hat{S} = \hat{s}\hat{d}$. As for threshold subsidies (see example 4 on page 12), the contract is the following: each firm is offered to carry out an R&D project which takes $\hat{d}$ units of input or more, and the subsidy is set equal to the difference in profits in the cases of accepted and rejected contract.

So far, it was assumed that the government faces no budget constraint and monetary transfers between the government and firms cannot affect the social welfare. The qualitative results will be basically the same if we release this assumption.

For example, suppose that there is the budget constraint, so the government must collect taxes in order to be able to give subsidies. Let per-unit sales tax τ be imposed on all firms ($\tau \in [0,1]$) and $S = \tau y$. Due to the inelastic supply of input, this tax will not be distorting, so the outcome of such policy will be exactly the same as under no budget constraint and $S = \frac{\tau y}{1-\tau}$. Note that the range of possible outcomes remains the same despite the fact that the all possible S are bounded from above by the maximal (Lafferian) tax revenue.

If it is necessary to capture the fact that monetary transfers between the government and firms are not neutral (this is the case under distorting taxation), then one can each period add the term λS ($0 \leq \lambda \leq 1$) to the government criterion (21) or, which is equivalent, add it to the left-hand side of (24) (then B will depend on λ). It is easy to show that the situation is equivalent to the case of lower ρ or δ, i. e. optimal d and e are decreasing in λ. All relationships among the variables are the same as before. Perhaps, there is the only important difference from the case of neutral transfers: now it is incorrect to treat as equivalent (with respect to welfare) all subsidizing schemes that lead to the same outcome. The most preferable form of subsidies is the threshold one.

In any case, rent-seeking may substantially restrict the government in its set of feasible strategies, so that it cannot completely internalize the spillover effect and reach the firstbest optimum (according to the chosen criterion of optimality). Only the second-best policy resulting in a slower speed of growth is implementable.

5 Two-Sector Model: Rent-Seeking and Infant Industry Argument

So far, the industrial structure of the economy has been assumed to be homogeneous. In this section, I am going to analyze a more diversified model with traditional and modern (high-technology) sectors. It is known that such structure itself may cause an underdevelopment trap. In the present model, this situation also occurs. Can the government bring the economy out of the trap by using a proper subsidization policy? It turns out that it can but, as before, only in the absence of serious rent-seeking opportunities from the producers' side. Otherwise, the government can only narrow the zone of attraction of the trap but is unable to eliminate it at all.

So, let us look at the model in its heterogeneous version. there are two sectors, A and B. Sector A is "traditional". It includes agriculture, natural resource extraction and so on. The main feature of the traditional sector is that its managers cannot affect the productivity of their firms by investment in training and innovation. On the contrary, sector B is "high-technological": the productivity of firms in this sector can be increased by investment in R&D. Specifically, the output of firms from sectors A and B is, respectively, given by

$$\begin{aligned} y_A &= x_A\Big(f_A(z_A) + f_A(\tilde{z}_A)\Big); \\ y_B &= x_B\Big(f_B(z_B) + g(e) f_B(\tilde{z}_B)\Big), \end{aligned} \tag{32}$$

where f_A and f_B are the production functions in the corresponding sectors and g is the "production function" in the R&D sector; these functions are assumed to satisfy the same assumptions as before. Analogously to the one-sector case, z_i and $\tilde{z}_i$ $(i = A, B)$ stand for the amount of input engaged in production in the corresponding sector at the corresponding stage; e is the amount of input engaged in research and development in sector B (for unification, one can think that sector A also has its function "g" which is a constant equal to 1, so there is no sense in choosing positive e in this sector). Given w and $\tilde{w}$, the input prices at the two stages (they are universal within the whole economy, provided the perfect mobility of input), the optimal choices of $z_A, \tilde{z}_A, z_B$ and $\tilde{z}_B$ are given by

$$\begin{aligned} &x_A f_A'(z_A) = w; \\ &x_A f_A'(\tilde{z}_A) = \tilde{w}; \\ &x_B f_B'(z_B) = w; \\ &x_B g(e) f_B'(\tilde{z}_B) = \tilde{w}. \end{aligned} \tag{33}$$

