行政院國家科學委員會專題研究計畫 期末報告

政府公共支出、維修支出、與貨幣融通：局部不確定性與經濟成長(第 2 年)

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報 告 附 件 ：移地研究心得報告

公 開 資 訊 ：本計畫涉及專利或其他智慧財產權，2 年後可公開查詢

中 華 民 國 102 年 04 月 10 日

中文摘要： 此一兩年期計畫，探討關於政府支出及其融通政策的相關議題。第一年計畫此研究延伸 Ott and Turnovsky (2006)。Ott and Turnovsky (2006)考量政府公共支出具擁擠性並可區分成二種：可排除性(excludable)與不可排除性(non-excludable)。他們發現在最佳政策分析之下，擁擠效果愈大，具可排他性公共支出的使用費應愈低。此一結論並不符合經濟直覺。根據經濟直覺，為避免太多人使用具擁擠性公共財，政府可以提高使用費率。我與一位學生曾推導一個簡單模型，期望獲得比較符合經濟直覺的結論，然而，此一模型確有許多不合理的設定。在本計畫，我們延伸 Ott and Turnovsky (2006)的模型，但允許民眾可以直接選擇可排除性的公共服務之使用量，結論發現擁擠效果愈大，政府應提高使用費， 以避免民眾過度使公共服務，也因此，可以降低所得稅率。此一結論雖然與 Ott (2001)與 Ott and Turnovsky (2006)不同，但較符合經濟直覺。

第二篇文章探討不完全競爭與政府最式稅率的關係。近期文獻在探討不完全競爭程度與最適稅率關係時，將不完全競爭程度與規模報酬遞增以同一個變數代表，發現不完全競爭程度愈高，最適稅率應愈低。本計畫第二篇文章延伸近期文獻，但將不完全競爭程度與規模報酬遞增分別以不同的變數代表，發現與現存文獻不同的結論：不完全競爭程度愈高，最適稅率應愈高。

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英文關鍵詞： Optimal Policy； Congestion； Excludability； Imperfect Competition； Economic Growth

行政院國家科學委員會補助專題研究計畫 □期中進度報告 ■期末報告

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本計畫除繳交成果報告外，另含下列出國報告，共 _2_ 份：
■移地研究心得報告
□出席國際學術會議心得報告
□國際合作研究計畫國外研究報告

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Abstract

This project finishes two papers. The first paper examines optimal policies on taxation and user fees in a model where government spending is productive, rival, and congestive, and can be further classified as excludable and non-excludable public inputs. We propose functions for the services of excludable and non-excludable public inputs received by the individual firm that allow the individual firm to choose its usage of public inputs. Under this setting, the user fee will influence the individual's incentive in determining his usage of public inputs. We find that an increase in the degree of congestion, under the first- and second-best optimum, should be associated with an increase in the user fee to induce the efficient usage of public inputs. This conclusion contradicts recent studies but accords well with economic intuitions.

The second paper examines the optimal factor taxation under a model with imperfect competition. By using a same parameter to represent the degrees of monopolistic competition and increasing returns, recent studies conclude that the optimal tax rate on factor incomes are decreasing in the degree of monopolistic competition and imperfect competition always leads to over entry of firms. By separating monopolistic competition from increasing returns to fully disentangle their corresponding effects, this paper finds that optimal tax rates on factor incomes are decreasing in the degree of increasing returns, but are independent of the degree of market power. Moreover, free entry may lead to over or too little entry relative to the social optimum, depending on the relative strengths of the effects from increasing returns, market power, and congestion. These conclusions are different from the recent study that uses the same parameter to characterize increasing returns and monopolistic competition.

Key Words: Optimal Policy; Congestion; Excludability; Imperfect Competition; Economic Growth

The First Paper:

1. Introduction

The study of the government-provided public services as inputs to private production and hence as a determinant of economic growth has been pioneered by Barro (1990) in the literature of endogenous growth. Barro's (1990) original setting assumed that public services/inputs are non-rival and non-excludable. Numerous studies have since then incorporated many aspects of public inputs into models of endogenous growth to examine their effects on economic growth and corresponding optimal fiscal policies. One strand of literature, in particular, focuses on the rivalry of public inputs (Glomm and Ravikumar (1994), Fisher and Turnovsky (1998), Eicher and Turnovsky (2000), and many others). Another important characteristic of public goods that has been recognized by the public goods literature is the possibility that public inputs are excludable (e.g., Drèze, 1980; Fraser, 1996). However, this is rarely considered in the context of endogenous growth.[1] The purpose of this paper is to fill up this gap of literature by developing a simple endogenous growth model in which government-provided public inputs may be rival as well as excludable.

With the presence of excludable public inputs, the government in general can use taxation and/or user charges (such as highway tolls and parking charges) to finance her spending. User charges, however, raise two additional issues compared with taxation (Borge, 1995; Ott and Turnovsky, 2006). First, user charges increase the government's total revenues and hence may change the government's policies in financing its expenditures. This is a revenue effect of user charges. Second, most of public services/inputs are subject to a certain degree of the rivalry. Without considering user charges, individuals tend to excessively use public inputs and hence congestion in public services arises. The presence of user charges may be able to reduce congestion by preventing individuals from excessively (and suboptimally) using the public services. This is an incentive effect of user charges. Due to the following reasons, these two effects must have important implications to economic growth and optimal fiscal policies.

First, many studies have found that user charges account for a significant part of government revenue and expenditure. For example, Huber and Runkel (2009) report that U.S. government reliance on user charges by percentage of general revenue ranges from 6.4% to 15.3%.[2] O'Hagan and Jennings (2003) point out that most countries in Europe run public broadcasting stations that are financed by user fees. Netzer (1992) indicate that user charges on highway and parking facility as the percentage of expenditure on these services in the U.S. has increased from 14% to 35.5%. Borge (1995), Dewees (2002), and Blomquist and Christiansen (2005) also indicate that user charges have become an important source for government revenue. As user charges have accounted for a significant proportion of government revenue and expenditure, studies of optimal fiscal policies should consider the roles played by excludable public inputs and user fees.

