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Abstract

This paper provides a politico-economic analysis of the European Union's (EU) R&D policy. It develops an open-economy R&D-growth model characterized by two parameters that capture respectively the degree of technology spillover and the effectiveness of lobbying. In a non-cooperative equilibrium, each country chooses the level of R&D subsidy independently and fails to internalize technology spillover. Consequently, R&D subsidy is underprovided. In an economic union, the central government internalizes technology spillover but is vulnerable to lobbying by politicians from each country, who attempt to free-ride on the central government budget. Consequently, R&D subsidy is overprovided; however, this overprovision becomes less severe as the degree of technology spillover increases. Therefore, technology spillover has a surprisingly positive effect on welfare in an economic union. As for the effect on relative welfare, there is a cutoff value for the degree of technology spillover such that if and only if spillover is above this threshold, then an economic union dominates independent countries in welfare. Furthermore, this threshold is an increasing function in the effectiveness of lobbying. This paper also considers the possibility that the EU faces a binding budget ceiling. In this case, lobbying on R&D subsidy exerts a distortionary effect on revenue allocation, and hence a welfare loss continues to exist.

***Keywords*:** endogenous growth, policy coordination, lobbying, R&D subsidy

***JEL classification*:** D72, H20, O38, O41

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1. Introduction

At the European Council of 2002 in Barcelona, the European Union (EU) sets an objective of increasing the research and development (R&D) effort in Europe to 3% of the EU's GDP by 2010. Because of externalities associated with R&D investment, the market equilibrium level of R&D spending is likely to be lower than the social optimum.[1] Therefore, government intervention may be able to correct for this market failure. For example, in a quantitative analysis, Eaton et al. (1998) find that increasing R&D subsidy can lead to a significant increase in the EU's per capita income.[2] However, because these benefits of R&D subsidy are largely shared across countries, individual country has little incentive to pursue these policies on its own. This conventional policy argument suggests a role for supranational government intervention, such as the EU for the European economies, on R&D policies.

An important example is the Framework Programme (FP) for Research and Technological Development,[3] which is the EU's main instrument for funding research in Europe. Two interesting features of the FP are (a) the budget of FP7 (2007 to 2013) has increased significantly to €50.5 billion compared to €17.5 billion for FP6 (2002 to 2006), and (b) research priorities in FP are the result of political negotiations. During the Commission's initial drafting of proposals for the FP and the process of reviewing these proposals in the European Parliament and the Council, interest groups have opportunities to exert their influences through lobbying.[4] For example, in a study by the European Institute of Romania, the authors argue that "[t]he current system in which the priorities of The Framework programs are the result of political negotiations in the Council… leads to a useless increase of the priorities number…" Pre-Accession Impact Studies III (no. 8, p. 50)

This paper provides a politico-economic analysis of the EU's R&D policies and argues that there exists a non-trivial tradeoff between R&D subsidy provided by an economic union and R&D subsidy

[1] See, for example, Jones and Williams (1998, 2000).

[2] "It takes less than a 5% research subsidy to raise average per capita income levels in the European Union to a higher steady-state level of 10%." Eaton et al. (1998, p. 408)

[3] Detailed information about this program is posted on its website (http://cordis.europa.eu/fp7/home_en.html).

[4] Langenberg (2004) provides a detailed case study of the decision-making process on FP6 and discusses the opportunities in which interest groups can influence the Commission and the Parliament. Bache and George (2006) provide a comprehensive discussion on the EU's policy process and the influences of interest groups.

provided by independent countries. In particular, it develops a simple open-economy R&D-growth model characterized by two parameters that capture respectively the degree of technology spillover and the effectiveness of lobbying.

In a non-cooperative equilibrium between independent countries, each country chooses the level of R&D subsidy non-cooperatively and fails to internalize the benefits of technology spillover on the other country. As a result, R&D subsidy is underprovided, and this underprovision becomes more severe as the degree of technology spillover increases. In an economic union, the central government is vulnerable to lobbying by politicians from each country, who have the incentive to free-ride on the central government budget. As a result, R&D subsidy is overprovided, and this overprovision becomes more severe as the effectiveness of lobbying increases. In contrast, as the degree of technology spillover increases, the overprovision of R&D subsidy becomes less severe. Therefore, technology spillover has a surprisingly positive effect on welfare in an economic union. As for the effect on relative welfare, there is a cutoff value for the degree of technology spillover such that if and only if spillover is above this threshold, then an economic union dominates independent countries in welfare. Furthermore, this threshold for technology spillover is an increasing function in the effectiveness of lobbying.

The above analysis implicitly assumes that the central government can raise as much revenue as it sees fit. However, the EU's budget has a ceiling of 1.24% of the EU-27's gross national income. Therefore, this paper also considers the possibility that the EU faces a binding budget constraint and shows that lobbying on R&D subsidy continues to exert a distortionary effect through revenue misallocation and leads to a welfare loss.

Related Literature

This paper relates to the R&D endogenous-growth literature. In variants of closed-economy R&D-growth models, Segerstrom (2000) analyzes the growth effects of R&D subsidy while Peretto (2007) analyzes the welfare effects of R&D tax credit. In an open-economy R&D-growth model, Impullitti (2007, 2008) performs a quantitative analysis of international R&D-subsidy game and quantifies the welfare effects of

R&D-subsidy coordination. The current study complements this literature by incorporating the political-economy aspects, such as lobbying and free-riding, of coordination into the analysis of R&D subsidy within an endogenous-growth model.[5]

Persson and Tabellini (1994) analyze the effect of centralization on the size of government budget and the provision of local public goods and find that a positive effect arises due to lobbying by politicians, who have the incentive to free-ride on the central government budget.[6] The current study incorporates this effect into the analysis of R&D subsidy and extends their study by allowing for spillover effects and considering the possibility of a binding budget ceiling. I show that the presence of technology spillover reduces the magnitude of overprovision and that lobbying in the case of a binding budget ceiling continues to exert a distortionary effect through revenue misallocation.