If there is no government intervention (and, thereby, no rent-seeking), then

$$\begin{aligned} &x_B g'(e) f_B(\tilde{z}_B) = w, \quad \text{if } e > 0; \\ &x_B g'(0) f_B(\tilde{z}_B) \leq w, \quad \text{if } e = 0. \end{aligned} \tag{34}$$

Thus, the equilibrium in this case is determined by

$$f_A'(z_A) = \xi f_B'(z_B); \tag{35}$$

$$f_A'(\tilde{z}_A) = \xi g(e) f_B'(\tilde{z}_B); \tag{36}$$

$$f_B'(z_B) \begin{cases} = g'(e) f_B(\tilde{z}_B), & \text{if } e > 0; \\ \geq g'(0) f_B(\tilde{z}_B), & \text{if } e = 0 \end{cases} \tag{37}$$

along with the balance conditions

$$(1-\mu) z_A + \mu (z_B + e) = 1; \tag{38}$$

$$(1-\mu)\tilde{z}_A + \mu \tilde{z}_B = 1, \tag{39}$$

where $\xi \stackrel{\text{def}}{=} x_B / x_A$ is the relative advantage in development of sector B over A and μ is the share of sector B in the whole economy, i. e. the number of high-technological firms relative to the total number of firms. As usual, the total amount of input in the economy is normalized to 1.

Now let us turn to dynamics. As before, I assume that the technological level of a firm is affected by that of its predecessors. But in the two-sector environment, this spillover is non-homogeneous: firstly, the high technology is more sensitive to obsolescence and human capital depreciation than the traditional one, and, secondly, the intersectoral spillovers are weaker than intrasectoral ones (especially, the impact of the traditional sector on the hi-tech one is not likely to be significant). Thus, the transition to the next period can be modeled as follows:

$$\begin{aligned} x_{A_{+1}} &= \delta_A x_A + \delta_{BA} g(e) x_B; \\ x_{B_{+1}} &= \delta_B g(e) x_B, \end{aligned} \tag{40}$$

where $0 < \delta_{BA} < \delta_B < \delta_A < 1$ (so, the intersectoral spillover is possible only from B to A). In relative terms, (40) can be rewritten as

$$\xi_{+1} = \frac{\delta_B}{\dfrac{\delta_A}{g(e)\xi} + \delta_{BA}}. \tag{41}$$

The shape of the graph of function $\xi_{+1}(\xi)$, especially, its location relative to the diagonal $\xi_{+1} = \xi$, is the key to studying the evolution of the economy.

Thus, the hi-tech sector can contribute to the development of the traditional one. On the other hand, the existence of the traditional sector may negatively affect the growth opportunities of the hi-tech sector, as the following proposition shows:

Proposition 3 *In the unregulated two-sector economy, the equilibrium level of innovative activity positively depends on ξ, the relative advantage in development of the hi-tech sector. As a consequence, there is an underdevelopment trap: low-developed new sector may fall into further depression.*

Proof Equation (36) along with the balance condition (39) determines $\tilde{z}_A$ and $\tilde{z}_B$ as functions of e and ξ: $\tilde{z}_A = \tilde{z}_A(e, \xi)$, $\tilde{z}_B = \tilde{z}_B(e, \xi)$. Note that $\tilde{z}_A(e, \xi)$ is decreasing and $\tilde{z}_B(e, \xi)$ is increasing in e and ξ.

