Industrial policy, collective action, and the direction of technological change

Temel, Tugrul

Development Research Institute (IVO), Tilburg University

29 June 2011

Industrial Policy, Collective Action, and the Direction of Technological Change

Tugrul Temel, Development Research Institute
Tilburg University (t.temel@uvt.nl)
Terry L. Roe, Department of Applied Economics
University of Minnesota (troe@dept.agecon.umn.edu)

June 28, 2011

Abstract

This paper studies patterns of technological change under two scenarios. In Scenario I, a distorted government is open to the influence of producers' collective action, while in Scenario II a benevolent government operates to maximize national income. The paper draws attention to the role that institutional arrangements and asymmetries in sectoral technology absorption play in shaping the path of technological change. Simulation results are threefold. First, biased institutions under Scenario I might help drag the economy towards the right trajectory, with current generations experiencing welfare loss. Secondly, the benevolent government under Scenario II supports the path of capital-augmenting technological change, which is also supported by the distorted government only when institutions deliberately favor the investment goods producing sector. Thirdly, sectoral asymmetries in technology assimilation do not help industries overcome disadvantageous situations in the political market, and hence do not influence the direction of technological developments.

JEL Codes: O33 - Technological change: Choices and Consequences, O38 - Government Policy, P26 - Political Economy

Keywords: Technological change, industrial policy and lobbying, and political-economic equilibrium.

1. Introduction[1][2]

The comforting belief that technological change is neutral has come under attack in the recent past. Although the evidence is by no means uniform, there appears to be sufficient of it to show that public R&D investments induce factor-saving technical changes [Griliches (1979), Gorter and Zilberman (1985), Pardey and Craig (1989), Justman and Teubal (1986, 1991), Coe and Helpman (1993), Mamuneas (1993), Nadiri and Mamuneas (1994a, 1994b)]. This obviously suggests a role for public intervention in subsidizing R&D activities, and in fact, as it turns out, government intervention has been quite marked throughout the developed world. Government's share of total R&D spending is currently about 50 percent in the US and France, 33 percent in Germany, and 20 percent in Japan [see Aghion and Howitt (1998), p.485]. R&D subsidies, as expected, have been heavily criticized in various countries for being wasteful and unnecessary, and are also subject to political lobbying in a context of widespread informational asymmetries between government agencies and entrepreneurs.

The uncomfortable evidence, that technical changes are, in part, endogenous to government policies and, therefore, likely to be non-neutral in their effects on the direction of technological developments, has drawn significant attention in the literature on technology and growth [see Fuhrer and Little (1996) for an extensive survey of studies]. The most recent line of research has focused on the role of factors such as human capital and R&D investments in the process of growth [Romer (1986, 1990), Lucas (1988), Murphy et al. (1989), Grossman and Helpman (1991), Barro and Sala-i-Martin (1992)]. The models of endogenous growth in this regard have stressed learning and purposive R&D activities as driving forces of growth through the creation of new products and the improvement in the quality of existing ones. Unlike in the neoclassical models of the Solow-type, long-run growth rates in these models are not pinned down by a forever diminishing marginal productivity of capital, and can be affected by government policies. A second approach has made heavy use of search concepts to characterize the process of invention and attempted to model the distribution of potential inventions as an uncertain outcome of a sequence of research experiments [Nordhaus (1969),

[1] The first author is affiliated with Development Research Institute (IVO) at Tilburg University in The Netherlands; The second author is with the Department of Applied Economics at the University of Minnesota in the USA.

[2] The authors would like to thank Michiel A. Keyzer, Vernon W. Ruttan, and Xinshen Diao for their comments on the earlier version of this paper.

Evenson and Kislev (1976), Binswanger and Ruttan (1978)]. Remaining within the confines of the search framework, the models of induced innovation have concerned with the determinants of the direction of search. These models investigate whether the search is for more labor-intensive or for more capital-intensive techniques, and hypothesize that expected factor prices affect the direction of search activity [Binswanger and Ruttan (1978)]. The determination of the factors that affect the spread of innovations across firms engaging in similar activities has been the main concern of so called diffusion models. Focusing on the evolution and adoption of a well-specified technology, these models assume that the probability of adopting an innovation depends on the proportion of the firms in the industry that have already adopted the innovation, on the benefits from adopting it, and on the costs of its adoption. Various applications of these models signify that adoption decisions are mainly economically motivated [Griliches (1957), Mansfield (1961)]. Inspired from the observation that a large residual in per capita output growth cannot be attributed to the growth of per capita capital service flows, growth accounting methods have concentrated on the sources of this large residual [Solow (1957)]. Research has directly focused on the variables that determine input and output qualities as well as contribute to the residual, like public and private R&D, schooling, infrastructure, and the policy regime [Griliches (1957, 1963), Denison (1962)]. The last, but not the least, line of research has attempted to establish the basic rational for intellectual property rights and focused on the role that existing property rights, patents, and incentives to engage in R&D play in inventions [Arrow (1962), Nordhaus (1969), Dasgupta and Stiglitz (1980), Dasgupta (1986)].

It is to our surprise that, although emphasizing the importance of government policies at every chance they have, studies in the literature have paid almost no attention to the fact that these policies are open to the influence of interest-groups[3]. This is precisely what we attempt to model in the present study by bringing together the main elements of induced innovation, growth accounting, and rent-seeking approaches. From the rent-seeking theory we adopt the idea that policy decision regarding the allocation of public resources is intrinsically open to the influence of interest groups. From the induced innovation approach, we further borrow the idea that expected factor prices play the key role in influencing the direction of search for production techniques that save the most scarce factor. Getting factor prices right is important not only for choice of technique but for

[3]Two exceptions to this are studies by Binswanger and Ruttan (1978) and Hayami and Ruttan (1985), though they did not treat the matter with the rigor that we have in the present study.

design of incentives to affect the direction of search activity as well. Finally, we borrow from growth accounting approach that enhancing the quality of inputs would, in part, account for the variation in total factor productivity. Publicly provided R&D might be considered one of those factors that would improve the quality of private inputs, capital and labor.

Taking together these three approaches, we consider the direction of technological change to be endogenous to producers' collective action for public R&D that induces factor-augmenting technical changes. This view finds its most apparent expression in the context of industrial policy that is implemented, in slightly different forms, throughout the developed world. The supporting argument for an industrial policy is that future economic growth is strongly linked to the soundness of strategically vital industries. It has recently been observed that these industries in various countries started exerting pressure on government for economic assistance in the provision of R&D subsidies. Such assistance, however, has often been criticized for being arbitrary and discretionary in the choice of beneficiaries, because it is the government rather than a properly functioning market that decides who will receive funding. This means that there is always room for genuine mistakes on the government's part, as well as incentives on the firms' part to waste resources lobbying for lucrative contracts. The problem grows more critical compared with other branches of government decision making for several reasons. First, knowledge externalities are particularly hard to identify and measure adequately, as are the various market imperfections that motivate intervention in the R&D sector. Second, picking winners is always hazardous, especially in the R&D sector whose activities are often unpredictable. Third, there are severe informational asymmetries between the government and potential beneficiaries with respect to the impact of R&D investments [see Krugman (1983), Norton (1986), Magee, Brock, and Young (1989), Aghion and Howitt (1998) for a survey of studies on industrial policy].

In this study the above argument is modeled in a framework in which distorted and undistorted governments can be compared with respect to the implied paths of technological change. Such comparison would also allow, though not falling within the scope of the current study, for an approximate measure of welfare loss. A distorted government is assumed to operate with a predetermined policy decision rule for the distribution of R&D subsidies, while an undistorted government achieves the distribution via the maximization of total income. Producers signal their willingness to pay for R&D subsidies via political lobbying; and thereafter, winners are picked and their shares of subsidies are determined by using the policy decision rule [see Lin and Nugent (1995) for an extensive survey of studies on the role of collective action in policy formation, De Janvry, Sadoulet, and Fafchamps (1989), Li (1993), Alston, Chalfant, and Pardey (1993), Hayami and Ruttan (1985)]. The theory of rent-seeking behavior has advanced in many directions since the pioneering contributions by Tullock (1967), Krueger (1974), and Posner (1975). Perhaps because of the early preoccupation with the social costs of monopoly, the literature has tended to emphasize contests in which the "winner takes all" [Tullock (1980, 1984), Corcoran (1984), and Hillman and Katz (1984)]. This approach is appropriate when agents compete for a monopoly rent, a contract or any other indivisible transfer. On the contrary, producers in the current study expand resources competing for a share of a divisible rather than for the whole of an indivisible rent, like lobbying by factor owners for a share of national product and by intermediate and final goods producers in an industry for/against protection of intermediate goods.