In a complementary study, Chu and Yang (2008) also analyze the tradeoff between spillover effects of local public goods under decentralization and the common-pool problem under centralization. Chu and Yang (2008) simplify the macroeconomy by using a simple AK-growth model in order to formulate the strategic interaction between agents as a differential game and analyze the equilibrium outcomes under different solution concepts. In contrast, the current study simplifies the game-theoretic dimension of the analysis in order to focus on a richer growth engine that is suitable for analyzing R&D subsidy, which is an important policy instrument.

The rest of this paper is organized as follows. Section 2 presents the underlying R&D-growth model. Section 3 provides the politico-economic analysis. The final section concludes. All proofs are relegated to Appendix A.

[5] Drazen (2000, ch. 11) and Persson and Tabellini (2000, ch. 14) provide a comprehensive review on the political economy of growth. In a related study, Chu (2008) provides a politico-economic analysis on the special interest politics of pharmaceutical patents in the US.

[6] This idea of centralization causing a common-pool problem has long been recognized by political economists and was formalized by Weingast et al. (1981) in a model of pork-barrel spending. In a cross-country empirical study, Bradbury and Crain (2001) provide supportive evidence for the presence of this common-pool problem.

2. The Model

The quality-ladder growth model is a modified version of Aghion and Howitt (1992) and Grossman and Helpman (1991a). There are two symmetric countries indexed by $n \in \{a,b\}$. Transportation costs are assumed to be zero, and trade is balanced in every period. For analytical tractability, the model features both differentiated goods and homogenous goods with a quasi-linear preference as in Grossman and Lai (2004). Each monopolistic firm sells intermediate goods in both countries. At the aggregate level, any transfer of dividend income across the two countries is balanced by an equal value of trade in homogenous goods. The model is also modified to allow for in-house R&D performed by industry leaders as in Peretto (1999) and to eliminate scale effects as in Segerstrom (1998).[7] Given that quality-ladder models are relatively well-studied, the model's components are briefly sketched out in Sections 2.1 – 2.4, and detailed derivations are relegated to an unpublished appendix available upon request. The balanced-growth equilibrium is defined in Section 2.5, and the welfare function that will be used for the policy analysis is derived in Section 2.6.

2.1. Households

There is a continuum of identical households on the unit interval residing in each of the two symmetric countries indexed by a superscript $n \in \{a,b\}$. Their lifetime utility function is

(1) $$U^n = \int_0^\infty e^{-(\rho - g_L)t} u_t^n dt ,$$

and the instantaneous utility function is

(2) $$u_t^n = c_{h,t}^n + (1-\theta)\ln c_{q,t}^{n,n} + \theta \ln c_{q,t}^{n,m} .$$

$c_{h,t}^n$ is the per capita consumption of homogenous goods chosen as the numeraire. $c_{q,t}^{n,m}$ refers to quality-enhancing differentiated goods consumed by country n and produced by country m. $\theta \in [0,0.5]$ is the share of differentiated goods traded and captures the degree of technology spillover. Each household has

[7] See Jones (1995a, 1999) for a discussion of scale effects in R&D-growth models.

$L_t = \exp(g_L t)$ members at time *t*, and g_L is the exogenous population growth rate. $\rho > g_L$ is the subjective discount rate. Each household maximizes utility subject to a sequence of budget constraints

(3) $$\dot{a}_t^n = (r_t - g_L)a_t^n + w_t^n - c_{h,t}^n - P_{q,t}^{n,n} c_{q,t}^{n,n} - P_{q,t}^{n,m} c_{q,t}^{n,m} - \tau_t^n .$$

a_t^n is the per capita holding of financial assets, and $\dot{a}_t^n$ denotes the change in a_t^n with respect to time. r_t is the real rate of return on a_t^n and equals ρ for all *t* (a property of the quasi-linear preference) from the household's intertemporal optimization. Because r is constant over time, its time subscript will be suppressed for easier exposition. As for the value of financial assets, it equals the market value of monopolistic firms. Each person supplies one unit of homogenous labor in each period to earn a wage income w_t^n and pays a lump-sum tax τ_t^n.

Differentiated final goods are produced by a CES aggregator over a continuum of differentiated intermediate goods $j \in [0,1]$ given by

(4) $$Y_{q,t}^{n,m} = \left(\int_0^1 (Y_{q,t}^{n,m}(j))^{\varepsilon} dj \right)^{1/\varepsilon}$$

where $\varepsilon \in (0,1)$. $Y_{q,t}^{n,m}(j)$ refers to intermediate goods *j* consumed by country *n* and produced by country *m*. The elasticity of substitution between intermediate goods is $1/(1-\varepsilon)$.

2.2. Homogenous Goods

There exists a large number of competitive firms in each country producing the homogenous goods $Y_{h,t}^n$. The production function has constant returns to scale in labor input $L_{h,t}^n$ given by

(5) $$Y_{h,t}^n = \alpha L_{h,t}^n .$$

The marginal cost of production is

(6) $$MC_{h,t}^n = w_t^n / \alpha .$$

Because the homogenous goods are chosen to be the numeraire and this sector is characterized by marginal-cost pricing, $MC_{h,t}^{n}=1$ and $w_t^n=\alpha$ for $n\in\{a,b\}$.

2.3. Differentiated Goods

In each country, there is a continuum of industries on the unit interval producing the differentiated intermediate goods. Each industry $j\in[0,1]$ in country *n* is dominated by a permanent monopolistic leader as in Peretto (1999). The production function in industry *j* is

$$Y_{q,t}^{n,n}(j)+Y_{q,t}^{m,n}(j)=A_t^n(j)L_{q,t}^n(j). \tag{7}$$

$L_{q,t}^n(j)$ is the number of workers in industry *j* of country *n*. $A_t^n(j)$ is the industry leader's marginal product of labor, which increases over time due to technological innovation driven by the leader's R&D investment. The marginal cost of production in industry *j* of country *n* is $MC_{q,t}^n(j)=w_t^n/A_t^n(j)$. To maximize profit, the industry leader charges a markup μ over the marginal cost such that

$$P_{q,t}^{n,n}(j)=P_{q,t}^{m,n}(j)=\mu MC_{q,t}^n(j), \tag{8}$$

where $\mu\equiv 1/\varepsilon$ is determined by the elasticity of substitution between intermediate goods.