[1] Exceptions are Ott (2001) and Ott and Turnovsky (2006). Both studies are reviewed below.

[2] See table 1 in Huber and Runkel (2009).

Second, rivalry of public services in recent studies is modeled as congestion externality. By ignoring congestion externalities, private agents tend to excessively use public services. Many studies have shown that congestion costs are very significant to the economy. Piecyk and McKinnon (2007), for example, point out that congestion costs account for about 40 percent of all external costs of lorry traffic in Britain. Similarly, Sansom et al. (2001) show that road congestion contributes to 75-84 percent of total estimated marginal external road costs for the UK. Moreover, in examining the correlation between highway congestion and output in a sample of California counties from 1977 to 1987, Boarnet (1995) finds evidence that returns to highway is greater where there is less congestion and congestion levels are negatively correlated with output. As congestion costs are significant to the economy and they are harmful to production/productivity, studies of optimal fiscal policies must allow the government to set up user fees that induce efficient private usages of public services.

In this paper, we construct a simple model of endogenous growth in which government expenditures are important inputs to private production (and hence are termed as public inputs). We follow Eicher and Turnovsky (2000) and Ott and Turnovsky (2006) by focusing on relative congestion such that the services of public inputs received by an individual firm depends solely on the firm's private capital stock relative to the aggregate capital stock of the economy. In other words, an individual firm under this setting is not allowed to directly select its usages of public services/inputs. We further develop the framework used in Eicher and Turnovsky (2000) and Ott and Turnovsky (2006) who focus on the optimal policy related to the user fees that can induce the efficient usages of public inputs. The key feature that distinguishes our study from Ott and Turnovsky (2006) is that we also allow the individual firm to choose its usage of public inputs, with an assumption that an increase in the *individual usage* of public inputs increases the marginal product of private capital (MPK), but an increase in the *aggregate usage* inevitably leads to congestion and hence lowers MPK. Consequently, the services of public inputs received by each individual firm depends both on the private capital relative to aggregate capital and private usage of public inputs relative to aggregate usage.

In this setting, an individual firm in a decentralized economy, by ignoring congestion externalities, will over-estimate the MPK as well as marginal product of excludable public inputs (MPE) faced by the individual when compared with the centralized economy. Moreover, since individuals ignore congestion externality, an increase in the degree of congestion, an exogenously given variable, will lead each individual to over-estimate MPK to a greater extent. Thus, similar to Ott and Turnovsky (2006), such an increase should be associated with an increase in the tax rate to prevent individual's over-estimation of MPK under the first-best optimum. Given this, an increase in the degree of congestion for excludable public inputs leads to two opposite effects on the after-tax MPE faced by the individual in this paper. First, it raises the tax rate and hence reduces the after-tax MPE, a result identical to Ott and Turnovsky (2006). Second, it directly leads individuals to over-estimate MPE, implying that the after-tax MPE (faced by each individual) increases. Recall that individual firm in Ott and Turnovsky (2006) cannot choose its usage of excludable public inputs; hence, the second effect is missing in Ott and Turnovsky (2006).[3] At the optimum, the user fee on excludable public inputs must be equal to the after-tax MPE. Thus, with only the presence of the first effect, an increase in the degree of congestion in Ott and Turnovsky (2006) must be associated with a decrease in user fee. This result seems counter-intuitive. In our model, the second effect is present and it is found that the second effect always dominates the first one. Hence, an increase in the degree of congestion must be associated with an increase in the user fee, contradicting to Ott and Turnovsky (2006). This result, however, accords well with intuition as an increase in the user fee is needed to induce efficient usage of public inputs when the degree of congestion increases. We also verify that this conclusion still holds under the second-best optimum.

The remainder of this paper is organized as follows. Section 2 sets up the model, and Sections 3 and 4 present the equilibrium consequences for a centralized economy and a decentralized economy, respectively. In Section 5, we derive optimal policies by focusing on the first-best optimum. The second-best optimal policies are derived in Section 6. Section 7 concludes.

2. Model

Consider a closed economy populated by a government and n identical individuals who consume and produce a single good.[4]

2.1. Individual producer

As a producer, the representative individual can employ the amount of private capital k to produce output y using a constant-returns technology given as[5]

$$y = k^{\alpha} e_s^{\beta} g_s^{\gamma}, \quad \alpha + \beta + \gamma = 1, \quad 0 < \alpha, \beta, \gamma \leq 1 \tag{1}$$

where e_s and g_s are the services of excludable and non-excludable inputs received by the individual, respectively. Note also that α, β, and γ are the output elasticity of k, e_s, and g_s, respectively.[6] Following Ott and Turnovsky (2006), both excludable and non-excludable inputs are flow of public services provided by the government (and hence termed as public inputs). As can be seen below, β and γ govern the sizes of externality created by excludable and non-excludable public inputs.[7] As is well recognized, public inputs, excludable or non-excludable, are rival and thus are subject to congestion. In this paper, we follow Ott and Turnovsky (2006) by focusing on the relative congestion. Most studies on the relative congestion of public inputs, including Ott and Turnovsky (2006), assume that the services of public inputs received by an individual depends on the individual's capital stock relative to the aggregate (private) capital stock. This assumption implies that the individual does not directly select his usage of public inputs. Under this case, the