Suppose that $e > 0$ in equilibrium. Then, according to (37), the following equality holds:

$$f'_B(z_B) = g'(e) f_B(\tilde{z}_B(e)). \tag{42}$$

The right-hand side of (42) is decreasing in e. Indeed, due to (36) and (39),

$$\frac{d}{de}\Big(g'(e) f_B(\tilde{z}_B(e))\Big) = \frac{\mu f''_A(\tilde{z}_A) f_B(\tilde{z}_B) g''(e) + (1-\mu)\xi \Delta(\tilde{z}_B, e)}{\mu f''_A(\tilde{z}_A) + (1-\mu)\xi f''_B(\tilde{z}_B) g(e)}, \tag{43}$$

where

$$\Delta(\tilde{z}_B, e) \stackrel{\text{def}}{=} f_B(\tilde{z}_B) g(e) f''_B(\tilde{z}_B) g''(e) - f'_B(\tilde{z}_B)^2 g'(e)^2.$$

Since $f_B(\tilde{z}_B) g(e)$ is concave in $(\tilde{z}_B, e)$, then $\Delta(\tilde{z}_B, e)$ is always non-negative, whence $\frac{d}{de}\Big(g'(e) f_B(\tilde{z}_B(e))\Big) < 0$.

As follows from the proved fact, if ξ changes so that e rises, then z_B rises too, so due to (38) z_A falls. On the other hand, (35) implies that this is possible only if ξ increases. Hence, e is increasing in ξ.

Now let us investigate function $\xi_{+1}(\xi)$. Suppose that ξ is very low (close to zero). Then $f'_B(z_B)$ is high and $f_B(\tilde{z}_B)$ is low, so, due to (37), $e = 0$ (this will be the case for $\xi \leq \underline{\xi}$, see Figure 5). Therefore, due to (41),

$$\frac{\xi_{+1}}{\xi} = \frac{\delta_B}{\delta_A + \delta_{BA}\xi} \approx \frac{\delta_B}{\delta_A} < 1.$$

Hence, $\xi_{+1} < \xi$ and the depression evolves further.

On the other hand, if ξ is very high, then $\xi_{+1} \to \dfrac{\delta_B}{\delta_{BA}}$, i. e. ξ_{+1} is again lower than ξ. Therefore, either the unregulated economy always collapses, no matter where it has started from, or there are at least three stationary values of ξ (see Figure 5). At least, two

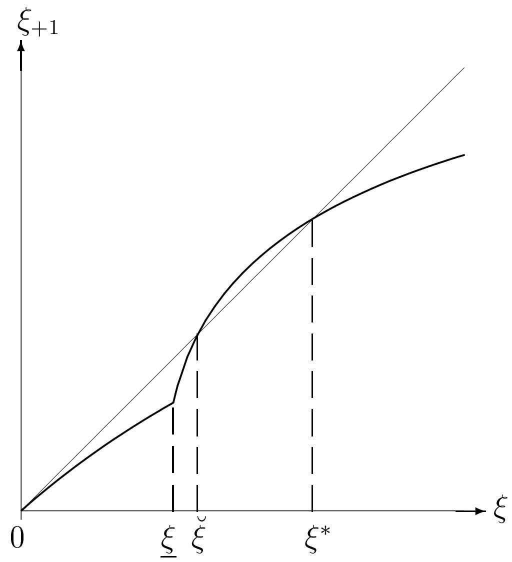


Figure 5. The graph of $\xi_{+1}(\xi)$ for the unregulated economy.

of them are stable: $\xi = 0$ and some high stationary value $\xi = \xi^*$. There is also an unstable stationary point $\breve{\xi} \in (0, \xi^*)$. If there is positive growth at the high steady state ξ^*, we have a typical underdevelopment trap: economies with relatively weak hi-tech sector are doomed to decline whereas those with more developed technologies prolong to grow (see Figure 6). In this case, the unstable stationary point $\breve{\xi}$ is the upper boundary of the trap. $\square$

The intuitive sense of Proposition 3 is clear: if the hi-tech industry it at a low level of development, it cannot successfully compete with the traditional sector, so managers have weak incentives to invest in R&D (partly, because of those short-term horizon). As a result, the hi-tech sector starts to collapse. The traditional sector still proceeds to grow for some time (as was noted above, it is less sensitive to depreciation) until sector B falls so low that the spillover effect it exerts gets negligible. Then sector A starts to collapse too. The dynamics of the underdevelopment trap for an unregulated economy is depicted in Figure 6. Notice that successful and dangerous trajectories may look very similar at their initial segments.