An overlapping generations (OLG) framework has been adopted as it provides an appropriate demographic structure to analyze situations where lobbying has consequences that outlive generations. This framework facilitates analysis of intergenerational externalities which are intrinsically hard to internalize because those who impose the externalities are not alive at the same time as those who enjoy or suffer the consequences. One such externality that arises in the context of the lobbying economy model is that collective action today determines the nature of technological change that will arise tomorrow. And hence future generations are bound to act on it. Although intergenerational issues have been extensively discussed in the literature of exhaustible resources [see, for example, Solow (1974, 1986)], the very same issues are almost absent in models of collective action, except for Sandler (1982). Despite the advantages of the OLG framework, one should also recognize the complications introduced by it. First, analysis of Pareto-improving policies becomes demanding since it requires an ordering of the welfare of infinitely many generations. Second, competitive equilibrium can be dynamically inefficient: in which case all generations would benefit if they accumulated less capital and increased their consumption. Our study also attempts to investigate optimal policies with respect to the direction of technological advances and the conditions under which dynamic inefficiency is likely to arise.

A central claim of this paper is that technological change and its direction are endogenous to the workings of producers' collective action. The rational for producers to lobby is that they can reduce the cost of production by changing the direction in their favor.

The paper proceeds as follows. In the next section, we describe the lobbying economy model and define important concepts often encountered in the paper. We further explain the roles of and interactions between agents in the model economy. For simplicity and readability, mathematical formulations of agents' maximization problems are all given in Appendix. After that, we illustrate the key properties of the model economy using a numerical example. The final section concludes.

2. Description of a lobbying economy model[4]

Producers. The model economy consists of two sectors, each of which produces at time t a perishable consumption good Y_t^1 and an investment good Y_t^2, using the production technology of the form:

$$Y_t^i = (1 - R_t^i) E_{t-1}^i [\theta^i (A^i(G_t^i) K_t^i)^{\rho^i} + (1 - \theta^i)(D^i(G_t^i) L_t^i)^{\rho^i}]^{\frac{\gamma^i}{\rho^i}} \equiv (1 - R_t^i) \overline{Y}_t^i \quad (2.1)$$

The labor-intensive and a capital-intensive technologies are employed in the production of consumption and of investment goods, respectively. A representative firm in sector i employs three inputs: capital K_t^i, labor L_t^i, and public input G_t^i. The third input enters the production function in the form of factor-augmenting research and development (R&D) investments and enhances the productivity of other inputs. This feature is incorporated into the production technology via the terms, $A^i(G_t^i) = e^{\lambda^i G_t^i}$ and $D^i(G_t^i) = e^{(1-\lambda^i) G_t^i}$, where λ^idenotes the rate of capital augmentation ($\lambda^1 < \lambda^2 < 1$). The production technologies are assumed to exhibit decreasing returns (i.e., $0 < \gamma^i < 1$) with respect to (K_t^i, L_t^i) given G_t^i. The two sectors are distinguished by the type of public R&D they wish to have: The labor-intensive (capital-intensive) sector wishes to obtain the labor-augmenting (capital-augmenting) type. The parameter values ($0 < \theta^1 < \theta^2 < 1$) reflect that the consumption (investment) good producing sector is labor (capital) intensive. And ρ^i determines the elasticity of substitution between K_t^i and L_t^i.

Technology absorption. In the production technology (2.1), two stocks of resources are distinguished: production capacity and technological capacity. The former incorporates the resources used to produce goods at given levels of efficiency and given input combinations. Technological capability, however, incorporates the additional and distinct resources needed to generate and manage technical change,

[4] For presentational simplicity, agents' maximization problems and first order conditions are all provided in Appendix. Here we only focus on the description of the main concepts utilized in the model economy.

including skills, knowledge and experience, and institutional structures. Technology absorption is said to occur when sectors, through their research efficiency or efficient managerial structures, are able to exploit the past technologies to create new ones. Pharmaceutical industries, in which new medicines are quite often the mix of already existing medicines, and machine industries are those industries where such assimilation takes place at a rather high rate.

Technology absorption is represented in this study by the term, $E_{t-1}^{i} \equiv e^{\eta^{i} G_{t-1}}$, where G_{t-1}, predetermined at time $t-1$, denotes the stock of public R&D inherited from the last period. This inherited resource is assumed to improve the productive efficiency of all factors neutrally, however, sectors' awareness of this is limited and varies across sectors[5]. This brings about asymmetries regarding sectors' capabilities of technology assimilation [see Pavitt (1984), Malerba (1992) for evidence on sectoral patterns of technical change]. The parameter η^{i} represents sector i's technology absorption capability, and asymmetries are reflected by the parameter specification: $\eta^{1} > \eta^{2}$ or $\eta^{2} > \eta^{1}$.

An important implication of technology assimilation is that the sector with higher capability of absorption would be less interested in lobbying activities because that sector would choose to augment its output by exploiting the existing stock of public R&D. This is the situation in which free riding problem is likely to emerge. Nonetheless, the very same sector would still incur a cost of not lobbying enough via increased price of factor that is intensively used in the production. Such a trade-off implies that in equilibrium sector i's marginal cost of not lobbying (in terms of increased factor prices) should be equal to marginal benefit from technology absorption.

Distorted government. We introduce a distorted government: One that only carries out the outcome of lobbying, and that does not represent any political interest group. It is nothing but an intermediary agent that translates producers' lobbying activities into influence. It uses a predetermined policy decision rule, which is not subject to any change over time. Such a government structure has been adopted for two reasons. First, this allows one to eliminate the bias introduced by the government behavior to the direction of technological change. Second, it is often the case that perverse policy responses are a logical outcome of the conflicts between interest groups [de Janvry and Sadoulet (1988)]. A neutral role attributed to the government is the main distinguishing feature of our

[5]Of course, sectors which are aware of positive externalities might invest in factors likely to enhance their capability to internilize the externalities. This will endogenize η^{i}, however, this is beyond the scope of the current study.

approach from the other approaches adopted in the models of rent-seeking theory. In these models, a usual type of government operates as a third agent with specific preferences such as revenue-maximizing or political support-maximizing [Hillman and Ursprung (1988), Potters and Van Winden (1992), Downs (1957), Magee, Brock, and Young (1989), Grindle and Thomas (1991)]. A final remark on the behavior of the distorted government is that it follows a balanced budget policy and finances the production of public R&D via labor and capital income taxes from the young and old generations, respectively.

Endogenous policy via collective action. The government in office is assumed to be distorted and its policy as regards to the sectoral distribution of public R&D characterized by three institutional rules: (i) producers, knowing that the government accepts any outcome of lobbying, influence its policy decision via lobbying, (ii) the government considers the impact of the existing institutions (ϕ^i) on its policy decision, and (iii) relative lobbying governs the sectoral distribution. Remaining along the same line with studies in the rent-seeking literature, the present study introduces pressure and influence functions to describe how political pressure is translated into the distributional weights [Becker (1983), Tullock (1980)]. It is simply assumed that pressure B_t^i, $B_t^i = \phi^i R_t^i \overline{Y}_t^i$, is produced by spending resources $R_t^i \overline{Y}_t^i$, and that an influence function of the form $I_t^i = (\frac{B_t^i}{\sum_{i=1}^2 B_t^i})$ subsequently translates pressure into the distributional weights I_t^i. The influence function, which is concave in R_t^i, implies that (i) the higher the lobbying by sector i, the higher is its effectiveness, (ii) its influence starts weakening after a certain level of lobbying expenditures. For the sectoral share of R&D to be determined, the government uses a *policy decision rule*[6], $G_t^i = I_t^i G_t$, reflecting the institutional setting within which lobbying takes place. Endogenous policy in this context is nothing more that endogenizing the distributional weights.

The lobbying process introduced in this study works as follows. Represented by a lobby group, each sector confronts the policy decision rule which is announced by the government in the beginning of time t. Thereafter, given ϕ^i for $i = 1, 2$, lobbyists in sector i extend resources to influence the policy, G_t^i. Finally, the government makes public input available to the sectors in such a way that it

[6]As seen from the influence function, indeterminacy occurs with respect to the distributional weights if both sectors simultaneously choose the strategy of "no-lobbying". Such indeterminacy could have been avoided by specifying an alternative form of influence function, $G_t^i = (\frac{1}{1+e^{(B_t^2 - B_t^1)}})G_t$ for $i = 1, 2$ [Hirshleifer (1989)]. The goal of the present study is merely to focus on the path of lobbying-driven technological change, therefore the strategy of "simultaneously no-lobbying" is discarded.

cannot incur a fiscal policy.

Consumers. The model economy consists of overlapping generations of two-period-lived consumers, and each generation is assumed to comprise only a single individual. In the first period, an individual born at time $t \geq 1$ supplies her unit endowment of labor inelastically, earns labor income and pays taxes, receives profit share, and makes savings for the next period consumption. In the second period, she retires and earns income from savings, pays capital income tax. An initial old person alive at time $t = 1$ spends her income on the second period consumption. The model assumes perfect foresight, $E(p_{t+1}) = p_{t+1}$ where p_{t+1} is the relative price of output at time $t+1$, and that the gross return to savings (or return to capital at time $(t+1)$) $(1 + i_{t+1})$ is known at time t by borrowers and lenders. The initial labor and capital endowments $(L_0, K_0) > 0$ are exogenously given at $t = 0$, and economy-wide labor force is constant at $L_t = \overline{L} = 1\ \forall_t$.