[3] In other words, only the revenue effect of the user charges appears in Ott and Turnovsky (2006).
[4] To ease the exploration, it is assumed that population is constant over time.
[5] Results derived below still hold for the CES production function. Derivations are available upon request.
[6] From eqs. (5) and (20) below, β and γ are also the output elasticity of the government spending on excludable and non-excludable public inputs under the market equilibrium.
[7] Many empirical studies have reported the productivity of government spending. See Romp and De Haan (2008) and Bom and Ligthart (2009) for comprehensive analyses.

incentive effect of the user fee for excludable public inputs cannot be examined, simply because the user fee will not affect individual's incentive in determining his usage of public inputs. To study the incentive effect of the user fee, one must allow individual to directly choose his usage of public inputs. For this purpose, we propose the following function for the services of excludable public inputs received by the individual as

$$e_s = E[(\frac{k}{K})^{\phi_e}(\frac{\bar{e}^d}{E^d})^{1-\phi_e}]^{\epsilon_e}, \quad 0 \leqslant \epsilon_e, \phi_e \leqslant 1. \tag{2a}$$

where E is the flow of aggregate amount of excludable public inputs provided by the government, K is the aggregate capital stock, $\bar{e}^d$ is the usage of excludable public inputs chosen by the individual, and E^d is the aggregate usage of excludable public inputs. Note that, due to the presence of congestion, the amount of the services received by each firm (i.e., e_s) differs from the usage of excludable public inputs chosen by the firm ($\bar{e}^d$). From eq. (2a), congestion of excludable public inputs in this paper stems from two sources: first, individual's capital stock (k) relative to the aggregate capital stock (K) and, second, individual's usage of excludable public inputs ($\bar{e}^d$) relative to aggregate usage (E^d).[8] Note that an increase in ϵ_e implies that the aggregate amount of private capital K and the aggregate amount of usage of public inputs E^d create a larger degree of congestion to private production. Thus, parameter ϵ_e, an exogenously given variable, governs the overall degree of congestion for excludable public inputs from both sources.[9] To capture the case that the degree of congestion from these two sources may be different, we use ϕ_e to measures the relative degree of congestion stemmed from the first source over the second source. An increase in ϕ_e implies that the degree of congestion stemmed from the first source increases while the degree of congestion from the second source decreases.

The economic reasoning of eq. (2a) can be described as follows. Consider a producer (an individual firm) who must ship her products to markets as part of production process. The firm can ship her products to the market by highways or public transit system (both are government-provided excludable public inputs). To ship more products by highways, the firm should accumulate her own capital k (such as trucks). An increase in k for $0 < \epsilon_e, \phi_e < 1$ implies that the firm ships more products to markets and hence enhances the firm's production. However, as the aggregate capital stock K increases, more trucks are on the highways which inevitably lead to congestion. In addition to shipping products by highways, eq. (2a) implies that the firm may ship her products to markets by using public transit system, such as railways and postal service. Thus, even if the firm's stock of capital (and hence the aggregate capital stock) is constant, the firm can increase her production by using public transit system (i.e., by increasing her usage of public transit system $\bar{e}^d$). Similarly,

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[8] Note that the supply of excludable public inputs E must be equal to the demand E^d under the equilibrium. Hence, eq. (2a) can be further reduced to $e_s = E^{1-(1-\phi_e)\epsilon_e}(k/K)^{\phi_e\epsilon_e}(\bar{e}^d)^{(1-\phi_e)\epsilon_e}$, implying that in order for the government-provided public inputs E and the chosen level of excludable public inputs by each individual $\bar{e}^d$ to remain constant over time for a given k, the growth rate of E must be related to the growth rate of K in accordance with $[1-(1-\phi_e)\epsilon_e]\frac{\dot{E}}{E} = \phi_e\epsilon_e\frac{\dot{K}}{K}$.

[9] As indicated by Eicher and Turnovsky (2000), the case of $\epsilon_e > 1$ is unlikely at the aggregate level. As we focus on economic growth of an aggregate economy, we consider the case where $0 < \epsilon_e \leq 1$.

if the aggregate usage of public transit system (i.e., E^d) increases, congestion of excludable public inputs inevitably arises.

Eq. (2a) is general enough to capture whether or not the incentive effect of the user fee is present. To see this, recall first that parameter ϕ_e governs the relative degree of congestion stemmed from two sources. If $\phi_e = 1$, then eq. (2a) is identical to the one proposed by Ott and Turnovsky (2006) and, in this case, individual firm does not choose his usage of excludable public inputs. Thus, when $\phi_e = 1$, the incentive effect of the user fee does not appear. On the other hand, if $0 < \phi_e < 1$, then the individual firm can choose his usage of excludable public inputs and a change in the user fee will influence the individual firm's decision on his usage.

The government also provides non-excludable public inputs to the economy. For the sake of symmetry, we propose the following function for the services of non-excludable inputs received by the individual[10]

$$g_s = G[(\frac{k}{K})^{\phi_g}(\frac{\bar{g}^d}{G^d})^{1-\phi_g}]^{\epsilon_g}, \quad 0 < \phi_g, \epsilon_g \leq 1, \qquad (2b)$$

where G is the aggregate amount of non-excludable public inputs provided by the government , $\bar{g}^d$ is the usage of non-excludable public inputs chosen by the individual, and G^d is the aggregate usage of non-excludable public inputs by all individuals. Congestion also stems from two sources (k/K and $\bar{g}^d/G^d$) for non-excludable public inputs. Similar to the services of excludable public inputs, ϵ_g governs the overall degree of congestion for non-excludable public inputs from these two sources, while ϕ_g refers to the relative degree of congestion caused by the first source over the second one. An increase in ϕ_g implies that the degree of congestion caused by k/K increases while the degree of congestion caused by $\bar{g}^d/G^d$ decreases.