Now suppose that the government has decided to stimulate R&D by per-unit subsidy $s = \sigma x_B$ in order to lower the risk of getting into the trap. However, as in the

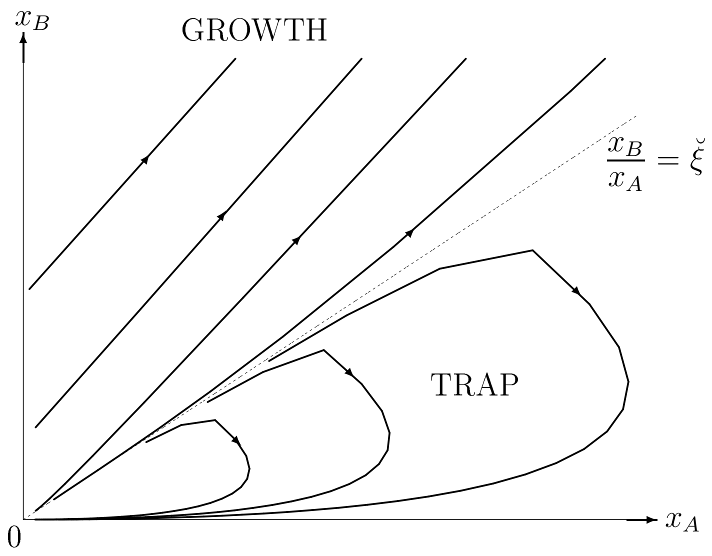


Figure 6. Phase diagram of the evolution of the unregulated economy.

symmetric version of the model, firms are able to seek the induced rent. Let us assume that the cost function of rent-seeking for sector B is the same as in section 3: $C(e,d) = dc(\varepsilon)$. Firms from sector A also can seek rent but they do not really invest in R&D (e, as well as d, is an unproductive waste of their resources), so, in compliance with the general form of the cost function, they need to use β units of input to get one unit of rent ($0 \le \beta \le 1$). If the hi-tech sector has more influential opportunities than the traditional one, then $\beta > \underline{c} = c(\underline{\varepsilon})$, otherwise $\beta < \underline{c}$. Of course, in any case, sector A exercises rent-seeking in its most hard (counterproductive) form.

Suppose that A and B declare, respectively, d_A and d_B as their levels of R&D activity to the subsidizer. Then the equilibrium is determined by (35), (36), along with the following equality:

$$\begin{cases} f_B'(z_B)c'(0) \ge g'(0)f_B(\tilde{z}_B), & \text{if } \varepsilon = 0; \\ f_B'(z_B)c'(\varepsilon) = g'(e)f_B(\tilde{z}_B), & \text{if } 0 < \varepsilon < 1; \\ f_B'(z_B)c'(1) \le g'(e)f_B(\tilde{z}_B) \le f_B'(z_B), & \text{if } \varepsilon = 1; \\ g'(e)f_B(\tilde{z}_B) = f_B'(z_B), & \text{if } e > d_B, \end{cases} \tag{44}$$

where $\varepsilon = \dfrac{e}{d_B}$. The balance condition (38) now takes the following form:

$$(1-\mu)(z_A + \beta d_A) + \mu(z_B + c(\varepsilon)d_B) = 1. \tag{45}$$

From now on, without loss of generality, let us define the subsidizing strategy for any ξ as a menu of contracts $(d_A(\xi), d_B(\xi), S_A(\xi), S_B(\xi))$[16]. The optimal strategy is defined as in section 4. Let us assume here that discount factor ρ is high enough, so that the problem of strategy optimization be equivalent to the problem of maximal growth stimulation (see section 4). Clearly, d_A should not exceed d_B in optimum. If monetary transfers between the government and firms do not affect the social welfare, then S_A and S_B can be set so large that neither sector will reject the contract with the government. However, each firm must choose the contract assigned for it, not for the other sector, so the incentive compatibility constraint must hold:

$$\begin{aligned} &\Pi_A(d_A) + S_A \geq \Pi_A(d_B) + S_B; \\ &\Pi_B(d_B) + S_B \geq \Pi_B(d_A) + S_A, \end{aligned} \tag{46}$$

where $\Pi_i(d_j)$ — is the profit of a firm from sector i, which chooses the contract for sector j (subsidies are not included), $i, j = 1, 2$. As follows from (46), pair (d_A, d_B) can be implemented by properly choosing S_A and S_B, if the following condition holds:

$$\Pi_A(d_A) + \Pi_B(d_B) \geq \Pi_A(d_B) + \Pi_B(d_A). \tag{47}$$

Thus, the task of the government is to choose d_A and d_B for each ξ so that the equilibrium value of e reaches its maximum subject to the incentive compatibility constraint (47). Other things being equal, it would be better to set $d_A = 0$, in order not to induce the traditional sector to dissipate its resources for counterproductive rent-seeking. Unfortunately, sometimes this may be impossible because of (47)[17]. So, let us allow for d_A the possibility to be positive. Denote the optimal (growth-maximizing) strategy as $\bar{d}(\xi) = (\bar{d}_A(\xi), \bar{d}_B(\xi))$.

What subsidization strategy could be recommended in the two-sector framework? There is a tradeoff. On the one hand, the government of an economy with weak hi-tech

[16] Such representation is correct because, as follows from the equilibrium conditions, the equilibrium values of all variables are functions of $\xi = \frac{x_B}{x_A}$.

[17] It can be shown that when only linear subsidies are allowed, the traditional sector should always get no subsidies. However, this may not be the case for arbitrary non-linear subsidies.

sector should try to get it out of the trap, so intensive intervention is needed. Thus, $\bar{d}_B(\xi)$ must be decreasing in ξ (at least, for low ξ). Such kind of reasoning is known as the *infant industry argument.*

On the other hand, the managers of low-developed firms cannot expect high profits from competition with the traditional sector, so they are likely to rely mostly on their influential rather than productive or innovative efforts. As was shown in Section 3, it may be not a good policy to offer them a lot of support in this case. So, $\bar{d}_B(\xi)$ must be increasing in ξ. This reasoning will be referred to as the *rent-seeking argument.*

Which of these two opposite arguments actually determines the optimal policy? It turns out that the answer to this question depends very much on how serious the threat of rent dissipation is.

Proposition 4 *The character of the optimal strategy $\bar{d}(\xi)$ depends on the rent-seeking opportunities in the economy:*

1. *If hi-tech firms can get subsidies only with some R&D activity ($\underline{\varepsilon} > 0$), then growth-maximizing strategy $\bar{d}(\xi)$, is such that $\bar{d}_B(\xi)$ tends to the maximal possible value as $\xi \to 0$, i. e. it is rational to support infant industries.*
2. *Otherwise (more exactly, when $c'(0) > 0$), there must be no subsidies at all for low ξ. Additionally, if rent-seeking by sector B is counterproductive (when $\varepsilon = 1$ in optimum), then $\bar{d}(\xi)$ is increasing in ξ. So, infant industries should not be supported in this case.*

Besides the character of the influence activity from the side of hi-tech sector, the alignment of sectors' rent-seeking opportunities substantially affects the optimal subsidization strategy.