Consumers receive profit income and realize that they have no control over prices. They act as producers maximizing profits when at work, and act as individuals maximizing utility when at home. And these objectives at different times of the day do not contradict the fact that the government is of a distorted type, setting policy under the influence of lobbyists.

Lobbying works its way through to consumers via changes in output and input prices. First, lobbying influences the supply of R&D that enhances the productivity of capital and labor. Second, it pulls resources away from the productive activities and affects the scale of production. The first effect creates changes in factor prices as the second causes changes in the relative price of output. These effects make their presence known through changes in consumer demand for consumption and investment goods as well as changes in the supply of factors that they own.

Undistorted government. Maximizing gross national product, $Y_t = p_t Y_t^1 + Y_t^2$, the undistorted government is assumed to think of all agents' well being without any prejudice against/for any agent. The resource allocation suggested by such government is called *optimal*. With the introduction of the undistorted government, one can measure output loss from engaging in lobbying activities and give a view of how far away agents are from the optimal allocation. Another advantage is that it enables us to compare the optimal path with the lobbying-driven path of technological change. In the present model, technological change is said to occur whenever factor-augmenting R&D is made available to producers. A path is called *optimal (lobbying-driven)* if it is suggested by the undistorted (distorted) government. Furthermore, a path is called an optimal capital (labor) augmenting path if the undistorted government favors the production of R&D that augments capital (labor); likewise, a path is a lobbying-driven capital (labor) augmenting path if the distorted government happens to favor the production of capital (labor) augmenting R&D.

Evolution of capital stock. An important feature of the lobbying model is that the capital stock at time $t+1$ is assumed to be equal to the output of the investment good produced at time t,

$$K_{t+1} = (1 - s_t^2)\overline{Y}^2(K_t^2, L_t^2, G^2(s_t^1, s_t^2)). \tag{2.2}$$

This equation clearly indicates that the entire path of capital stock is determined by sector 2's capital-labor use and lobbying efforts of producers in both sectors[7]. In accordance with this path, gross national income is obtained from

$$Y_t = p_t(1 - s_t^1)\overline{Y}^1(K_t^1, L_t^1, G^1(s_t^1, s_t^2)) + (1 - s_t^2)\overline{Y}^2(K_t^2, L_t^2, G^2(s_t^1, s_t^2)). \tag{2.3}$$

The unique steady-state level of capital follows from[8]

$$\triangle K_t \equiv (K_{t+1} - K_t) = (1 - s_t^2)\overline{Y}^2(K_t^2, L_t^2, G^2(s_t^1, s_t^2)) - K_t = 0.$$

[7] For the stock of capital to grow, the following relation should hold for given (K_t^2, L_t^2, s_t^1), $\frac{\partial K_{t+1}}{\partial s_t^2} = -\overline{Y}_t^2 + (1 - s_t^2)\frac{\partial \overline{Y}_t^2}{\partial G_t^2}\frac{\partial G_t^2}{\partial s_t^2} > 0$ where $\frac{\partial \overline{Y}_t^2}{\partial G_t^2} > 0$ and $\frac{\partial G_t^2}{\partial s_t^2} > 0$. This implies that a politically strong capital-intensive sector is desirable for the economy to grow.

[8] Denote $\dot{K} \equiv \frac{\partial K_t}{\partial t} = \frac{K_{t+1} - K_t}{t-(t-1)}$. Assuming $L_t = \overline{L}$ for all t implies

$$\dot{L} = 0. \tag{2.4}$$

The lobbying economy model assumes $K_{t+1} = Y_t^2$ that can be re-written as

$$\dot{K} \equiv K_{t+1} - K_t = Y_t^2 - K_t. \tag{2.5}$$

Taking the total derivative of $K_t = k_t L_t$ with respect to t results in

$$\dot{K} = k_t \dot{L} + \dot{k} L_t. \tag{2.6}$$

Now substituting (2.4 and 2.5) into (2.6) and solving the resulting equation for $\dot{k}$ yileds

$$\dot{k} = \frac{Y_t^2}{L_t} - k_t \equiv g(K_t^2, L_t^2, s_t^2, s_t^1, \overline{L}, k_t).$$

That $\dot{k} = 0$ has to be satisfied in equilibrium implies $\left(\frac{1}{L_t}\right) Y_t^2 = k_t$.

3. A numerical example

This numerical example serves as a qualitative illustration of the main features of political-economic equilibrium (see Appendix for its definition). It envisages two extremes. At one, sectors are assumed to have no ability of absorbing technology, which is represented by $E^i_{t-1} = 1$ (i.e., $\eta^i = 0 \ \forall_i$). At the other extreme, asymmetric absorption is assumed across sectors, which is represented by $E^i_{t-1} > 0 \ \forall_i$ and $E^1_{t-1} \neq E^2_{t-1}$ (i.e., $\eta^i > 0 \ \forall_i$ and $\eta^1 \neq \eta^2$). Simulations are carried out to describe the role of institutions and asymmetries in influencing the direction of technological change and welfare along with the implied direction. Numerical experiments are also performed for the case in which the government is undistorted (6.29), and the results from these experiments are then contrasted with those obtained from political-economic equilibrium.

The set of the parameter values that have been commonly used in all experiments is: $\{\rho^1 = \left(\frac{1}{3}\right), \lambda^1 = \theta^1 = 0.4, \gamma^1 = \gamma^2 = 0.8, \rho^2 = -1, \lambda^2 = \theta^2 = 0.6, \alpha = 0.95, 1.8 \geq K_t \geq 0.7, \overline{L} = 1, \delta = 0.5\}$. To eliminate any bias in k^i_t that might be introduced by the distorted government we set $\delta = 0.5$ in (6.6). Some of the other parameter values have been taken from studies in the literature. For example, $\rho^1 = \left(\frac{1}{3}\right)$ and $\rho^2 = -1$ were adopted from Uzawa (1962), Craven (1973), and Fisher (1992) to guarantee the stability of the political-economic equilibrium; the discount factor $\alpha = 0.95$ from Parente and Prescott (1993). The rest of the parameter values has been chosen in such a way that the lobbying economy model satisfies that (i) production functions are concave with respect to the choice variables and (ii) reaction functions intersect only once.

3.1. Sectors are unable to absorb technology

Unbiased institutions ($\phi^1 = \phi^2$). Under this specification of institutions, two results are worth of elaborating. First, technological change follows the path in which the distorted government increasingly supplies the labor-augmenting R&D. This is an immediate result of capital that becomes abundant over time, in which case raising wage-rental ratio induces producers of the labor-intensive good to lobby for the labor-augmenting R&D. Responding to their political pressure, the government makes the desired type of technology available using its policy decision rule. On the other hand, producers of the capital-intensive good happily reduce their lobbying efforts as increasing wage-rental ratio lowers the cost of production in this sector. Second, welfare of the old (young) generation is expected to decline (improve) along with the labor-augmenting path because declining $\overline{r}_t = (1 - \tau^K_t) r_t$

would reduce the income of the old. Obviously, there are two sources of a welfare loss on the part of the old generation. One is the imposition of heavy capital taxes given the rental rate of capital, and the other is a decrease in the rental rate of capital given a certain fiscal policy. But results from the numerical experiments under alternative fiscal regimes suggest that heavy capital taxes, in fact, improve the total welfare while making the old worse off. This situation would lead in the long run to dynamic inefficiency in which case all generations would save less and increase their consumption.

Biased institutions ($\phi^2 > \phi^1$). Under this specification, institutional structure favors the investment good producing sector, and as a result, the economy augments capital at a higher rate than it does labor because biased institutions exaggerate the influence of lobbyists representing the capital-intensive sector. Consequently, the capital-augmenting path emerges as the dominant path along which the production of the investment good raises (i.e., $\frac{\partial Y_t^2}{\partial \phi^2} > 0$). This is so called first round effect of technology. The second round effect takes place due to rising relative price of output and to declining production of the consumption good as labor-augmenting R&D becomes scarce (i.e., $(\frac{\partial p_t}{\partial \phi^2} Y_t^1 + p_t \frac{\partial Y_t^1}{\partial \phi^2}) \geq$ or < 0). Institutional bias will then be harmful for economic growth if the second round effect is negative and dominates the first one; it will be beneficial if the second round effect is positive[9]. In our model, there exists a political-economic equilibrium in which bias results in shrinking gross income.