2.2. Individual consumer

As a consumer, the representative individual has an intertemporal utility function given as[11]

$$U = \int_0^\infty \frac{c^{1-\sigma} - 1}{1-\sigma} e^{-\rho t} dt, \ \sigma > 0, \ \rho > 0 \qquad (3)$$

where $1/\sigma$ denotes the intertemporal elasticity of substitution, c is individual consumption, and ρ is the rate of time preference.

2.3. Government

In the following analyses, we consider two scenarios related to the government's behavior. In the first one, the government is a benevolent social planner who treats the producer and consumer as the same individual and

[10] Note that the government cannot charge the user fee from private utilization of non-excludable public inputs; thus, the incentive and revenue effects of the user fee cannot be examined for non-excludable public inputs. Given this, the conclusions about the incentive and revenue effects of user fee (of excludable public inputs) derived below do not change if we follow Ott and Turnovsky (2006) by assuming that $g_s = G(\frac{k}{K})^{\epsilon_g}$.

[11] To focus on issues related to economic growth, we follow Ott and Turnovsky (2006) by focusing on the case that government-provided public goods are inputs to private production and do not enter into the utility function. Allowing public services into the utility function must have important implications to social welfare. This, however, is out of the scope of our study.

maximizes the representative individual's utility by directly allocating resources. In the second scenario where the economy is decentralized, each individual, as a producer and consumer, makes his own decisions and the government provides excludable and non-excludable public inputs. In this latter case, the government imposes a tax rate τ on output and charges user fees q on each producer's per-unit utilization of excludable public inputs to finance her provision of excludable public inputs E and non-excludable public inputs G. As can be seen below, output taxation and user fees may not be enough to finance government provisions of excludable and non-excludable inputs under the first-best optimum. In such a case, lump sum taxation is needed to balance the government budget.

In order to focus on the balanced growth path (which is defined below), we assume that the government in the centralized or decentralized economy maintains a constant share of her expenditures on each type of public inputs relative to the aggregate level of output Y; thus,

$$E = \theta_e Y \tag{4a}$$

and

$$G = \theta_g Y, \tag{4b}$$

with θ_e, $\theta_g \in (0,1)$ are constant expenditure shares on excludable public inputs and non-excludable public inputs.

3. Equilibrium Consequences under a Centralized Economy

As a benchmark case, we first examine the equilibrium consequences in a centralized economy. The government, as a benevolent social planner, can dictate each individual's (as a producer and consumer) decision by directly allocating resources to maximize the intertemporal utility of a representative individual. The social planner is aware of any possible congestion effects and hence the link between individual and aggregate usages of public inputs can be internalized. More specifically, the social planner will realize that $K = nk$, $E^d = n\bar{e}^d$, and $G^d = n\bar{g}^d$. Note that the supply of public inputs must be equal to the demand in the equilibrium; hence, $E = E^d$ and $G = G^d$.[12] Then, the congestion functions in eqs. (2a) and (2b) become $e_s = E(\frac{1}{n})^{\epsilon_e}$ and $g_s = G(\frac{1}{n})^{\epsilon_g}$, respectively. Substituting these results into eq. (1), the production function faced by the social planner becomes

$$y = k^\alpha E^\beta G^\gamma (1/n)^{\beta\epsilon_e + \gamma\epsilon_g}. \tag{5}$$

Eq. (5) indicates that β and γ are the output elasticities of government spending on excludable and non-excludable public inputs, respectively.

The social planner allocates output y to $\bar{e}^d (=\theta_e y)$, $\bar{g}^d (=\theta_g y)$, consumption c and private capital investment $\dot{k}$ to maximize the representative individual's utility function in eq. (3) subject to the resource

[12] Thus, eqs. (4a) and (4b) indicate that $\bar{e}^d = \theta_e y$ and $\bar{g}^d = \theta_g y$.

constraint (in per capita terms) given as

$$\dot{k} = (1 - \theta_e - \theta_g)y - \delta k - c, \tag{6}$$

where δ denotes the depreciation rate of private capital. To obtain the optimal decisions of the social planner, we follow Ott and Turnovsky (2006) by first taking θ_e and θ_g as arbitrarily set variables. Denote λ_C as the co-state variable associated with eq. (6). The optimality conditions for the social planner (taking θ_e and θ_g as given) are given by

$$c^{-\sigma} = \lambda_C \tag{6a}$$

$$\lambda_C[(1 - \theta_e - \theta_g)\frac{\partial y}{\partial k} - \delta - \rho] = -\dot{\lambda}_C + \rho\lambda_C. \tag{6b}$$

The transversality condition is given as

$$\lim_{t\to\infty} k\lambda_c exp(-\rho t) = 0. \tag{6c}$$

Combining the eqs. (6a) and (6b) yields the following growth rate of private consumption

$$\frac{\dot{c}}{c} = \frac{1}{\sigma}[(1 - \theta_e - \theta_g)\frac{\partial y}{\partial k} - \delta - \rho]. \tag{7}$$

We now determine the optimal values of θ_e and θ_g (denoted as θ_e^* and θ_g^*) under a centralized economy. To do so, first substitute eqs. (4a) and (4b) as well as $Y = ny$ and $\alpha = 1 - \beta - \gamma$ into eq. (5) to derive

$$y = \theta_e^{\frac{\beta}{\alpha}}\theta_g^{\frac{\gamma}{\alpha}}\bar{n}k, \tag{8}$$

where $\bar{n} = n^{\frac{1}{\alpha}[\beta(1-\epsilon_e)+\gamma(1-\epsilon_g)]}$. Following Ott and Turnovsky (2006), we consider the equilibrium under the balanced growth path (BGP) in which capital stock, consumption and output grow at the same rate, i.e. $\dot{k}/k = \dot{c}/c = \dot{y}/y$. From eq. (8), the marginal product of capital faced by the planner is given by

$$\frac{\partial y}{\partial k} = \theta_e^{\frac{\beta}{\alpha}}\theta_g^{\frac{\gamma}{\alpha}}\bar{n}. \tag{9}$$