Proposition 5 *If the rent-seeking opportunities of the hi-tech sector are at least as good as those of the traditional sector ($\beta \geq \underline{c}$), then $\bar{d}_A = 0$. Otherwise, it is worthwhile not to discriminate between the sectors ($\bar{d}_A = \bar{d}_B$) when the hi-tech sector is an infant industry.*

Proof of propositions 4 and 5. It is easy to check that condition (47), which is necessary for incentive compatibility, takes the following form:

$$\begin{aligned}&(\beta - c(\varepsilon))(d_B - d_A) + d_A(c(\varepsilon') - c(\varepsilon)) \geq \\ &\geq g(e)(\tilde{z}_B - \tilde{z}'_B) - \frac{g(e)f_B(\tilde{z}_B) - g(e')f_B(\tilde{z}'_B)}{f'_B(z_B)},\end{aligned} \tag{48}$$

where $\tilde{z}'_B$, e' and $\varepsilon' = \dfrac{e'}{d_A}$ are the values of the corresponding variables in the hypothetical case where hi-tech firms choose the contract assigned to sector A. If $\varepsilon' < 1$, then pair $(\tilde{z}'_B, e')$ is determined by the following system of equations:

$$g(e)f'_B(\tilde{z}_B) = g(e')f'_B(\tilde{z}'_B); \tag{49}$$

$$f'_B(z_B)c'(\varepsilon') = g'(e')f_B(\tilde{z}'_B). \tag{50}$$

As follows from the concavity of $g(e')f_B(\tilde{z}'_B)$ in $(\tilde{z}'_B, e')$, e' is increasing in d_A, the size of the contract for which hi-tech firms could defect (actual d_A chosen by traditional firms being unchanged), whence $e' \leq e$, $\tilde{z}'_B \leq \tilde{z}_B$ and $\varepsilon' \geq \varepsilon$.

Let $\beta \geq \underline{c}$. If we stand $\underline{\varepsilon}$ for ε in (48), then (48) will hold (its left-hand side is non-negative and the right-hand side is non-positive). For the optimal ε, the term corresponding to $\Pi_B(d_B)$ in (47) will be larger than for $\varepsilon = \underline{\varepsilon}$, so (48) will hold all the more. Hence, for any d_B one can manage so that $d_A = 0$, i. e. traditional firms do not exercise the influence activity. Obviously, this will be so in the optimum. As for d_B, the optimal choice of this policy variable is the following:

$$-\left(\frac{(1-\mu)f'_A(z_A)}{f''_A(z_A)} + \frac{\mu f'_B(z_B)}{f''_B(z_B)}\right)\varepsilon = \mu\, d_B\, \frac{c'(\varepsilon)}{c''(\varepsilon)}\Big(c(\varepsilon) - \varepsilon c'(\varepsilon)\Big) \tag{51}$$

(provided that $0 < \varepsilon < 1$). As follows from the equilibrium conditions, $\varepsilon \to \underline{\varepsilon}$ as $\xi \to 0$, regardless of the subsidizing policy. Hence, if $\underline{\varepsilon} > 0$, then the right-hand side of (51) tends to zero as $\xi \to 0$, so the left-hand side tends to zero too, which is possible only when $z_A \to 0$ and $z_B \to 0$, i. e., due to the balance conditions, $d_B \to \dfrac{1}{\mu\underline{c}}$ (this is the maximal possible value of d_B).

Otherwise, if, $c'(0) > 0$ (and thus $\underline{\varepsilon} = 0$), then due to (44) $\varepsilon = 0$ for sufficiently low ξ. Under these circumstances, it is optimal for the government to give subsidies to neither sector.

Now suppose that $\beta < \underline{c}$. Then the incentive compatibility constraint (48) not necessarily holds for any d_A and d_B. In particular, since $\varepsilon \to \underline{\varepsilon}$, $\varepsilon' \to \underline{\varepsilon}$, $z_B \to 0$, $\tilde{z}_B \to 0$ and $\tilde{z}'_B \to 0$ as $\xi \to 0$, then (48) can be approximately rewritten as

$$(\beta - \underline{c})(d_B - d_A) \geq 0, \tag{52}$$

which is possible only if $d_A = d_B$, due to our assumption. Hence, it is impossible to discriminate among the sectors for low ξ. The corresponding optimality condition for choice of $d = d_A = d_B$ takes the form

$$-\left(\frac{(1-\mu)f'_A(z_A)}{f''_A(z_A)} + \frac{\mu f'_B(z_B)}{f''_B(z_B)}\right)\varepsilon = d\,\frac{c'(\varepsilon)}{c''(\varepsilon)}\Big(\mu(c(\varepsilon) - \varepsilon c'(\varepsilon)) + (1-\mu)\beta\Big). \tag{53}$$