Optimal versus lobbying-driven path. Simulation results indicate that the undistorted government favors the capital-augmenting path reflected by $\hat{G}_t^1 < \hat{G}_t^2$ that contradicts the path $\tilde{G}_t^1 > \tilde{G}_t^2$ implied by the political-economic equilibrium with unbiased institutions[10]. It also appears that the distorted government is unable to correct this wrong direction with respect to technological developments no matter what fiscal scheme it implements. To this end, one can reasonably conclude that the direction of technological change is wrong and irreversible if institutions are neutral. Could institutional bias help drag the economy towards the right direction? Results reveal that the path under biased institutions $\tilde{G}_t^1 < \tilde{G}_t^2$ agrees with the optimal path, strongly supporting the significant role that insti-

[9] Gross national product is defined as $Y_t = p_t Y_t^1 + Y_t^2$. In equilibrium, $Y_t^i = Y^i(\phi^1, \phi^2; \bullet)$ and $p_t = p(\phi^1, \phi^2; \bullet)$, hence $\frac{\partial Y_t}{\partial \phi^2} = \left[(\frac{\partial p_t}{\partial \phi^2} Y_t^1 + p_t \frac{\partial Y_t^1}{\partial \phi^2}) + \frac{\partial Y_t^2}{\partial \phi^2} \right]$ where $\frac{\partial Y_t}{\partial \phi^2} < 0$ if $(\frac{\partial p_t}{\partial \phi^2} Y_t^1 + p_t \frac{\partial Y_t^1}{\partial \phi^2}) < 0$ and $\mid (\frac{\partial p_t}{\partial \phi^2} Y_t^1 + p_t \frac{\partial Y_t^1}{\partial \phi^2}) \mid > \frac{\partial Y_t}{\partial \phi^2}$.

[10] An overhead cap, $\hat{x}$, and an overhead tilde, $\tilde{x}$, indicate that the variable x applies to the benevolent and passive government, respectively.

tutional structure plays in characterizing the nature of technological change and that biasedness helps eliminate inefficiencies with respect to the type of technology supplied. A second result obtained from the comparison of optimal and lobbying-driven paths is that lobbying leads to an excess supply of R&D, that is, $\tilde{G}_t > \hat{G}_t$. This is because in the lobbying economy model producers determine, without paying for it, the amount to be produced while consumers finance its production through taxes.

3.2. Sectors asymmetrically absorb technology

This specification imposes asymmetries with respect to sectors' ability to assimilate the existing stock of R&D that has been inherited from the last period. Such asymmetry is incorporated into the model by parameter values, $\{\eta^1 = 0.8 > \eta^2 = 0.2$ and $\eta^1 = 0.2 < \eta^2 = 0.8\}$. The asymmetry of the type $\eta^1 > \eta^2$ corresponds to a situation in which the consumption good producing sector assimilates technology more than does the investment good producing sector. The rest of the parameters used in the simulations takes on the same values as in Section (3.1). The direction of technological change is investigated under alternative institutional structures.

Unbiased institutions. The maximal (minimal) amount of public R&D is produced under the regime that labor (capital) income is heavily taxed, and whatever the type of asymmetries, the amount produced remains the same[11]. In general, given a fiscal regime the total R&D production remains the same no matter which sector is of more capable in assimilating the stock of technology. In the case of sectoral R&D allocation, unbiased institutions support the type of R&D that augments labor. The maximum production of this type is again attained when the government collects heavy labor income taxes[12]. Apparent that absorption asymmetries do not change the course of technological advances, only thing that matters, of course to the extent that the lobbying model allows, is fiscal regime. This has direct links with consumers' well-being through changing disposable income. The young is more supportive to the technology reproduction by tax payments than the old.

The simulation results draw an interesting picture with respect to the relationship between asymmetries and the relative output price. With the type of

[11] $G_t(\tau_t^L > \tau_t^K, \phi^2 = \phi^1) > G_t(\tau_t^L = \tau_t^K, \phi^2 = \phi^1) > G_t(\tau_t^L < \tau_t^K, \phi^2 = \phi^1)$.

[12] $G_t^1(\tau_t^L > \tau_t^K, \phi^2 = \phi^1) > G_t^2(\tau_t^L > \tau_t^K, \phi^2 = \phi^1)$, $G_t^1(\tau_t^L = \tau_t^K, \phi^2 = \phi^1) > G_t^2(\tau_t^L = \tau_t^K, \phi^2 = \phi^1)$, and $G_t^1(\tau_t^L < \tau_t^K, \phi^2 = \phi^1) > G_t^2(\tau_t^L < \tau_t^K, \phi^2 = \phi^1)$.

asymmetry ($\eta^1 > \eta^2$) in which the consumption good producing sector has a higher absorption capability than does the other sector, the price reveals a cyclical pattern: rising until capital and labor become equally abundant and declining when capital is relatively abundant. While this cyclicality remains, price levels show convergence across alternative fiscal policies. In the case of $\eta^2 > \eta^1$, the price continuously increases at a decreasing rate, but interestingly reveal divergence across fiscal regimes (see Figure 1). What is obvious in this comparison is that asymmetries inject disturbances into output markets, influencing only consumers' welfare. Since these asymmetries do evoke proportional change in factor demand, the wage-rental ratio remains unchanged.

Biased institutions. The maximal (minimal) amount of public R&D is produced under the regime that labor (capital) income is heavily taxed, and whatever the type of asymmetries, the amount produced remains the same[13]. This means that given a fiscal policy the total R&D production remains the same no matter which sector is of more capable in assimilating the stock of technology. In the case of sectoral R&D allocation, biased institutions support the type of R&D that augments capital. The maximum production of this type is again attained when the government collects heavy labor income taxes[14]. Parallel to the case of unbiased institutions, fiscal policy is the driving force behind technology supply as the role of asymmetries is nil. What is apparent in these results, when compared to those from the scenario with unbiased institutions, is that relative position of the young (the old) with respect to changes in its disposable income does not change as the wage-rental ratios under both scenarios are equal.

We observe that cyclicality, convergence, and divergence of output price paths still remain, strongly suggesting that this is a result of technological asymmetries. Wage-rental ratios do not experience any change either, remaining equal across asymmetries.

Comparison of biased and unbiased institutions. Four final conclusions are drawn. First, with respect to fiscal policy the government finds it more productive to impose heavy labor income taxes independently from institutional structure. Second, the total production of R&D remains the same under alternative institutional structures[15], which implies that the government's demand for capi-

[13] $G_t(\tau_t^L > \tau_t^K, \phi^2 > \phi^1) > G_t(\tau_t^L = \tau_t^K, \phi^2 > \phi^1) > G_t(\tau_t^L < \tau_t^K, \phi^2 > \phi^1)$.

[14] $G_t^2(\tau_t^L > \tau_t^K, \phi^2 > \phi^1) > G_t^1(\tau_t^L > \tau_t^K, \phi^2 > \phi^1)$; $G_t^2(\tau_t^L = \tau_t^K, \phi^2 > \phi^1) > G_t^1(\tau_t^L = \tau_t^K, \phi^2 > \phi^1)$; $G_t^2(\tau_t^L < \tau_t^K, \phi^2 > \phi^1) > G_t^1(\tau_t^L < \tau_t^K, \phi^2 > \phi^1)$.

[15] $G_t(\tau_t^L > \tau_t^K, \phi^2 = \phi^1) = G_t(\tau_t^L > \tau_t^K, \phi^2 > \phi^1)$ indicates that total production of R&D is independent of institutional structure.

tal and labor changes proportionally. Third, the political-economic equilibrium is indeterminate if institutions favor the consumption good producing sector. Precisely because unbiased institutions already suggest the labor augmenting path, an additional and deliberate prejudice towards the same direction expectably creates indeterminacy. Lastly, for a given fiscal policy, wage-rental ratios remain unchanged across different sectoral absorptions[16]. When compared across institutional arrangements, factor-price ratios are maximal (minimal) with unbiased (biased) institutions [17]. As stated earlier, labor-augmentation becomes a dominant direction of technological change when institutions are unbiased, implying that labor is scarce and therefore expensive. This is why producers of the labor-intensive sector intensively lobby to obtain labor-augmenting R&D. It is expected wages to decline once the labor-augmenting R&D is made available. Thus high wages are to take place ex ante.

Growth and welfare in the lobbying economy. In the presence of unbiased insti-

[16] For instance, if the fiscal policy of $(\tau_t^L > \tau_t^K)$ is implemented then wage-rental ratio satisfies $\omega_t(\tau_t^L > \tau_t^K, \phi^2 = \phi^1, \eta^2 = \eta^1) = \omega_t(\tau_t^L > \tau_t^K, \phi^2 = \phi^1, \eta^2 > \eta^1) = \omega_t(\tau_t^L > \tau_t^K, \phi^2 = \phi^1, \eta^2 < \eta^1)$. This equality indicates that with unbised institutions wage-rental ratio will remain unchanged regardles of the type of asymmetries. The same applies to biased institutions as well: $\omega_t(\tau_t^L > \tau_t^K, \phi^2 > \phi^1, \eta^2 = \eta^1) = \omega_t(\tau_t^L > \tau_t^K, \phi^2 > \phi^1, \eta^2 > \eta^1) = \omega_t(\tau_t^L > \tau_t^K, \phi^2 > \phi^1, \eta^2 < \eta^1)$.