Substituting this into eq. (7), the growth rate becomes

$$\frac{\dot{c}}{c} = \frac{1}{\sigma}[(1 - \theta_e - \theta_g)\theta_e^{\frac{\beta}{\alpha}}\theta_g^{\frac{\gamma}{\alpha}}\bar{n} - \delta - \rho] = \frac{1}{\sigma}[(1 - \theta_e - \theta_g)\frac{y}{k} - \delta - \rho]. \tag{10}$$

Since the intertemporal utility of the representative individual is increasing in the growth rate under the BGP,[13] θ_e^* and θ_g^* can be obtained by maximizing economic growth in eq. (10). Differentiating (10) with respect to θ_e and θ_g and setting each of them equal to 0, we have the following results:

Proposition 1. Under a centralized economy, the optimal expenditure share of excludable public inputs is given as

$$\theta_e^* = \beta, \tag{11a}$$

while the optimal expenditure share of non-excludable public inputs is given by

[13] Similar to Ott and Turnovsky (2006), the growth-maximizing expenditure shares are equal to those of welfare-maximizing.

$$\theta_g^* = \gamma. \tag{11b}$$

Proposition 1 is quite intuitive. By internalizing the link between individual and aggregate usages of public inputs, the government realizes that the productive elasticities of excludable and non-excludable public inputs are equal to β and γ, respectively. Thus, increasing either form of public inputs will lead to an increase in output (and hence the rate of economic growth) until the share of government expenditures on public inputs equals its corresponding productive elasticity, a result that is identical to Barro (1990).

Substituting Proposition 1 into eq. (10), we obtain the optimal rate of growth under the centralized economy (denoted as Ω_c^*) as

$$\Omega_c^* = \frac{\dot{c}}{c} = \frac{1}{\sigma}[(1-\beta-\gamma)\beta^{\frac{\beta}{\alpha}}\gamma^{\frac{\gamma}{\alpha}}\bar{n} - \delta - \rho]. \tag{12}$$

4. Equilibrium Consequences under a Decentralized Economy

We now examine the equilibrium consequences for a decentralized economy. Under the decentralized economy, the individual, as a producer, maximizes his profit by selecting k (rented from consumers), $\bar{e}^d$ and $\bar{g}^d$. The profit of an individual producer at any point of time is given as[14]

$$\pi = (1-\tau)y - rk - q\bar{e}^d, \tag{13}$$

where τ is the tax rate on output, r is the rental rate of capital, and q is the user fee on the usage of excludable public inputs. The optimal condition for k, $\bar{g}^d$, and $\bar{e}^d$ are given as

$$(1-\tau)(\alpha + \beta\phi_e\epsilon_e + \gamma\phi_g\epsilon_g)\frac{y}{k} = r; \tag{13a}$$

$$(1-\tau)(1-\phi_g)\epsilon_g\gamma\frac{y}{\bar{g}^d} = 0 \text{ or } \quad g_s = \frac{G}{n^{\epsilon_g}} = \bar{g}^d n^{1-\epsilon_g} \text{ if } (1-\tau)\frac{\partial y}{\partial \bar{g}^d} > 0 \tag{13b}$$

$$(1-\tau)(1-\phi_e)\beta\epsilon_e\frac{y}{\bar{e}^d} = q. \tag{13c}$$

Eq. (13a) and (13c) are the conditions such that the after–tax marginal product of private capital and excludable public inputs are equal to their corresponding marginal costs. Since the government cannot charge the user fee for private usage of non-excludable public inputs, the individual will choose $\bar{g}^d$ such that $(1-\tau)\partial y/\partial \bar{g}^d = 0$ holds, leading to eq. (13b). For given G and G^d, it is clear from eqs. (1) and (2b) that an increase in $\bar{g}^d$ reduces $\partial y/\partial \bar{g}^d$. Thus, unless $\bar{g}^d$ approaches infinity, $(1-\tau)\partial y/\partial \bar{g}^d = 0$ will not hold for $\tau \in (0,1)$. If $(1-\tau)\partial y/\partial \bar{g}^d > 0$, then the amount of non-excludable public inputs each individual can choose must be constrained by the amount provided by the government. In equilibrium, the aggregate supply of non-excludable public inputs must be equal to the aggregate demand; hence, $G = G^d$. Since $nk = K$ and $G = G^d = n\bar{g}^d$ in equilibrium, it is clear that the services of non-excludable public inputs received by the representative producer in this case is given as $g_s = G/n^{\epsilon_g} = \bar{g}^d n^{1-\epsilon_g}$.

On the other hand, as a consumer, the representative individual chooses consumption c and the

[14] One may argue that user fees are tax deductible. However, to facilitate the comparison between our model with Ott and Turnovsky (2006), we follow Ott and Turnovsky by assuming that user fees are not tax deductible.

accumulation of asset $\dot{a}$ to maximize her lifetime utility in eq. (3). As the representative producer is also the consumer, the producer's profit accrues to the consumer's income; hence, the representative consumer faces the following budget constraint

$$\dot{a} = ra + \pi - \delta a - c - d, \tag{14}$$

where δ is the depreciation rate of asset, d is per capita lump sum tax imposed by the government and π is given in (13). Note that the only asset in the economy is private capital; hence, the rate of return from asset a is the same as that from private capital, r. The optimal conditions are given as

$$c^{-\sigma} = \lambda_D \tag{14a}$$

$$\lambda_D(r - \delta) = -\dot{\lambda}_D + \rho\lambda_D. \tag{14b}$$

The transversality condition is given as

$$\lim_{t\to\infty} a\lambda_c exp(-\rho t) = 0 \tag{14c}$$

In equilibrium, $a = k$. Using eqs. (13a), (14a), and (14b), we obtain an expression for the growth rate of consumption as:

$$\frac{\dot{c}}{c} = \frac{1}{\sigma}[(1-\tau)\frac{\partial y}{\partial k} - \delta - \rho] = \frac{1}{\sigma}[(1-\tau)(\alpha + \beta\phi_e\epsilon_e + \gamma\phi_g\epsilon_g)\frac{y}{k} - \delta - \rho]. \tag{15}$$