2.4. R&D

Given a level of technology $A_t^n(j)$ in industry j of country *n* at time *t*, the *gross* amount of flow profit in this industry before deducting the cost of R&D investment is given by

$$\pi_t^n(j)=(\mu-1)MC_{q,t}^n(j)(Y_{q,t}^{n,n}(j)+Y_{q,t}^{m,n}(j)), \tag{9}$$

which is increasing in the industry's level of technology relative to the country's level of technology given by $A_t^n\equiv\left(\int_0^1 A_t^n(j)^{\varepsilon/(1-\varepsilon)}dj\right)^{(1-\varepsilon)/\varepsilon}$. To improve its level of technology, an industry leader invests in R&D, and the law of motion for $A_t^n(j)$ is given by

(10) $$\dot{A}_t^n(j) = \overline{\varphi}_t^n (L_{r,t}^n(j))^{\gamma},$$

where $\gamma \in (0,1)$ captures the degree of decreasing returns to scale in R&D investment, and $\overline{\varphi}_t^n$ is the R&D productivity in country *n* that the industry leader takes as given. To eliminate scale effects, $\overline{\varphi}_t^n$ is assumed to be

(11) $$\overline{\varphi}_t^n = \varphi (A_t^n)^{\phi},$$

where the parameter $\phi < 1$ captures the externality of intertemporal knowledge spillovers from the country's level of technology.[8]

The *net* amount of flow profit after deducting the cost of R&D is

(12) $$\widetilde{\pi}_t^n(j) = \pi_t^n(j) - (1 - s_t^n)(w_t^n L_{r,t}^n(j)),$$

where $s_t^n \in [0,1]$ is the subsidy rate for R&D investment in country *n*. The market value of firm j in country *n* is the present value of the stream of net profits $\widetilde{\pi}_t^n(j)$ given by

(13) $$V_t^n(j) = \int_t^{\infty} e^{-r(u-t)} \widetilde{\pi}_u^n(j) du.$$

An industry leader maximizes (13) subject to (10) taking A_t^n and s_t^n as given. As in Peretto (1999), I focus on the symmetric equilibrium across industry $j \in [0,1]$ within each country.

2.5. Balanced-Growth Equilibrium

The analysis starts at $t = 0$ when the economy has reached its balanced-growth path corresponding to the fiscal policies $\{s^n, \tau^n\}$ for $n \in \{a,b\}$. The equilibrium is a sequence of prices $\{r_t, w_t^n, P_{q,t}^{n,n}, P_{q,t}^{n,m}, V_t^n\}_{t=0}^{\infty}$ and a sequence of allocations $\{a_t^n, c_{h,t}^n, c_{q,t}^{n,n}, c_{q,t}^{n,m}, L_{q,t}^n, L_{r,t}^n, L_{h,t}^n\}_{t=0}^{\infty}$ for $n \in \{a,b\}$. Also, in each period,

[8] As discussed in Jones (1995b), $\phi \in (0,1)$ corresponds to the "standing-on-shoulder" effect, in which R&D productivity increases as the level of technology increases. On the other hand, $\phi < 0$ corresponds to the opposite case of the "fishing-out" effect. I assume local knowledge spillover at the national level as in Grossman and Helpman (1991b).

(a) households in country n choose $\{a_t^n, c_{h,t}^n, c_{q,t}^{n,n}, c_{q,t}^{n,m}\}$ to maximize (1) subject to (2) taking $\{r_t, w_t^n, P_{q,t}^{n,n}, P_{q,t}^{n,m}\}$ and the lump-sum tax τ^n as given;

(b) the competitive homogenous-goods firms in country n choose $\{L_{h,t}^n\}$ to maximize profits taking $\{w_t^n\}$ as given;

(c) industry leader j in country n chooses $\{P_{q,t}^{n,n}(j), P_{q,t}^{m,n}(j), L_{q,t}^n(j), L_{r,t}^n(j)\}$ to maximize the firm's market value taking $\{Y_{q,t}^{n,n}(j), Y_{q,t}^{m,n}(j), w_t^n, A_t^n\}$ and the R&D subsidy rate s^n as given;

(d) the global market for homogenous goods clears;

(e) the market for quality-enhancing goods in each country clears;

(f) the labor market in each country clears.

To solve for the balanced-growth rate of A_t^n denoted by g_A^n, the law of motion for A_t^n becomes

(14)
$$\dot{A}_t^n = \varphi (A_t^n)^{\phi} (L_{r,t}^n)^{\gamma}$$

after substituting (11) into (10) and applying the symmetry condition. In the followings, I show that $L_{r,t}^n$ increases at g_L. Therefore, g_A^n must be proportional to g_L because

(15)
$$g_A^n \equiv \frac{\dot{A}_t^n}{A_t^n} = \frac{\varphi (L_{r,t}^n)^{\gamma}}{(A_t^n)^{1-\phi}} = \frac{\gamma}{1-\phi} g_L .$$

Given $g_A^a = g_A^b$, I denote $g_A \equiv g_A^a = g_A^b = g_L \gamma/(1-\phi)$. The long-run technology growth rate is determined by exogenous parameters (i.e. a semi-endogenous growth model as in Jones (1995b, 1999)). In this model, a permanent increase in R&D subsidy increases the long-run level of technology holding the long-run growth rate constant.