[17] $\omega_t(\tau_t^L > \tau_t^K, \phi^2 = \phi^1) > \omega_t(\tau_t^L = \tau_t^K, \phi^2 = \phi^1) > \omega_t(\tau_t^L < \tau_t^K, \phi^2 = \phi^1)]$ wher $\omega_t(\tau_t^L > \tau_t^K, \phi^2 = \phi^1)$ is the wage-rental ratio when institutions are unbiased and heavy labor income tax imposed. The same ranking applies to biased institutional set up as well. The comparison of rankings across institutions and across fiscal policies yields $\omega_t(\tau_t^L > \tau_t^K, \phi^2 = \phi^1) > \omega_t(\tau_t^L = \tau_t^K, \phi^2 = \phi^1) > \omega_t(\tau_t^L < \tau_t^K, \phi^2 = \phi^1) > \omega_t(\tau_t^L > \tau_t^K, \phi^2 > \phi^1) > \omega_t(\tau_t^L = \tau_t^K, \phi^2 > \phi^1)$ $> \omega_t(\tau_t^L < \tau_t^K, \phi^2 > \phi^1)$. The response of the wage-rental ratio to a change in institutional structure can be derived from

$$\omega_t = A^2 e^{z^2(\phi^1,\phi^2)\rho^2} (k^2(\phi^1, \phi^2))^{1-\rho^2}$$

where $A^2 \equiv \left(\frac{1-\theta^2}{\theta^2}\right)$ and $z^2(\phi^1, \phi^2) = (1 - 2\lambda^2)\left(\frac{\phi^2 s_t^2 \overline{Y}_t^2}{\phi^1 s_t^1 \overline{Y}_t^1 + \phi^2 s_t^2 \overline{Y}_t^2}\right)$. Taking the natural logarithm of ω_t

$$\ln \omega_t = \ln A^2 + \rho^2 z^2(\phi^1, \phi^2) + (1 - \rho^2) \ln k^2(\phi^1, \phi^2)$$

and then the derivative of the resulting function with respect to ϕ^2 yields

$$\frac{\partial \ln \omega_t}{\partial \phi^2} = \rho^2 \frac{\partial z^2(\phi^1, \phi^2)}{\partial \phi^2} + (1 - \rho^2) \frac{\partial \ln k^2(\phi^1, \phi^2)}{\partial \phi^2}.$$

The fact that the closed forms for the partial derivatives on the right hand side of $\frac{\partial \ln \omega_t}{\partial \phi^2}$ are not known leaves us with numerical techniques.

tutions, gross national product is maximized when the investment good producing sector has higher technological capability and the government collects heavy labor income taxes, $Y_t(\tau_t^L > \tau_t^K, \eta^2 > \eta^1, \phi^2 = \phi^1)$. When institutions favor the capital intensive sector, national product increases, that is $Y_{t,}(\tau_t^L > \tau_t^K, \eta^2 > \eta^1, \phi^2 > \phi^1) > Y_t(\tau_t^L > \tau_t^K, \eta^2 > \eta^1, \phi^2 = \phi^1)$, implying a positive growth effect. However, welfare reaches its maximum level when $(\tau_t^L < \tau_t^K, \eta^2 < \eta^1, \phi^2 = \phi^1)$, which looks a little puzzling. What it implies, in fact, is that policies encouraging institutional bias as well as increasing technological capabilities of the investment good producing sector help correct the direction of technological change, and generate growth at the expense of welfare gains. In the situation where welfare is maximized however, dynamic inefficiency emerges due to the implementation of heavy capital taxes $\tau^K > \tau^L$.

4. Concluding remarks

This study develops a two-sector overlapping generations model, supposing that government is open to the influence of producers' collective action. Remaining within the confines of industrial policy arguments, the study draws attention to the role that distortions in government and asymmetrical technology absorption might play in the process of technological change. The goal is to provide a qualitative assessment of the effects of political lobbying on the direction of technical changes and on welfare along with the implied direction. This is accomplished by analyzing two scenarios. At one, sectors are not able to absorb the externalities from the existing stock of technology; at the other scenario, they are assumed to have asymmetric absorption capabilities.

Simulation results suggest that current generations are expected to experience welfare loss while a technologically advantageous environment is prepared for future generations. The undistorted government supports the path of capital-augmenting technological change, which is also the dominant path supported by the distorted government, operating with institutions that deliberately favor the investment good producing sector. This coincidence of the two paths implies a cost for the imposition of a biased institutional structure. A second main result is that sectoral asymmetries with respect to technology assimilation capabilities do not help industries cope with weaknesses in the political market, and hence do not help change the direction of technological developments. Finally, lobbying leads to excess supply of R&D compared to the level supported by the undistorted government, which further implies that consumers will have more tax burden in the lobbying economy.

5. References

1. Aghion,P., & Howitt, P. (1998). *Endogenous growth theory.* Cambridge: the MIT Press.

2. Alston, J. M., Chalfant, J. A., & and Pardey, G. P. (1993). Structural adjustment in OECD agriculture: Government policies and technical change (WP No. 93-3). St. Paul, MN: University of Minnesota, Center for International Food and Agricultural Policy.

3. Arrow, J. K. (1962). Economic welfare and the allocation of resources for inventions. In R. R. Nelson, (Ed.), T*he rate and direction of inventive activity.* Princeton: Princeton University Press.

4. Barro, R., & Sala-i-Martin, X. (1992). Economic growth. Unpublished manuscript. New Heaven, Connecticut: Yale University.

5. Becker, G. (1983). A theory of competition among pressure groups for political influence. *Quarterly Journal of Economic* 98: 371-400.

6. Binswanger, P. H., & Ruttan, W. V. (Eds.) (1978). *Induced innovation: Technology, institutions, and development.* Baltimore, Maryland: Johns Hopkins University Press.

7. Coe, D. T., & Helpman, E. (1993). International R&D spillover. NBER Working Paper No. 4463. Cambridge, Massachusetts: National Bureau of Economic Research.

8. Corcoran, W. J. (1984). Long-run equilibrium and total expenditures in rent-seeking. *Public Choice* 43: 89-94.

9. Craven, J. (1973). Stability in a two-sector model with induced bias. *The Economic Journal* 83: 858-862.

10. Dasgupta, P., & Stiglitz, J. (1980). Industrial structure and the nature of innovative activity. *Economic Journal*, 90: 266-293.

11. Dasgupta, P. (1986). The theory of technological competition. In J. E. Stiglitz and G. F. Mathewson, (Eds.), *New Developments in the Analysis of Market Structure.* Cambridge: MIT Press.

12. de Gorter, H., & Zilberman, D. (1985). On the political economy of providing public good inputs (WP No. 355). Berkeley: California Agricultural Experiment station.

13. de Janvry, A., & Sadoulet, E. (1988). Alternative approaches to the political economy of agricultural policies: Convergence of analytics, divergence of implications. Paper for Twentieth International Conference of Agricultural Economists, Buenos Aires.

14. de Janvry, A., Sadoulet, E., & and Fafchamps, M. (1989). Agrarian structure, technological innovations, and the state. In P. Bardhan (Ed.), *The economic theory of agrarian institutions.* Oxford: Clarendon Press.

15. Fisher, O. E. (1992). Sustained growth in the model of overlapping generations. *Journal of Economic Theory* 56: 77-92.

16. Denison, F. E. (1962). *Sources of economic growth in the US and the alternatives before us.* New York: Committee for Economic Development.

17. Downs, A. (1957). *An economic theory of democracy.* New York: Harper & Row.

18. Fisher, O. E. (1992). Sustained growth in the model of overlapping generations. *Journal of Economic Theory* 56: 77-92.

19. Evenson, E. R., & Westphal, E. L. (1995). Technological change and technology strategy. In J. Behrman & T. N. Srinivasan (Eds.), *Handbook of Development Economics*, vol. 3A. Amsterdam, NL: Elsevier Science B.V.

20. Evenson, E. R., & Kislev, Y. (1976). A stochastic model of applied research. *Journal of Political Economy* 84: 265-281.

21. Fuhrer, C. J., & Little, S. J. (Eds.) (1996). *Technology and growth.* Conference Proceedings, Federal Reserve Bank of Boston.

22. Hayami, Y., & Ruttan, W. V. (1985). Toward a theory of technical and institutional change. In Y. Hayami and V. W. Ruttan, *Agricultural development: An international perspective.* Baltimore: The Johns Hopkins University Press.

23. Hillman, A. L., & Katz, E. (1984). Risk-averse rent seekers and the social cost of monopoly power. *Economic Journal* 94: 104-110.

24. Hillman, A. L., & Ursprung, H. W. (1988). Domestic politics, foreign interests, and international trade policy. *American Economic Review* 78: 729-745.

25. Hirshleifer, J. (1989). Contest and rent-seeking functions: Ratio versus difference models of relative success. *Public Choice* 54: 63-82.

26. Griliches, Z. (1957). Hybrid corn: An exploration in the economies of technological change. *Econometrica* 25: 501-522.

27. Griliches, Z. (1963). The sources of measured productivity growth: U.S. agriculture 1940-1960. *Journal of Political Economy* 71: 331-346.