In a decentralized economy, the representative producer takes the aggregate usage of public inputs (E^d and G^d), the aggregate public inputs provided by the government (E and G), and the aggregate capital stock K as given. The production function faced by the individual can be written as

$$y = k^{\alpha+\phi_e\epsilon_e\beta+\phi_g\epsilon_g\gamma}\{E[(1/K)^{\phi_e}(e^d/E^d)^{1-\phi_e}]^{\epsilon_e}\}^{\beta}\{G[(1/K)^{\phi_g}(g^d/G^d)^{1-\phi_g}]^{\epsilon_g}\}^{\gamma}. \tag{16}$$

A comparison between eq. (16) and the production function faced by the social planner (i.e., eq. (5)) reveals the following two propositions.

Proposition 2. (i) The marginal product of private capital k faced by an individual is greater than the one faced by the social planner; (ii) an increase in either ϵ_e, ϵ_g, ϕ_e, or ϕ_g increases the marginal product of capital in the decentralized economy and an increase in either ϵ_e or ϵ_g increases the marginal product of capital in the centralized economies; (iii) the gap between the marginal product of capital faced by the individual and the social planner is increasing in ϵ_e, ϕ_e, ϵ_g, and ϕ_g.

Proposition 3. (i) Under the market equilibrium (i.e., $E = E^d = n\bar{e}^d$), the marginal product of $\bar{e}^d$ faced by the individual under a decentralized economy is smaller than the one faced by the social planner; (ii) an increase in ϵ_e or a decrease in ϕ_e increases the marginal product of $\bar{e}^d$ in the decentralized economy.

To see the first result of Proposition 2, taking the derivative on eq. (5) with respect to k, the marginal product of capital faced by the social planner is given by

$$\frac{\partial y}{\partial k} = \alpha k^{\alpha-1}E^{\beta}G^{\gamma}(1/n)^{\beta\epsilon_e+\gamma\epsilon_g}, \tag{17a}$$

$$= \alpha \frac{y}{k}. \tag{17b}$$

On the other hand, the marginal product of capital faced by the individual (derived from eq. (16)) is given as

$$\frac{\partial y}{\partial k} = (\alpha + \phi_e \epsilon_e \beta + \phi_g \epsilon_g \gamma) k^{\alpha + \phi_e \epsilon_e \beta + \phi_g \epsilon_g \gamma - 1} \{E[(\frac{1}{K})^{\phi_e} (\frac{\bar{e}^d}{E^d})^{1-\phi_e}]^{\epsilon_e}\}^{\beta}$$
$$\{G[(\frac{1}{K})^{\phi_g} (\frac{\bar{g}^d}{G^d})^{1-\phi_g}]^{\epsilon_g}\}^{\gamma}. \tag{18}$$

To compare this equation with eqs. (17a) and (17b), substitute $K = nk$, $E^d = n\bar{e}^d$ and $G^d = n\bar{g}^d$ under the market equilibrium into the above equation to derive

$$\frac{\partial y}{\partial k} = (\alpha + \phi_e \epsilon_e \beta + \phi_g \epsilon_g \gamma) k^{\alpha - 1} E^{\beta} G^{\gamma} (\frac{1}{n})^{\epsilon_e \beta + \epsilon_g \gamma}. \tag{19a}$$

$$= (\alpha + \phi_e \epsilon_e \beta + \phi_g \epsilon_g \gamma) \frac{y}{k}. \tag{19b}$$

A direct comparison between eqs. (17a) and (19a) reveals that, for given E and G, the marginal product of capital faced by the individual (i.e., eq. (19a)) is higher than that faced by the social planner (i.e., eq. (9)). Thus, without internalizing externality, individual will over-estimate the market product of capital and hence over-accumulate the capital stock. Moreover, the ratio of the marginal product of capital faced by the individual over that faced by the social planner is given as $(\alpha + \phi_e \epsilon_e \beta + \phi_g \epsilon_g \gamma)/\alpha$. Obviously, an increase in either ϵ_e, ϵ_g, ϕ_e, or ϕ_g increase this ratio, implying that the gap between the marginal product of capital faced by the individual and the social planner is increasing in ϵ_e, ϵ_g, ϕ_e, or ϕ_g. In other words, an increase in either ϵ_e, ϵ_g, ϕ_e, or ϕ_g will lead individual to over-estimate the marginal product of capital to a greater extent.