In the unpublished appendix available upon request, I show that the balanced-growth equilibrium outcomes are characterized by

(16)
$$L_{q,t}^n = \left(\frac{\varepsilon}{\alpha} \right) L_t ,$$

(17)
$$L_{r,t}^{n} = \left(\frac{1}{1-s^{n}}\right)\left(\frac{g_A\gamma}{\rho+g_A-g_L}\right)\left(\frac{\varepsilon}{\alpha}\right)L_t,$$

(18)
$$L_{h,t}^{n} = \left(1-\frac{\varepsilon}{\alpha}\left(1+\left(\frac{1}{1-s^{n}}\right)\frac{g_A\gamma}{\rho+g_A-g_L}\right)\right)L_t,$$

(19)
$$c_{q,t}^{n,n} = \theta\left(\frac{A_t^{n}\varepsilon}{\alpha}\right),$$

(20)
$$c_{q,t}^{n,m} = (1-\theta)\left(\frac{A_t^{m}\varepsilon}{\alpha}\right),$$

(21)
$$c_h^{n} = \alpha - 1 - \tau^{n} + (\rho - g_L)a^{n},$$

(22)
$$(\rho - g_L)a^{n} = 1-\varepsilon\left(1+\frac{g_A\gamma}{\rho+g_A-g_L}\right).$$

α is assumed to be sufficiently large such that each person in country *n* consumes a positive amount of homogenous goods. Also, the following parameter restriction ensures that the amount of dividend income $(\rho - g_L)a^{n}$ is positive.

(a1)
$$\varepsilon \in (0,\bar{\varepsilon}),$$

where $\bar{\varepsilon} \equiv (\rho + g_A - g_L)/(g_A\gamma + \rho + g_A - g_L)$. (a1) imposes an upper bound on the substitution elasticity to ensure that the gross amount of monopolistic profit is sufficient to pay for the cost of R&D.

2.6. Social Welfare

This section derives the social-welfare function that will be used for the policy analysis. Given the equilibrium conditions on the balanced-growth path, the representative household's lifetime utility (1) can be rewritten as

(23)
$$U^{n} = \frac{c_h^{n} + (1-\theta)\ln c_{q,0}^{n,n} + \theta \ln c_{q,0}^{n,m}}{\rho - g_L} + \left(\int_0^{\infty} e^{-(\rho-g_L)t}(g_A t)dt\right).$$

After dropping the constant terms and the exogenous balanced-growth path, social welfare becomes

(24) $$W^n \equiv (\rho - g_L)U^n = c_h^n(\tau^n) + (1-\theta)\ln A_0^n(s^n) + \theta \ln A_0^m(s^m).$$[9]

c_h^n is a function of τ^n because an increase in τ^n reduces the consumption of c_h^n. A_0^n is a function of s^n because an increase in s^n raises the number of R&D workers and hence the level of technology in country *n*. Differentiating the balanced-growth condition (15) with respect to s^n yields

(25) $$\frac{\partial \ln A_0^n}{\partial s^n} = \left(\frac{\gamma}{1-\phi}\right)\frac{\partial \ln L_{r,0}^n}{\partial s^n}.$$

For $\theta > 0$, an increase in s^n increases A_0^n that benefits households in both countries while the tax burden of $\tau^n L_t = s^n w^n L_{r,t}^n$ falls upon domestic households. This leads to a positive externality of technology spillover, and the degree of spillover is determined by the share of differentiated goods traded.

3. A Politico-Economic Analysis

There is a group of politicians in each country, and their objective is to maximize the welfare of households in their country. In the case of independent countries, politicians in each country form a national government and choose the level of R&D subsidy independently and simultaneously. This policy outcome will be referred to as the non-cooperative equilibrium between independent countries. In the case of an economic union, there is a central government that internalizes technology spillover; however, this central government is vulnerable to lobbying by politicians from each country. This policy outcome will be referred to as the political equilibrium in an economic union. In both regimes, I follow Grossman and Lai (2004) to solve the Nash equilibrium in which agents choose their policies once and for all at time 0. The following sections derive the cooperative equilibrium, the non-cooperative equilibrium between independent countries, and the political equilibrium in an economic union. Then, I consider the possibility of a binding budget ceiling faced by the economic union.

[9] In order to perform the welfare analysis analytically, I focus on social welfare along the balanced-growth path as in Grossman and Lai (2004). To capture the transition dynamics, numerical analysis becomes necessary.

3.1. Cooperative Equilibrium

I firstly derive the cooperative equilibrium that is free from lobbying and technology spillover. This equilibrium serves as a very useful benchmark for comparison. In this case, the two groups of politicians cooperate and maximize $W^a + W^b$ subject to $(\tau^a + \tau^b)L_t = s^a w^a L^a_{r,t} + s^b w^b L^b_{r,t}$. To simplify notation, two new parameters $\Omega \equiv \varepsilon g_A(1-\phi)/(\rho + g_A - g_L) > 0$ and $\Phi \equiv \gamma/(1-\phi) > 0$ are defined.

Lemma 1: *The cooperative equilibrium is characterized by*

(26) $$s^* = 1 - \Omega,$$

(27) $$\tau^* = \Phi(1-\Omega).$$

At the optimal R&D subsidy rate s^*, the number of R&D workers is at the social optimum given by $L^*_{r,t} \equiv \arg\max(W^a + W^b) = \Phi(L_t/\alpha)$. The government is able to use R&D subsidy to achieve the first-best outcome for R&D spending because the lump-sum tax does not have any distortionary effect.

3.2. Independent Countries

I now derive the non-cooperative equilibrium between independent countries that is vulnerable to technology spillover. In this case, politicians in country n choose s^n to maximize W^n subject to $\tau^n L_t = s^n w^n L^n_{r,t}$ taking s^m as given.

Lemma 2: *The non-cooperative equilibrium between independent countries is characterized by*

(28) $$s^{ind}(\underset{-}{\theta}) = 1 - \Omega/(1-\theta) \leq s^*,$$

(29) $$\tau^{ind}(\underset{-}{\theta}) = \Phi(1-\theta-\Omega) \leq \tau^*.$$

(28) shows that $s^{ind} < s^{*}$ for $\theta > 0$. Due to the positive externality of technology spillover, the two countries under-subsidize R&D in equilibrium. The magnitude of this underprovision is increasing in the degree of technology spillover θ.