28. Griliches, Z. (1979). Issues in assessing the contribution of R&D to productivity growth. *Bell Journal of Economics* 10: 92-116.

29. Grindle, S. M. & Thomas, J. W. (1991). Policy makers, policy choices, and policy outcomes: Political economy of reform in developing countries. In D. H. Perkins, and M. Roemer (Eds.), *Reforming economic systems in developing countries.* Cambridge: Harvard University Press, 81-114.

30. Grossman, G., & Helpman, E. (1991). *Innovation and growth in the global economy.* Cambridge: MIT Press.

31. Justman, M., & and Teubal, M. (1986). Innovation policy in an open economy: A normative framework for strategic and tactical issues. *Research Policy* 15: 121-138.

32. Justman, M., & and Teubal, M. (1991). A structuralist perspective on the role of technology in economic growth and development. *World Development*, 19: 1167-1183.

33. Krueger, A. (1974). The political economy of the rent-seeking society. *American Economic Review* 64: 291-303.

34. Krugman, R. P. (1983). Targeted industrial policies: Theory and evidence. *Federal Reserve Bank of Kansas City*, 123-155.

35. Li, F. (1993). Institutional arrangements and long-run economic growth. Ph.D. dissertation. St. Paul, MN: University of Minnesota, Department of Agricultural and Applied Economics.

36. Lin, Y. J., & B. J. Nugent. (1995). Institutions and economic development. In J. Behrman & T. N. Srinivasan (Eds.), *Handbook of Development Economics*, vol. 3A. Amsterdam, NL: Elsevier Science B.V.

37. Lucas, R. (1988). On the mechanics of economic development. Journal of Monetary Economics, 22: 3-42.

38. Mamuneas, P. T. (1993). Spillovers from publicly financed R&D capital in high-tech industries. Unpublished manuscript.

39. Mansfield, E. (1961). Technical change and the rate of imitation. *Econometrica* 29: 741-766.

40. Magee, P. S., Brock, A. W., & Young, L. (1989). *Black hole tariffs and endogenous policy theory: Political economy in general equilibrium.* Cambridge: Cambridge University Press.

41. Malerba, F. (1992). Learning by firms and incremental technical change. *Economic Journal* 102: 845-859.

42. Murphy, K., Shleifer, A., & Vishny, R. (1989). Industrialization and the big push. *Journal of Political Economy,* 97: 1003-1026.

43. Nadiri, M. I., & Mamuneas, P. T. (1994a). The effects of public infrastructure and R&D capital on the cost structure and performance of US manufacturing industries. *The Review of Economics and Statistics* LXXVI: 22-37.

44. Nadiri, M. I., & Mamuneas, P. T. (1994b). Infrastructure and public R&D investments, and the growth of factor productivity in US manufacturing industries (WP No. 4845). Cambridge: National Bureau of Economic Research.

45. Nordhaus, W. D. (1969). *Invention, growth, and wealth.* Cambridge: MIT Press.

46. Norton, D. R. (1986). Industrial policy and American renewal. *Journal of Economic Literature* XXIV: 1-40.

47. Pardey, G. P., & Craig, B. (1989). Causal relationship between public sector agricultural research expenditures and output. *American Journal of Agricultural Economics* 71: 9-19.

48. Parente, L. S., & Prescott, C. E. (1993). Barriers to technology adoption and development. Unpublished manuscript. Minneapolis, MN: Federal Reserve Bank of Minneapolis, Research Department.

49. Pavitt, K. (1984). Sectoral patterns of technical change: Towards a taxonomy and a theory. *Research Policy* 13, 343-373.

50. Posner, R. A. (1975). The social costs of monopoly and regulation. *Journal of Political Economy* 83: 807-827.

51. Potters, J. & Widen, V. F. (1992). Lobbying and asymmetric information. *Public choice* 74: 269-292.

52. Romer, P. (1986). Increasing returns and long-run growth. *Journal of Political Economy*, 94: 1002-1037.

53. Romer, P. (1990). Endogenous technological change. *Journal of Political Economy*, 98: S71-S102.

54. Sandler, T. (1982). A theory of intergenerational clubs. *Economic Inquiry* 20: 191-208.

55. Solow, M. R. (1957). Technical change and the aggregate production function. *Review of Economics and Statistics* 39: 312-320.

56. Solow, M. R. (1974). The economics of resources or the resources of economics. *American Economic Review* 64: 1-14.

57. Solow, M. R. (1986). On the intergenerational allocation of natural resources. *Scandinavian Journal of Economics* 88: 141-149.

58. Tullock, G. (1967). The welfare costs of tariffs, monopolies, and theft. *Western Economic Journal* 5: 224-232.

59. Tullock, G. (1980). Efficient rent-seeking. In J. Buchanan, R. Tollison, and G. Tullock (Eds.), *Towards a theory of the rent-seeking society.* College station: Texas A&M University Press.

60. Tullock, G. (1984). Long-run equilibrium and total expenditures in rent-seeking: A comment. *Public choice* 43: 95-97.

61. Uzawa, H. (1962). On a two-sector model of economic growth. *Review of Economic Studies* 29: 40-47.

6. Appendix

6.1. Producers

Given a vector of variables $(w_t, r_t, p_t^i, G_t^i, s_t^{-i}, Y_t^{-i}, G_t, G_{t-1}) > 0$, a representative firm in sector i solves the static profit maximization problem by choosing $(Y_t^i, K_t^i, L_t^i, R_t^i)$[18] :

$$\begin{aligned}
\underset{(Y_t^i,K_t^i,L_t^i,R_t^i)}{Max}\ \Pi_t^i &= p_t^i Y_t^i - w_t L_t^i - r_t K_t^i && (6.1)\\
s.t.\ Y_t^i &= (1-R_t^i)E_{t-1}^i[\theta^i (A^i(G_t^i)K_t^i)^{\rho^i} + (1-\theta^i)(D^i(G_t^i)L_t^i)^{\rho^i}]^{\frac{\gamma^i}{\rho^i}} \\
G_t^i &= \left[\frac{\phi^i R_t^i \overline{Y}_t^i}{\sum_{i=1}^2 \phi^i R_t^i \overline{Y}_t^i}\right] G_t \\
0 &\leq Y_t^i,\ 0 \leq K_t^i,\ 0 \leq L_t^i,\ 0 \leq R_t^i \leq 1 && (6.2)
\end{aligned}$$

where $Y_t^i \equiv (1-R_t^i)\overline{Y}_t^i$ denotes the after-lobbying output of sector i at time t, K_t^i capital, L_t^i labor, G_t^i public input employed by sector i, G_t aggregate public R&D, R_t^i proportion of the output used in lobbying activities, ϕ^i parameter of institutional bias (or parameter of lobbying efficiency), θ^i parameter of capital-intensity, λ^i efficiency parameter of the capital-augmenting R&D, γ^i parameter of returns to scale, η^i parameter of technology absorption capability (or parameter of ability to make effective use of technology), and $\sigma^i = (\frac{1}{1-\rho^i})$ the elasticity of substitution between K_t^i and L_t^i. The terms $A^i(G_t^i)$ and $D^i(G_t^i)$ are the capital and labor-augmentation functions, respectively. The relative price of output is denoted by $p_t \equiv (\frac{p_t^1}{p_t^2})$ where the investment good is taken as numeraire, (i.e., $p_t^2 \equiv 1$); the wage-rental ratio by $\omega_t \equiv (\frac{w_t}{r_t})$ where w_t and r_t are rental rates of labor and capital, respectively. An index

$$E_{t-1}^i = \left\{ \begin{array}{ll} e^{\eta^i G_{t-1}} & \text{if } \eta^i > 0\ \forall_i \text{ and } \sum_{i=1}^2 \eta^i = 1 \\ 1 & \text{if } \eta^i = 0\ \forall \end{array} \right\}$$

is used to differentiate between the two models: one with technology absorption, the other one with no absorption. It is important to note that G_t^i enters the production function as a parameter rather than as a choice variable because its value is determined at the political market where producers (namely, lobbyists) and the distorted government interact.

[18] If $i = 1$, then $-i = 2$ or vice versa.

6.2. Consumers

Given $(w_t,\ r_t,\ p_t,\ p_{t+1}) > 0$, $(\tau_t^K,\ \tau_t^L) \geq 0$, and $\overline{\Pi}_t \geq 0$, a young person at time $t \geq 1$ chooses $(c_t(t),\ c_t(t+1),\ S_t)$ to maximize his/her utility:

$$\begin{aligned}
\underset{(c_t(t),c_t(t+1),S_t)}{Max} U_t &= \ln c_t(t) + \alpha \ln c_t(t+1) \\
s.t.\ p_t c_t(t) + S_t &\leq \overline{w}_t \overline{L} + \overline{\Pi}_t \\
p_{t+1} c_t(t+1) &\leq (1+i_{t+1})(1-\tau_t^K) S_t \\
0 &\leq c_t(t),\ 0 \leq c_t(t+1),\ \text{given } \overline{L} = 1. \qquad (6.3)
\end{aligned}$$

The elements of the vector $(c_t(t),\ c_t(t+1),\ S_t)$ represent time t and time $(t+1)$ consumption of the person born at time t, and savings at time t, respectively. p_{t+1} denotes the expected relative price at time t of the consumption good in terms of investment good. Savings at time t enable individuals to consume during the second period of their lives. The gross return to savings (or capital) $(1+i_{t+1})$ is known at time t by both borrowers and lenders. Effective (or after-tax) wage rate is defined as $\overline{w}_t \equiv (1-\tau_t^L) w_t$; the tax rates on labor and capital incomes are denoted by τ_t^L and τ_t^K, respectively. The total profit distributed is equal to $\overline{\Pi}_t \equiv \sum_{i=1}^{2} \Pi_t^i$.