If $\underline{\varepsilon} > 0$, then, as in the case of (51), as $\xi \to 0$, the optimal amount $\bar{d}$ tends to the maximal possible value (which is now $\dfrac{1}{\mu\underline{c} + (1-\mu)\beta}$), such that $z_A = 0$ and $z_B = 0$. If $c'(0) > 0$, then $\bar{d} = 0$ for low ξ, as before.

Finally, let us check that if $\varepsilon = 1$, then $\bar{d}_B(\xi)$ is increasing in ξ (for example, consider the case $d_A = 0$). Indeed, in this case, the government should maximize d_B subject to $\varepsilon = 1$, so the optimality condition takes the form

$$f'_B(z_B)c'(1) = g'(d_B)f_B(\tilde{z}_B). \tag{54}$$

Thus, the optimal value of d_B can be determined in the same way as e for the unregulated economy (see equation (42) on page 29), up to constant multiplier $c'(1)$. Hence, $\bar{d}_B$ is increasing in ξ. □

Note. In Proposition 5 (case $\underline{\varepsilon} > 0$), it is significant that the subsidy function $S(d)$ takes a step form. It can be shown that if only continuously differentiable functions $S(\cdot)$ are allowed, then the non-discriminating outcome ($d_A = d_B > 0$) is possible only when

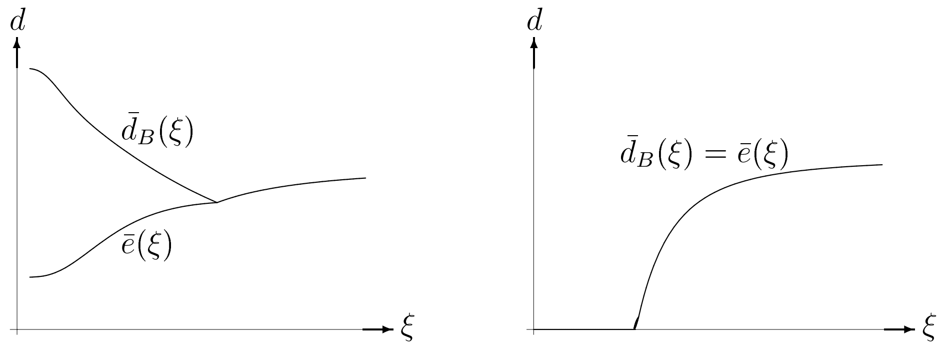
$c(\varepsilon) - \varepsilon\, c'(\varepsilon) \leq \beta$, i. e. when $\varepsilon \geq \varepsilon_0 > \underline{\varepsilon}$. As ξ decreases, one can maintain such level of ε only by lowering the subsidy until it gets zero. So, better rent-seeking opportunities of the traditional sector are equivalent (with respect to outcome) to hard rent-seeking by the hi-tech sector in this case. $\Box$

Thus, hard forms of seeking for subsidies reveal a shortcoming of infant industry argument: the less developed the new industry is, the more the shift to counterproductive rent-seeking is in this case, and the government is unable to make firms be honest and use subsidies in the optimal way. Although, if it is costly to get the support from the government without any actual R&D activity, then intensive industrial policy at early stages of development is relevant. However, rent dissipation and low current production activity are the costs of leaving the underdevelopment trap.

The optimal strategy $\bar{d}(\xi)$ for the two opposite situations described in Proposition 4 is depicted in Figure 7 (page 37). The development of the economy under the optimal subsidization evolves in compliance with Figure 8. Below the graphs of $\xi_{+1}(\xi)$ under the optimal policy (solid lines), the graphs for the unregulated economy are depicted for comparison (dashed lines). One can see from the pictures that the character of rent-seeking opportunities is crucial: under soft rent-seeking, the government is typically able to eliminate the trap completely, whereas under hard rent-seeking, the trap is always present, only its size can be decreased.