3.3. Economic Union

I now derive the political equilibrium in an economic union. In this case, the central government is vulnerable to lobbying by politicians from each country. The campaign-contribution lobbying model originates from Grossman and Helpman (1994).[10] Each group of politicians maximizes W^n by choosing an amount of campaign contribution z^n in each period that is financed by households in country *n*. I follow Persson and Tabellini (1994) to assume that the politicians can commit to a contribution schedule $z^n = Z(s^n)$ that is a differentiable and increasing function in s^n. Taking the contribution schedule $Z(s^n)$ as given, the central government maximizes

$$(W^a - z^a) + (W^b - z^b) + \omega(z^a + z^b), \tag{30}$$ [11]

subject to $(\tau^a + \tau^b)L_t = s^a w^a L^a_{r,t} + s^b w^b L^b_{r,t}$. ω is the weight that the central government places on campaign contributions and captures the effectiveness of lobbying. I assume $\omega > 1$ as in Persson and Tabellini (1994) so that lobbying will have an effect on the policy outcome.

[10] In the political-economy literature, there is another branch of lobbying model based on information asymmetry. See, for example, Grossman and Helpman (2001, Section II). In the EU, informational lobbying is probably more important than campaign contributions. However, I decide to adopt a campaign-contribution lobbying model for two reasons. Firstly, this model is more tractable to be incorporated into an R&D-growth model. Secondly, this formulation is consistent with Persson and Tabellini (1994) for an easier direct comparison.

[11] As in Persson and Tabellini (1994), I do not specify a political mechanism on how the central government uses the amount of campaign contributions. One possibility suggested in this type of literature is that the government uses the funding for redistributive politics in order to gain political support from marginal voters.

Lemma 3: *The political equilibrium in an economic union is characterized by*

(31) $$\underset{+\ \ -}{s^{eu}(\omega,\theta)} = 1 - \Omega\underbrace{\left(\frac{1+\omega}{2[1+(\omega-1)(1-\theta)]}\right)}_{\leq 1} \geq s^{*},$$

(32) $$\underset{+\ \ -}{\tau^{eu}(\omega,\theta)} = \Phi\left(\frac{2[1+(\omega-1)(1-\theta)]}{1+\omega} - \Omega\right) \geq \tau^{*},$$

(33) $$Z(s^{eu}) = \max\left[0, \left(\frac{s^{eu}}{1-s^{eu}} - \frac{s^{*}}{1-s^{*}}\right)\left(\frac{\Phi\Omega}{\omega-1}\right)\left(1 - \frac{1+\omega}{2[1+(\omega-1)(1-\theta)]}\right)\right].$$

(31) shows that $s^{eu} > s^{*}$ for $\theta < 0.5$ and $\omega > 1$. Having the incentive to free-ride on the central government budget, politicians from each country lobby the central government in order to obtain more R&D subsidy for their country. This multilateral attempt results into an excessive amount of R&D subsidy in equilibrium, and this overprovision is increasing in the effectiveness of lobbying ω. In contrast, the overprovision is decreasing in the degree of technology spillover θ because the politicians have less incentive to lobby the central government when increasing R&D subsidy partly benefits the other country. At $\theta = 0.5$, $s^{eu} = s^{*}$ for any $\omega > 1$ and hence $z^{eu} = 0$.

3.4. Welfare Analysis

(15) and (17) determine $A_0^n(s^n)$ while (21) determines $c_h^n(\tau^n)$. Substituting (26) – (29) into (24) yields the welfare difference between the cooperative equilibrium and the non-cooperative equilibrium between independent countries given by

(34) $$W^{*} - W^{ind}\underset{-}{(\theta)} = \Phi\left(\ln\left(\frac{1}{1-\theta}\right) - \theta\right) > 0$$

for $\theta > 0$. $W^{*} - W^{ind}$ is increasing in θ. Relative to the cooperative equilibrium, the non-cooperative governments underprovide R&D subsidies, and the welfare loss from this underprovision increases in θ.

Similarly, the welfare difference between the cooperative equilibrium and the political equilibrium in an economic union is

$$(35) \qquad W^* - W^{eu}(\underset{-}{\omega},\underset{+}{\theta}) = \Phi\left(\frac{(\omega-1)(1-2\theta)}{(1+\omega)} + \ln\left(\frac{1+\omega}{2[1+(\omega-1)(1-\theta)]}\right)\right) > 0,$$ [12]

for $\theta < 0.5$ and $\omega > 1$. $W^* - W^{eu}$ is increasing in ω and decreasing in θ. Relative to the cooperative equilibrium, politicians in country *n* attempt to externalize the tax burden of s^n to the other country by lobbying the central government to increase s^n. As ω increases, the central government becomes more responsive to contributions; as a result, the problem of overprovision becomes more severe. As θ increases, the benefit of increasing s^n for the households in country *n* decreases; as a result, politicians' lobbying intensity and the magnitude of overprovision decrease.

Finally, the welfare difference between the political equilibrium in an economic union and the non-cooperative equilibrium between independent countries is

$$(36) \qquad W^{eu}(\underset{-}{\omega},\underset{+}{\theta}) - W^{ind}(\underset{-}{\theta}) = \Phi\left(\ln\left(\frac{2[1+(\omega-1)(1-\theta)]}{(1-\theta)(1+\omega)}\right) - \theta - \frac{(\omega-1)(1-2\theta)}{(1+\omega)}\right).$$

Because W^{eu} is increasing in θ while W^{ind} is decreasing in θ, there exists a cutoff value $\underline{\theta}$ defined as $W^{eu} - W^{ind}\big|_{\theta=\underline{\theta}} = 0$. When θ is above $\underline{\theta}$, welfare is higher in an economic union. Furthermore, $\underline{\theta}$ is an increasing function in ω. Proposition 1 summarizes these findings.

Proposition 1: *There exists* $\underline{\theta} \in (0,0.5)$ *such that when* $\theta \in (\underline{\theta},0.5]$, $W^{eu} > W^{ind}$, *and* $\partial\underline{\theta}/\partial\omega > 0$.

[12] Note that for the political equilibrium, I define welfare in each country as the sum of the households' utility and the amount of campaign contributions given to the central government. I have checked that defining welfare as the households' utility and assuming that the amount of campaign contributions is completely wasted will change neither the properties of W^{eu} nor the results in Proposition 1.