The solution to (6.3) is $(c_t(t) = \frac{(\overline{w}_t+\overline{\Pi}_t)}{(1+\alpha)p_t},\ c_t(t+1) = \frac{\alpha(1+i_{t+1})(\overline{w}_t+\overline{\Pi}_t)}{(1+\alpha)p_{t+1}},\ S_t = \frac{\alpha(\overline{w}_t+\overline{\Pi}_t)}{(1+\alpha)})$. The indirect utility function then becomes

$$V_t(p_t, p_{t+1}, \overline{w}_t, i_{t+1}) = \ln\left(\frac{(\overline{w}_t+\overline{\Pi}_t)}{(1+\alpha)p_t}\right) + \alpha \ln\left(\frac{\alpha(1+i_{t+1})(\overline{w}_t+\overline{\Pi}_t)}{(1+\alpha)p_{t+1}}\right). \qquad (6.4)$$

At time $t=1$, the initial old person born at $t=0$ solves

$$\begin{aligned}
\underset{(c_0(1),S_0)}{Max} U_0 &= \alpha \ln c_0(1) \\
s.t.\ p_1 c_0(1) &\leq (1+i_1)(1-\tau_0^K) S_0 \\
c_0(1) &\geq 0,\ \text{given } S_0 = K_1 > 0 \qquad (6.5)
\end{aligned}$$

where $\overline{r}_1$ is effective (or after-tax) rental rate of capital at $t=1$; savings of the old person are equal to the economy-wide capital stock at $t=1$, that is, $S_0 = K_1$. The indirect utility level of the initial old person becomes $V_0(p_1, i_1) = \alpha \ln((1+i_1)(1-\tau_0^K) S_0/p_1)$.

6.3. Distorted government

Given (w_t, r_t, p_t^G, τ_t^K, τ_t^L), the distorted government chooses (G_t, K_t^G, L_t^G) to maximize the value of the production of R&D:

$$
\begin{aligned}
\underset{(G_t, K_t^G, L_t^G)}{Max} \; W_t^G &= p_t^G G_t \\
s.t. \; G_t &= (K_t^G)^{\delta}(L_t^G)^{1-\delta} \\
T_t &= w_t L_t^G + r_t K_t^G
\end{aligned}
\tag{6.6}
$$

where the shadow price p_t^G represents the value to society of incremental unit of R&D, in terms of the investment good. $K_t^G = \frac{\delta T_t}{r_t}$ and $L_t^G = \frac{(1-\delta)T_t}{w_t}$ are the government's demand for capital and for labor, respectively. The equilibrium provision of R&D is $G_t = (\frac{\delta}{r_t})^{\delta}(\frac{1-\delta}{w_t})^{1-\delta}T_t$ where δ stands for the share of capital in G_t. The government collects capital and labor income taxes, $T_t \equiv \tau_t^L w_t L_t + \tau_t^K r_t K_t$.

Definition 1. *(Political-economic equilibrium) Given* $(K_0, L_0) > 0$*, an allocation* $\{c_t(t),\ c_{t-1}(t),\ S_t,\ Y_t^i,\ K_t^i,\ L_t^i,\ G_t^i,\ R_t^i,\ K_t^G,\ L_t^G,\ G_t,\ G_{t-1}\ \forall_{i,t}\}$ *is feasible if* $R_t^i \in (0,1]$, $Y_t^i = (1-R_t^i)E_{t-1}^i[\theta^i(A^i(G_t^i)K_t^i)^{\rho^i} + (1-\theta^i)(D^i(G_t^i)L_t^i)^{\rho^i}]^{\frac{\gamma^i}{\rho^i}}$ *for* $i = 1, 2$, $G_t = (K_t^G)^{\delta}(L_t^G)^{1-\delta}$*, and* $G_t^i = I_t^i G_t$*. A political-economic equilibrium is a feasible allocation with accompanying price system* $\{w_t, r_t, p_t, p_t^G\}_{t=1}^{\infty}$*, a lobbying system* $\{R_t^i\}_{t=1}^{\infty}$*, and a tax scheme* $\{\tau_t^K, \tau_t^L\}_{t=1}^{\infty}$ *such that*

- representative firms solve (6.2),
- consumers solve (6.3 and 6.5),
- distorted government solves (6.6),
- capital market satisfies $K_{t+1} = S_t$ for all t, and
- input and output markets clear: $K_t = \sum_{i=1}^{2} K_t^i + K_t^G$, $L_t = \sum_{i=1}^{2} L_t^i + L_t^G$, $G_t = \sum_{i=1}^{2} G_t^i$, $S_t = Y_t^2$, and $c_t(t) + c_{t-1}(t) = Y_t^1$.

A political-economic equilibrium is an interior solution to the following system of equations. Given initial capital and labor endowments $(K_0, L_0) > 0$ and $E_0^i = 1$, this system is solved for $\{Y_t^i,\ K_t^i,\ L_t^i,\ G_t^i,\ R_t^i,\ \beta_{1t}^i,\ \beta_{2t}^i,\ c_t(t),\ c_t(t+1),\ S_t,\ \sigma_t,\ \sigma_{t+1},\ G_t,\ K_t^G,\ L_t^G,\ \mu_{1t},\ \mu_{2t},\ w_t,\ r_t,\ p_t \text{ for } \forall_{i=1,2}\}$:

$$\frac{\partial \ell^i}{\partial Y_t^i} = -\beta_{1t}^i + p_t^i = 0,\ \text{if } Y_t^i > 0 \tag{6.7}$$

$$\frac{\partial \ell^i}{\partial K_t^i} = (1 - R_t^i) Z_t^i e^{\rho^i \lambda^i G_t^i} (K_t^i)^{-1+\rho^i} \theta^i \beta_{1t}^i \gamma^i - r_t = 0,\ \text{if } K_t^i > 0 \tag{6.8}$$

$$\frac{\partial \ell^i}{\partial L_t^i} = (1 - R_t^i) Z_t^i e^{\rho^i (1-\lambda^i) G_t^i} (L_t^i)^{-1+\rho^i} (1 - \theta^i) \beta_{1t}^i \gamma^i - w_t = 0,\ \text{if } L_t^i > 0 \tag{6.9}$$

$$\frac{\partial \ell^i}{\partial R_t^i} = \beta_{2t}^i \left[\frac{\phi^i \overline{Y}_t^i}{\sum_{i=1}^2 \phi^i R_t^i \overline{Y}_t^i} - \frac{R_t^i (\phi^i \overline{Y}_t^i)^2}{(\sum_{i=1}^2 \phi^i R_t^i \overline{Y}_t^i)^2} \right] - \beta_{1t}^i \overline{Y}_t^i = 0,\ \text{if } R_t^i > 0 \tag{6.10}$$

$$\frac{\partial \ell^i}{\partial \beta_{1t}^i} = (1 - R_t^i) \overline{Y}_t^i - Y_t^i = 0,\ \text{if } \beta_{1t}^i > 0 \tag{6.11}$$

$$\frac{\partial \ell^i}{\partial \beta_{2t}^i} = \left[\frac{\phi^i R_t^i \overline{Y}_t^i}{\sum_{i=1}^2 \phi^i R_t^i \overline{Y}_t^i} \right] - C_t^i = 0,\ \text{if } \beta_{2t}^i > 0, \text{where } C_t^i \equiv (\frac{G_t^i}{G_t}) \tag{6.12}$$

$$\frac{\partial \ell^C}{\partial c_t(t)} = \frac{1}{c_t(t)} - \sigma_t p_t = 0,\ \text{if } c_t(t) > 0, \text{where } p_t \equiv (\frac{p_t^1}{p_t^2}) \tag{6.13}$$

$$\frac{\partial \ell^C}{\partial c_t(t+1)} = \frac{\alpha}{c_t(t+1)} - \sigma_{t+1} p_{t+1} = 0,\ \text{if } c_t(t+1) > 0 \tag{6.14}$$

$$\frac{\partial \ell^C}{\partial S_t} = \sigma_{t+1}(1 + i_{t+1})(1 - \tau_t^K) - \sigma_t = 0,\ \text{if } S_t > 0 \tag{6.15}$$