To see the first result of Proposition 3, substituting $E = n\bar{e}^d$ into eq. (5), the production function faced by the social planner (in terms of per capita) can be restated as

$$y = k^{\alpha} (n\bar{e}^d)^{\beta} G^{\gamma} (1/n)^{\beta \epsilon_e + \gamma \epsilon_g}, \tag{20}$$

implying that the marginal product of $\bar{e}^d$ faced by the social planner is given as

$$\frac{\partial y}{\partial \bar{e}^d} = \beta k^{\alpha} n^{\beta} (\bar{e}^d)^{\beta - 1} G^{\gamma} (1/n)^{\beta \epsilon_e + \gamma \epsilon_g} \tag{20a}$$

$$= \beta \frac{y}{\bar{e}^d}. \tag{20b}$$

On the other hand, by taking E, E^d, G, G^d, and K as given, the marginal product of $\bar{e}^d$ faced by an individual (derived from eq. (16)) is given as

$$\frac{\partial y}{\partial \bar{e}^d} = \beta \epsilon_e (1 - \phi_e) (\bar{e}^d)^{\beta \epsilon_e (1 - \phi_e) - 1} k^{\alpha} \{E[(\frac{k}{K})^{\phi_e} (\frac{1}{E^d})^{1-\phi_e}]^{\epsilon_e}\}^{\beta}$$
$$\{G[(\frac{k}{K})^{\phi_g} (\frac{\bar{g}^d}{G^d})^{1-\phi_g}]^{\epsilon_g}\}^{\gamma}. \tag{21}$$

To compare eq. (21) with eq. (20), substituting $K = nk$, $E = E^d$, and $G = G^d$ into eq. (21), the marginal product of $\bar{e}^d$ faced by the individual becomes

$$\frac{\partial y}{\partial \bar{e}^d} = \beta\epsilon_e(1-\phi_e)(\bar{e}^d)^{\beta-1}n^\beta k^\alpha G^\gamma (1/n)^{\beta\epsilon_e+\gamma\epsilon_g} \tag{21a}$$

$$= (1-\phi_e)\epsilon_e\beta\frac{y}{\bar{e}^d}. \tag{21b}$$

Eqs. (20b) and (21b) imply that the marginal product of $\bar{e}^d$ faced by the individual is smaller than the one faced by the social planner for $\epsilon_e, \phi_e \in (0,1)$. Similarly, by taking all possible externality into account, the outcome of the centralized economy is more efficient than the one under the decentralized economy. Since the marginal product of $\bar{e}^d$ faced by an individual is diminishing (i.e., $\partial^2 y/\partial(\bar{e}^d)^2 < 0$), this result implies that the individual in the decentralized economy should decrease his usage of excludable public inputs in order to increase the marginal product of $\bar{e}^d$. In other words, the individual in the decentralized economy will over-utilize excludable public inputs, compared with the centralized economy. It is also obvious that, from eqs. (20b) and (21b), an increase in ϵ_e or a decrease in ϕ_e rises the marginal product of e^d in the decentralized economy and thus reduce the gap of the marginal product of e^d between both economies.

Recall that the individual determines his usage of excludable public inputs by equating the after-tax marginal product of $\bar{e}^d$ to the user fee, q. As a result, government's setting on q in the decentralized economy plays an important role in affecting the individual's incentive in determining the usage of excludable public inputs. This incentive effect of the user fee will be further explored below.

Substituting eqs. (4a) and (4b), $K = nk$, $E = E^d$, $G = G^d$ and $\alpha = 1-\beta-\gamma$ into eq. (16), one can find y/k. Substituting this into eq. (20b), one can derive the marginal product of capital in the decentralized economy as

$$\frac{\partial y}{\partial k} = (\alpha + \beta\phi_e\epsilon_e + \gamma\phi_g\epsilon_g)\beta^{\frac{\beta}{\alpha}}\gamma^{\frac{\gamma}{\alpha}}\bar{n}. \tag{22}$$

Substituting eq. (22) into eq. (15), the growth rate of the economy under the decentralized economy (denoted as Ω_D^*) is derived as

$$\Omega_D^* = \frac{\dot{c}}{c} = \frac{1}{\sigma}[(1-\tau)(\alpha + \beta\phi_e\epsilon_e + \gamma\phi_g\epsilon_g)\beta^{\frac{\beta}{\alpha}}\gamma^{\frac{\gamma}{\alpha}}\bar{n} - \delta - \rho] \tag{23}$$

5. The first-best optimal polices

In this section, we explore the first-best optimal government policies.[15] Suppose that the government of a decentralized economy intends to replicate the outcomes of the centralized economy by setting the policies, taking individuals' decisions as given. To this end, it is clear that the optimal expenditure shares of excludable

[15] In Ott and Turnovsky (2006), the expenditure shares of excludable and non-excludable public inputs may be arbitrarily given by the government. If those shares are arbitrarily given, then the optimal tax rate and user fee are termed as the second-best policies in their analysis. In our model, the expenditure shares are always optimally obtained, however. The second-best optimal policies in our model are conventionally defined such that the government selects the optimal policies to maximize eq. (23), subject to the individuals' choice and government budget constraint.

and non-excludable public inputs are equal to β and γ (Proposition 1), respectively. Note that $E = E^d = n\bar{e}^d$ under the market equilibrium. Thus, $E/Y = \beta$ implies that $\bar{e}^d/y = \beta$. Equating eq. (23) to eq. (12), one can obtain the first-best optimal tax rate. Substituting the first-best optimal tax rate as well as $\bar{e}^d/y = \beta$ into eq. (13c), one can derive the first-best optimal user fee. We summarize the first-best optimal tax rate and user fee as follows:

Proposition 4. (*First-best optimal policies*) The first-best optimal tax rate (denoted as τ^*_{first}) is derived as

$$\tau^*_{first} = \frac{\beta\epsilon_e\phi_e + \gamma\epsilon_g\phi_g}{1-\beta(1-\epsilon_e\phi_e)-\gamma(1-\epsilon_g\phi_g)}, \tag{24a}$$

while the first-best optimal user fee (*denoted as* q^*_{first}) is derived as

$$q^*_{first} = \frac{\alpha(1-\phi_e)\epsilon_e}{1-\beta(1-\epsilon_e\phi_e)-\gamma(1-\epsilon_g\phi_g)}. \tag{24b}$$

Intuitively, the presence of congestion effect associated with public inputs causes the individual to overvalue the marginal product of capital. Due to this, the growth rate under the decentralized economy is sub-optimal. To replicate the optimal growth rate in eq. (12), the government should impose a positive tax rate to lower the rate of return from capital investment and hence reduce individuals' incentive in capital accumulation. Recall also that the individual determines his usage of excludable public inputs $\bar{e}^d$ by equating the after-tax marginal product of excludable public inputs to the user fee. Since the marginal product of $\bar{e}^d$ is diminishing, there must have a positive user fee that is equal to the after-tax marginal product of excludable public inputs.