To illustrate, Figure 1 plots $W^{eu} - W^{ind}$ against θ and shows the comparative statics with respect to increases in ω. Figure 2 plots the actual numerical values for $\underline{\theta}$ against ω.[13]

3.5. Economic Union with a Binding Budget Ceiling

A potential criticism against the previous formulation is that the economic union does not face a budget ceiling. In other words, the central government can raise as much revenue as it sees fit. However, this assumption may be inconsistent with the European institutional structure that the EU faces a ceiling on its budget. This section is devoted to analyze this scenario.

Suppose the EU's Commission is given a fixed tax rate $\overline{\tau}$. Then, the Commission would simply allocate an equal amount of R&D subsidy to each country. In this case, the equilibrium amount of campaign contributions would be zero because each country always receives half the tax revenue as R&D subsidy. If it turns out that $\overline{\tau}$ happens to be at the optimal level (i.e. $\overline{\tau} = \tau^*$ as in the cooperative equilibrium), then an economic union would trivially deliver the efficient outcome of R&D subsidy because lobbying is completely ineffective given a fixed amount of tax revenue. However, this reasoning only applies when there is a single item on the Commission's budget. In reality, there are multiples items on the Commission's budget, and the presence of lobbying may still lead to a distortionary effect through revenue misallocation. As a result, a tradeoff between R&D subsidy provided by an economic union and R&D subsidy provided by independent countries continues to exist.

To see this, I will incorporate an additional public goods into the households' utility function

(2') $$u_t^n = c_{h,t}^n + (1-\theta)\ln c_{q,t}^{n,n} + \theta \ln c_{q,t}^{n,m} + \ln G_t ,$$

where G_t is the *per capita* level of public goods in the economic union. An example of G_t is the per capita spending on union security in the EU. It is easy to see that the in the cooperative equilibrium, the equilibrium outcomes are $G = 1$, $s = s^*$ as in (26), and $\tau = 1 + \tau^*$, where τ^* is as in (27).

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[13] From (36), $\underline{\theta}$ is a function in only one parameter ω.

As for the political equilibrium, I will consider the case in which the maximum tax rate $\bar{\tau}$ is set to the efficient level $1+\tau^*$ such that if there is any distortionary effect, it arises from the misallocation of an efficient amount of tax revenue. Also, given that the public goods (i.e. union security) have complete spillover across the union, there is no incentive for lobbying on this item.

Lemma 4: *The political equilibrium in an economic union under a binding budget ceiling* $\tau \le \bar{\tau} \equiv 1+\tau^*$ *is characterized by*

(37)
$$s^{bc}(\underset{+}{\omega},\underset{-}{\theta}) = s^*\left(\frac{\tau^* + s^{eu}}{\tau^* + s^*}\right) \in [s^*, s^{eu}],$$

(38)
$$G^{bc}(\underset{-}{\omega},\underset{+}{\theta}) = \frac{1-s^{eu}}{1-s^{bc}} \le 1,$$

(39)
$$W^* - W^{bc}(\underset{-}{\omega},\underset{+}{\theta}) = \Phi \ln\left(\frac{1-s^{bc}}{1-s^*}\right) - \ln G^{bc} \ge 0.$$

(37) and (38) show that unless either $\omega = 1$ or $\theta = 0.5$, the presence of lobbying on R&D subsidy still distorts s^{bc} and G^{bc} away from their optimal levels. This distortionary effect results into a welfare loss relative to the cooperative equilibrium, and the magnitude of this welfare loss is increasing in the effectiveness of lobbying and decreasing in technology spillover as before. (39) shows that unless either $\omega = 1$ or $\theta = 0.5$, $W^{bc} < W^*$.

4. Conclusion

This paper provides a politico-economic analysis of R&D policies in the EU and argues that there exists a non-trivial tradeoff between R&D subsidy provided by an economic union (characterized by lobbying and overprovision) and R&D subsidy provided by independent countries (characterized by technology spillover and underprovision). The analysis suggests that the presence of externalities associated with

R&D subsidy is not a sufficient argument for supranational government intervention. However, despite ambiguity in policy prescription, the finding that an economic union dominates independent countries in welfare if and only if the degree of technology spillover is larger than a moderate value should be comforting to those advocating supranational government intervention by the EU on R&D policies. After all, a substantial degree of technology spillover is most likely to prevail in the real world, and R&D-policy coordination in Europe should do more good than harm.[14]

Finally, the model is highly stylized and features only one type of externality associated with R&D subsidy in order to highlight the tradeoff between overprovision from lobbying and underprovision from technology spillover that seems to be the most relevant factor. A more general model that features multiple externalities, such as a dividend-income externality and an international business-stealing effect, associated with R&D subsidy can be developed by assuming that the elasticity of substitution between home and foreign differentiated goods to be greater than one. In this model, some equilibrium conditions are substantially more complicated that the Nash-equilibrium level of R&D subsidies becomes an implicit function. Nonetheless, a tradeoff between centralized and decentralized provision of R&D subsidy should continue to exist in the presence of multiple externalities associated with R&D subsidy.

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[14] See, for example, Eaton et al. (1998).

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Appendix A

Proof for Lemma 1: The two groups of politicians cooperate and maximize

$$W^a + W^b = c_h^a + c_h^b + \ln A_0^a + \ln A_0^b$$

by sharing the tax burden equally. Substituting (17) into (15) and taking log yield

$$\ln A_t^n = \Phi \ln\left(\frac{1}{1-s^n}\right) + \Phi \ln\left(\frac{\varepsilon}{\alpha}\left(\frac{g_A \gamma}{\rho + g_A - g_L}\right) L_t\right) + \ln(\varphi / g_A).$$

Substituting (22) into (21) yields

$$c_h^n = \alpha - \varepsilon\left(1 + \frac{g_A \gamma}{\rho + g_A - g_L}\right) - \tau^n .$$

Therefore, after dropping the exogenous terms, the objective function simplifies to

$$W^a + W^b = -\tau^a - \tau^b + \Phi\left[\ln\left(\frac{1}{1-s^a}\right) + \ln\left(\frac{1}{1-s^b}\right)\right].$$