$$\frac{\partial \ell^C}{\partial \sigma_t} = \overline{\Pi}_t + \overline{L}\overline{w}_t - p_t c_t(t) - S_t = 0,\ \text{if } \sigma_t > 0 \tag{6.16}$$

$$\frac{\partial \ell^C}{\partial \sigma_{t+1}} = (1 + i_{t+1})(1 - \tau_t^K) S_t - p_{t+1} c_t(t+1) = 0,\ \text{if } \sigma_{t+1} > 0 \tag{6.17}$$

$$\frac{\partial \ell^G}{\partial G_t} = p_t^G - \mu_{1t} = 0, \text{ if } G_t > 0 \tag{6.18}$$

$$\frac{\partial \ell^G}{\partial K_t^G} = \delta (k_t^G)^{-1+\delta} \mu_{1t} - \mu_{2t} r_t = 0, \text{ if } K_t^G > 0, \text{ where } k_t^G \equiv (\frac{K_t^G}{L_t^G}) \tag{6.19}$$

$$\frac{\partial \ell^G}{\partial L_t^G} = (1-\delta)(k_t^G)^{\delta} \mu_{1t}^G - \mu_{2t} w_t = 0, \text{ if } L_t > 0 \tag{6.20}$$

$$\frac{\partial \ell^G}{\partial \mu_{1t}} = (k_t^G)^{\delta} - g_t = 0, \text{ if } \mu_{1t} > 0, \text{ where } g_t \equiv (\frac{G_t}{L_t^G}) \tag{6.21}$$

$$\frac{\partial \ell^G}{\partial \mu_{2t}} = T_t - (r_t K_t^G + w_t L_t^G) = 0, \text{ if } \mu_{2t} > 0, \tag{6.22}$$

$$K_t = \sum_{i=1}^{2} K_t^i + K_t^G \tag{6.23}$$

$$L_t = \sum_{i=1}^{2} L_t^i + L_t^G \tag{6.24}$$

$$G_t = \sum_{i=1}^{2} G_t^i \tag{6.25}$$

$$Y_t^2 = S_t \tag{6.26}$$

$$Y_t^1 = c_t(t) + c_{t-1}(t) \tag{6.27}$$

where we denote for notational simplicity $Z_t^i \equiv \left(\frac{\overline{Y}_t^i}{[\theta^i (A^i(G_t^i) K_t^i)^{\rho^i} + (1-\theta^i)(D^i(G_t^i) L_t^i)^{\rho^i}]} \right)$ and $\overline{Y}_t^i \equiv E_{t-1}^i [\theta^i (A^i(G_t^i) K_t^i)^{\rho^i} + (1-\theta^i)(D^i(G_t^i) L_t^i)^{\rho^i}]^{\frac{\gamma^i}{\rho^i}}$. There are 27 unknowns and 27 equations, implying the existence of a unique political-economic equilibrium. Manipulations of equation (6.8, 6.9) yield

$$k_t^i \equiv \left(\frac{K_t^i}{L_t^i} \right) = \left[\frac{\omega_t}{\left(\frac{1-\theta^i}{\theta^i} \right) e^{G_t^i (1-2\lambda^i) \rho^i}} \right]^{\left(\frac{1}{1-\rho^i} \right)} = k^i(\omega_t, G_t^i).$$

Substitution of (6.12) into $k^i(\omega_t, G_t^i)$ results in $k_t^i \left(\omega_t, \left(\frac{\phi^i R_t^i \overline{Y}_t^i}{\sum_{i=1}^2 \phi^i R_t^i \overline{Y}_t^i} \right) G_t \right)$, indicating that $k^i(.)$ is a function of $\left(\frac{K_t^i}{L_t^i} \right)$.

6.4. Undistorted government

Given $E_0^i = 1$, the undistorted government chooses (Y_t^i, K_t^i, L_t^i, G_t^i, K_t^B, L_t^B, G_t for $i = 1, 2$) to maximize gross national product, Y_t:

$$\begin{aligned}
\underset{(Y_t^i, K_t^i, L_t^i, G_t^i, K_t^B, L_t^B, G_t)}{Max} \; Y_t &= \sum_{t=0}^{\infty} \sum_{i=1}^{2} p_t^i Y_t^i \qquad (6.28) \\
s.t. \; Y_t^i &= E_{t-1}^i [\theta^i (e^{\lambda^i G_t^i} K_t^i)^{\rho^i} + (1-\theta^i)(e^{(1-\lambda^i)G_t^i} L_t^i)^{\rho^i}]^{\frac{\gamma^i}{\rho^i}}, \text{ for } i = 1, 2 \\
G_t &= (K_t^B)^{\delta} (L_t^B)^{1-\delta} \\
K_t &= \sum_{i=1}^{2} K_t^i + K_t^B \\
L_t &= \sum_{i=1}^{2} L_t^i + L_t^B \\
G_t &= \sum_{i=1}^{2} G_t^i.
\end{aligned}$$

The following system of equations is solved for $\{Y_t^i$, K_t^i, L_t^i, G_t^i, K_t^B, L_t^B, G_t, φ_{1t}^i for $i = 1, 2$, and φ_{jt} $\forall_{j=2,\ldots,5}\}$ where φ_{1t}^i and φ_{jt} are the Lagrangian multipliers:

$$\frac{\partial \ell^B}{\partial Y_t^1} = p_t - \varphi_{1t}^1 = 0, \text{ if } Y_t^1 > 0, \qquad (6.29)$$

$$\frac{\partial \ell^B}{\partial Y_t^2} = 1 - \varphi_{1t}^2 = 0, \text{ if } Y_t^2 > 0, \qquad (6.30)$$

$$\frac{\partial \ell^B}{\partial K_t^i} = Z_t^i e^{\rho^i \lambda^i G_t^i} (K_t^i)^{-1+\rho^i} \theta^i \gamma^i \varphi_{1t}^i - \varphi_{2t} = 0, \text{ if } K_t^i > 0, \qquad (6.31)$$

$$\frac{\partial \ell^B}{\partial L_t^i} = Z_t^i e^{\rho^i (1-\lambda^i) G_t^i} (L_t^i)^{-1+\rho^i} (1-\theta^i) \gamma^i \varphi_{1t}^i - \varphi_{3t} = 0, if \, L_t^i > 0, \qquad (6.32)$$

$$\begin{aligned}
\frac{\partial \ell^B}{\partial G_t^i} &= \left(\varphi_{1t}^i \gamma^i Z_t^i \left((1-\lambda^i)(1-\theta^i) \rho^i \left(D^i (G_t^i) L_t^i \right)^{\rho^i} + \lambda^i \theta^i \rho^i \left(A^i (G_t^i) K_t^i \right)^{\rho^i} \right) \right) / \rho^i - \varphi_{4t} \\
&= 0, \text{ if } G_t^i > 0, \qquad (6.33)
\end{aligned}$$

$$\frac{\partial \ell^B}{\partial G_t} = \varphi_{4t} - \varphi_{5t} = 0, \text{ if } G_t > 0, \tag{6.34}$$

$$\frac{\partial \ell^B}{\partial K_t^B} = \varphi_{5t}\delta \left(\frac{L_t^B}{K_t^B}\right)^{1-\delta} - \varphi_{2t} = 0, \text{ if } K_t^B > 0, \tag{6.35}$$

$$\frac{\partial \ell^B}{\partial L_t^B} = \varphi_{5t}(1-\delta) \left(\frac{K_t^B}{L_t^B}\right)^{\delta} - \varphi_{3t} = 0, \text{ if } L_t^B > 0, \tag{6.36}$$

$$\frac{\partial \ell^B}{\partial \varphi_{1t}^i} = E_{t-1}^i[\theta^i(A^i(G_t^i)K_t^i)^{\rho^i} + (1-\theta^i)(D^i(G_t^i)L_t^i)^{\rho^i}]^{\frac{\gamma^i}{\rho^i}} - Y_t^i = 0, \text{ if } \varphi_{1t}^i > 0, \tag{6.37}$$

$$\frac{\partial \ell^B}{\partial \varphi_{2t}} = K_t - K_t^1 - K_t^2 - K_t^B = 0, \text{ if } \varphi_{2t} > 0, \tag{6.38}$$

$$\frac{\partial \ell^B}{\partial \varphi_{3t}} = L_t - L_t^1 - L_t^2 - L_t^B = 0, \text{ if } \varphi_{3t} > 0, \tag{6.39}$$

$$\frac{\partial \ell^B}{\partial \varphi_{4t}} = G_t - G_t^1 - G_t^2 = 0, \text{ if } \varphi_{4t} > 0, \tag{6.40}$$

$$\frac{\partial \ell^B}{\partial \varphi_{5t}} = (K_t^B)^{\delta}(L_t^B)^{1-\delta} - G_t = 0, \text{ if } \varphi_{5t} > 0. \tag{6.41}$$

There are 18 unknowns and 18 equations, therefore there exists a unique solution.

Figure 1. Unbiased Institutions ($\phi^1=\phi^2$) and Technology Absorption ($\eta^i>0$ for i=1,2)