An important detail is that in a heterogeneous environment, the softness of rent-seeking (strategic complementarity with R$D) depends not only on the rent-seeking technologies of hi-tech industries but also on the distribution of influence opportunities among all industries. The situation, when less R&D-intensive industries have more influence opportunities, is very unfavorable[18]. It is curious that the losses are highest when the rent-seeking opportunities of the sectors are approximately the same, though the size of the "danger area" (the highest value of ξ for which the government has to subsidize the

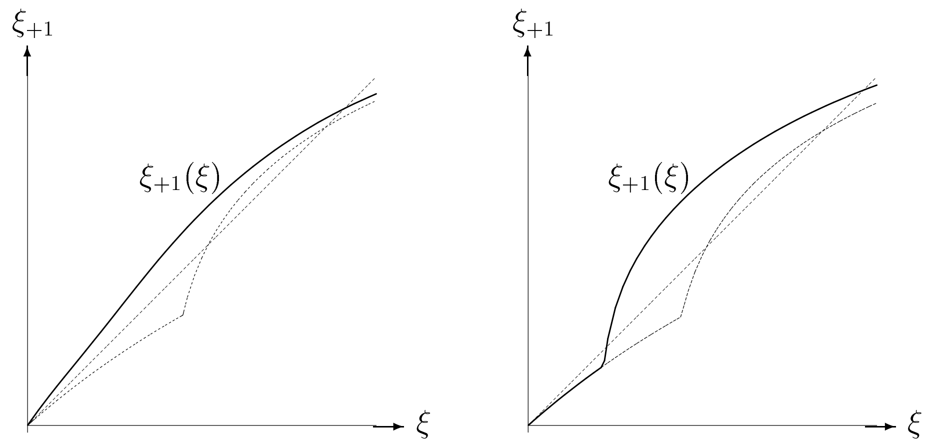
[18] Palda (1999) came to a similar conclusion for the case where two rival businesses try to get a unique monopoly license.



a) Proposition 4, case 1
(soft rent-seeking)

b) Proposition 4, case 2
(hard rent-seeking)

Figure 7. Optimal subsidization strategy $\bar{d}_B(\xi)$.



a) Proposition 4, case 1
(soft rent-seeking)

b) Proposition 4, case 2
(hard rent-seeking)

Figure 8. Graph of $\xi_{+1}(\xi)$ under the optimal subsidization policy.

traditional sector) is small in this case. The set of implementable policies is substantially restricted under such allocation of influence power: at early stages of development the government is unable to discriminate among the sectors and thus loses a considerable part of public funds as rents dissipated in traditional industries.

6 Conclusion

The central issue of the paper is the choice of growth promotion strategy adopting the possibility of rent-seeking. The analysis of the theoretical model shows that some caution is needed at this point. Too high subsidies increase the risk of getting into the rent-seeking trap, though they are beneficial for well-developed industries. High-growth outcomes become infeasible at all in the presence of rent-seeking, so the government has to look for second-best policies.

One of the most important problems is the tradeoff between two opposite policy arguments: the infant industry argument versus rent-seeking considerations. The analysis shows (see Propositions 4 and 5) that the optimal choice depends substantially on rent-seeking opportunities of producers. Namely, following the infant industry argument is recommended if the influence efforts exerted by hi-tech industries are not very unproductive. Otherwise, it is better to restrict the support for growing industries at initial stages of their development and only gradually increase it as the growth goes on. Another reasonable strategy is to reduce the moral hazard part of rents (by strengthening the control over project performance or designing revealing mechanisms) along with increasing R&D subsidies.

In any case, as it has been already said, the extent of support should be adequate to the current level of development. Actually, this is the main message of the present paper.

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