Substituting (17) into the balanced-budget condition yields

$$(\tau^a + \tau^b) L_t = s^a w^a L_{r,t}^a + s^b w^b L_{r,t}^b = \left(\frac{s^a}{1-s^a} + \frac{s^b}{1-s^b}\right)\left(\frac{\varepsilon g_A \gamma}{\rho + g_A - g_L}\right) L_t .$$

Maximizing $W^a + W^b$ subject to the balanced-budget condition yields (26) – (27).□

Proof for Lemma 2: The government in country *n* maximizes

$$W^n = c_h^n + (1-\theta) \ln A_0^n + \theta \ln A_0^m$$

by choosing s^n while taking s^m as given. Following the same steps as in Lemma 1 yields

$$W^n = -\tau^n + \Phi\left[(1-\theta) \ln\left(\frac{1}{1-s^n}\right) + \theta \ln\left(\frac{1}{1-s^m}\right)\right],$$

$$\tau^n L_t = s^n w^n L_{r,t}^n = \frac{s^n}{1-s^n}\left(\frac{\varepsilon g_A \gamma}{\rho + g_A - g_L}\right) L_t .$$

Maximizing W^n subject to the balanced-budget condition yields (28) – (29).□

Proof for Lemma 3: The central government maximizes

$$(W^a - z^a) + (W^b - z^b) + \omega(z^a + z^b) = (c_h^a - z^a) + (c_h^b - z^b) + \ln A_0^a + \ln A_0^b + \omega(z^a + z^b) .$$

Following the same steps as in Lemma 1 yields

$$\begin{aligned}&(W^a - z^a) + (W^b - z^b) + \omega(z^a + z^b)\\ &\quad = -\tau^a - \tau^b + \Phi\left[\ln\left(\frac{1}{1-s^a}\right) + \ln\left(\frac{1}{1-s^b}\right)\right] + (\omega - 1)[Z(s^a) + Z(s^b)]\end{aligned},$$

$$(\tau^a + \tau^b)L_t = s^a w^a L_{r,t}^a + s^b w^b L_{r,t}^b = \left(\frac{s^a}{1-s^a} + \frac{s^b}{1-s^b}\right)\left(\frac{\varepsilon g_A \gamma}{\rho + g_A - g_L}\right)L_t .$$

Maximizing $(W^a - z^a) + (W^b - z^b) + \omega(z^a + z^b)$ subject to the balanced-budget condition yields the first-order condition from the central government given by

$$-\left(\frac{1}{1-s^n}\right)^2\left(\frac{\varepsilon g_A \gamma}{\rho + g_A - g_L}\right) + \Phi\left(\frac{1}{1-s^n}\right) + (\omega - 1)\frac{\partial Z(s^n)}{\partial s^n} = 0 .$$

To determine $\partial Z(s^n)/\partial s^n$, the politicians in country n maximize $W^n - z^n$ by choosing s^n subject to $z^n = Z(s^n)$ and know that they will only share half of the tax burden from an increase in s^n (i.e. $\tau^n L_t = (s^n w^n L_{r,t}^n + s^m w^m L_{r,t}^m)/2$). Therefore, the first-order condition is

$$\frac{\partial(W^n - z^n)}{\partial s^n} = -\frac{1}{2}\left(\frac{1}{1-s^n}\right)^2\left(\frac{\varepsilon g_A \gamma}{\rho + g_A - g_L}\right) + \Phi\left(\frac{1-\theta}{1-s^n}\right) - \frac{\partial Z(s^n)}{\partial s^n} = 0 .$$

Substituting $\partial Z(s^n)/\partial s^n$ into the central government's first-order condition yields

$$-\left(\frac{1}{1-s^n}\right)^2\left(\frac{\varepsilon g_A \gamma}{\rho + g_A - g_L}\right)\left(\frac{1+\omega}{2[1 + (\omega - 1)(1-\theta)]}\right) + \Phi\left(\frac{1}{1-s^n}\right) = 0 .$$

Firstly, this condition and the balanced-budget condition yield (31) – (32). Secondly, combining this condition and the central government's first-order condition shows that

$$(\omega - 1)\frac{\partial Z(s^n)}{\partial s^n} = -\left(\frac{1}{1-s^n}\right)^2\left(\frac{\varepsilon g_A \gamma}{\rho + g_A - g_L}\right)\left(\frac{1+\omega}{2[1 + (\omega - 1)(1-\theta)]} - 1\right).$$

Integrating $\partial Z(s^n)/\partial s^n$ with respect to s^n yields

$$Z(s^n) = \frac{s^n}{1-s^n}\left(\frac{\varepsilon g_A \gamma}{\rho + g_A - g_L}\right)\left(\frac{1}{\omega-1}\right)\left(1 - \frac{1+\omega}{2[1+(\omega-1)(1-\theta)]}\right) + C,$$

where C is an integration constant. Using the property that $Z(s^{eu}) = 0$ for $s^{eu} \le s^*$, the contribution schedule is

$$Z(s^{eu}) = \max\left[0, \left(\frac{s^{eu}}{1-s^{eu}} - \frac{s^*}{1-s^*}\right)\left(\frac{\varepsilon g_A \gamma}{\rho + g_A - g_L}\right)\left(\frac{1}{\omega-1}\right)\left(1 - \frac{1+\omega}{2[1+(\omega-1)(1-\theta)]}\right)\right].$$

Substituting s^{eu} and s^* into $Z(s^{eu})$ yields

$$z^{eu} = \Phi\left(\frac{2\{[1+(\omega-1)(1-\theta)] - (1+\omega)\}^2}{(\omega-1)(1+\omega)[1+(\omega-1)(1-\theta)]}\right).\square$$

Proof for Proposition 1: W^{eu} is increasing in θ while W^{ind} is decreasing in θ. Therefore, $W^{eu} - W^{ind}$ is increasing in θ. When $\theta = 0$, $W^{eu} < W^{ind}$ due to the absence of externality in W^{ind}. When $\theta = 0.5$, $W^{eu} > W^{ind}$ due to the absence of free-riding in W^{eu}. Thus, there exists $\underline{\theta} \in (0, 0.5)$ such that when $\theta \in (\underline{\theta}, 0.5]$, $W^{eu} > W^{ind}$. For $\partial\underline{\theta}/\partial\omega > 0$, note $W^{eu} - W^{ind}$ is decreasing in ω.□

Proof for Lemma 4: The commission maximizes

$$\begin{aligned}&(W^a - z^a) + (W^b - z^b) + \omega(z^a + z^b)\\ &= c_h^a + c_h^b + \ln A_0^a + \ln A_0^b + 2\ln G + (\omega-1)(z^a + z^b)\end{aligned}.$$

Following the same steps as before yields

$$\begin{aligned}&(W^a - z^a) + (W^b - z^b) + \omega(z^a + z^b)\\ &= -2\tau + \Phi\left[\ln\left(\frac{1}{1-s^a}\right) + \ln\left(\frac{1}{1-s^a}\right)\right] + 2\ln G + (\omega-1)[Z(s^a) + Z(s^b)]\end{aligned}.$$

The commission maximizes this objective function subject to

$$2(\tau - G)L_t = s^a w^a L^a_{r,t} + s^b w^b L^b_{r,t} = \left(\frac{s^a}{1-s^a} + \frac{s^b}{1-s^b}\right)\left(\frac{\varepsilon g_A \gamma}{\rho + g_A - g_L}\right)L_t$$

taking the inequality constraint $\tau \leq \bar{\tau} \equiv \tau^* + 1$ as given. For the relevant case in which the inequality constraint is binding, the Commission's first-order condition with respect to s^n is

$$-\frac{1}{G}\left(\frac{1}{1-s^n}\right)^2\left(\frac{\varepsilon g_A \gamma}{\rho + g_A - g_L}\right) + \Phi\left(\frac{1}{1-s^n}\right) + (\omega - 1)\frac{\partial Z(s^n)}{\partial s^n} = 0 .$$

To determine $\partial Z(s^n)/\partial s^n$, the politicians in country n maximize $W^n - z^n$ by choosing s^n subject to $z^n = Z(s^n)$ and know that their country's tax burden will only be half of the reduction in G, i.e. $G = \bar{\tau} - (s^a w^a L^a_{r,t} + s^b w^b L^b_{r,t})/(2L_t)$. Therefore, the politicians' first-order condition is

$$\frac{\partial (W^n - z^n)}{\partial s^n} = -\frac{1}{2G}\left(\frac{1}{1-s^n}\right)^2\left(\frac{\varepsilon g_A \gamma}{\rho + g_A - g_L}\right) + \Phi\left(\frac{1-\theta}{1-s^n}\right) - \frac{\partial Z(s^n)}{\partial s^n} = 0 .$$

Substituting $\partial Z(s^n)/\partial s^n$ into the Commission's first-order condition yields

$$G^{bc}(1-s^{bc}) = \left(\frac{\varepsilon g_A (1-\phi)}{\rho + g_A - g_L}\right)\left(\frac{1+\omega}{2[1+(\omega-1)(1-\theta)]}\right),$$

where the terms in the right simplify to $1 - s^{eu}$ in (31). Combining this condition with the balanced-budget condition and $\bar{\tau} \equiv \tau^* + 1$ yields

$$s^{bc} = \frac{\bar{\tau} - 1 + s^{eu}}{\bar{\tau} - \tau^* + \tau^*/s^*} = s^*\left(\frac{\tau^* + s^{eu}}{\tau^* + s^*}\right),$$

$$G^{bc} = (1-s^{eu})/(1-s^{bc}) .$$

Substituting these conditions into the household's welfare function yields

$$W^* - W^{bc} = \left(-(\tau^* + 1) + \Phi \ln\left(\frac{1}{1-s^*}\right) + \ln G^*\right) - \left(-\bar{\tau} + \Phi \ln\left(\frac{1}{1-s^{bc}}\right) + \ln G^{bc}\right),$$

where $G^* = 1$.□

Figure 1: Comparative Statics in ω

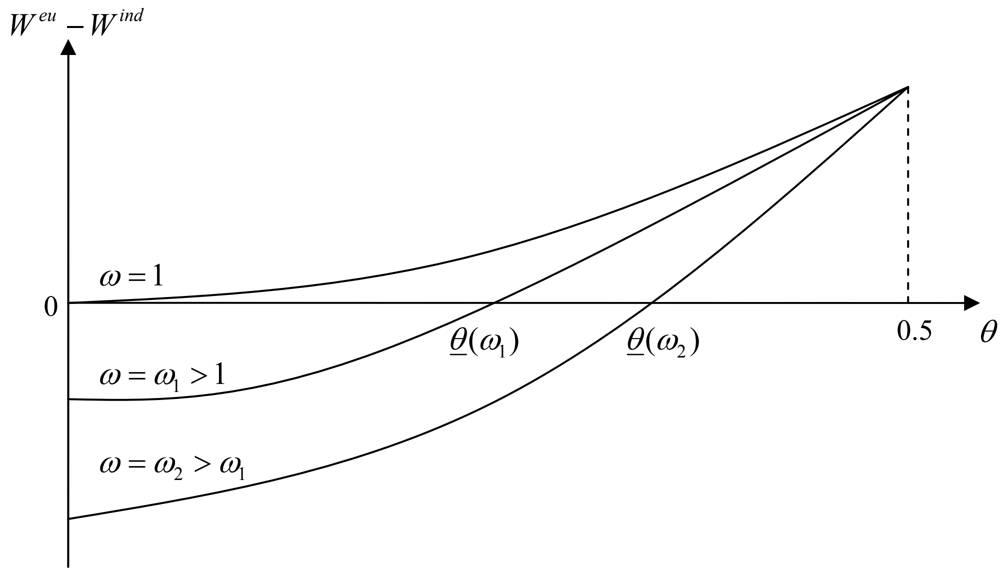

Figure 2: Cutoff Values for Technology Spillover