Note that the optimal tax rate under the first-best optimum is derived directly by equating the growth rate under the decentralized economy to that under the centralized one. This implies that the optimal tax rate under the first-best optimum is derived without taking the government budget constraint into account. In this case, lump sum taxation is needed to balance the government budget. To see this, note that the government expenditures under the first-best policies are given by $\theta^*_e Y + \theta^*_g Y$, while the government revenues collected from income taxation and user fees are given by $\tau^* Y + q^* E$. Divided both the expenditures and revenues by Y, we have the government expenditure share and revenue share as

$$\frac{E+G}{Y} = \theta^*_e + \theta^*_g = \beta + \gamma \tag{25a}$$

and

$$\begin{aligned}\frac{\tau^*_{first}Y + q^*_{first}E}{Y} &= \tau^*_{first} + q^*_{first}\theta^*_E \\ &= \beta + \gamma - \underbrace{\frac{(1-\beta-\gamma)[\beta(1-\epsilon_e)+\gamma(1-\epsilon_g\phi_g)]}{1-\beta(1-\phi_e\epsilon_e)-\gamma(1-\phi_g\epsilon_g)}}_{Lump-sum\ tax\ rate},\end{aligned} \tag{25b}$$

respectively. By comparing eq. (25a) with (25b), it is obvious that the government must imposes a lump sum tax to balance her budget for $\epsilon_e, \epsilon_g, \phi_e, \phi_g \in (0,1)$. Thus, similar to Ott and Turnovsky (2006), lump-sum tax is needed under the first-best optimum. The lump-sum tax rate is equal to the last term in the RHS of eq. (25b). Proposition 4 leads to the following results for $\epsilon_e, \epsilon_g, \phi_e, \phi_g \in (0,1)$:

Proposition 5. Under the first-best optimum, other thing be equal, (i) an increase in the degree of congestion for excludable public inputs, ϵ_e, leads to an increase in the first-best tax rate and the first-best user fee; (ii) an increase in the relative degree of congestion for excludable public inputs, ϕ_e, leads to an increase in the first-best tax rate but a decrease in the first-best user fee; (iii) an increase in the degree of congestion for non-excludable public inputs, ϵ_g, leads to an increases in the first-best tax rate but a decrease in the user fee.

For simplicity, we only provide intuitions for the effects of changes in ϵ_e and ϕ_e. The effects of changes in ϵ_g and ϕ_g follow similar logic. Recall that an increases in either ϵ_e or ϕ_e will lead individual to over-estimate the marginal product of capital to a greater extent. To prevent this over-estimation, the government should impose a higher tax rate in response to an increase in either ϵ_e or ϕ_e. Moreover, recall that an increase in ϵ_e or a decrease ϕ_e increases the marginal product of e^d faced by the individual. As the user fee must be equal to the after tax marginal product of e^d, an increase in ϵ_e leads to two opposite effects to the user fee: first, it decreases $1-\tau$; second, it increases the marginal product of e^d. Results of Proposition 5 imply that the second effect dominates the first one for an increase in ϵ_e, leading to an increase in the first-best user fee.[16]

Results of Proposition 5 are in sharp contrast with Ott and Turnovsky (2006), who find that an increase in the degree of congestion of excludable public inputs ϵ_e leads to a decrease in the user fee and an increase in the tax rate. Recall that Ott and Turnovsky (2006) is a special case of our model when $\phi_e = \phi_g = 1$.[17] If $\phi_e = \phi_g = 1$, then an increase in either ϵ_e or ϵ_g still leads the individual to over-estimate the marginal product of capital. Nevertheless, such a change will not affect the marginal product of e^d, as the congestion is totally caused by private capital in the case of $\phi_e = \phi_g = 1$. Similarly, to prevent the over-estimation of the marginal product of capital, the government should increase the tax rate in response of an increase in either ϵ_e or ϵ_g. However, as such changes will not affect the marginal product of e^d,[18] an increase in the tax rate unambiguously decreases the *after-tax* marginal product of e^d. Since the user fee is equal to the *after-tax* marginal product of e^d, an increase in either ϵ_e or ϵ_g, therefore, will lead to a decrease in the user fee in Ott and Turnovsky (2006). This is the revenue effect of the user fee highlighted by Ott and Turnovsky (2006), as a change in either the tax rate and/or the user fee will influence the government revenue, but not the individual's incentive in determining his usage of excludable public inputs. In contrast to Ott and Turnovsky (2006), by considering the possibility of $\phi_g, \phi_g \in (0,1)$, this paper allows individuals to directly choose their optimal

[16] The complete derivation of these results is available upon request.

[17] The services of excludable public inputs derived by an individual in Ott and Turnovsky (2006) is given as $E(k/K)^{\epsilon_e}$, which is the same as eq. (2a) in this paper when $\phi_e = 1$.

[18] Though the individual firm does not select e^d, Ott and Turnovsky (2006) claim that $q = (1-\tau)\partial y/\partial E$ under the optimum. Note that $\partial y/\partial E$ is independent of ϵ_e in Ott and Turnovsky (2006).

utilization of excludable and non-excludable public inputs. By so doing, we find that an increase in either ϵ_e or ϵ_g will increase the after-tax marginal product of e^d, as shown in Proposition 5. This will induce the individual to further over-utilize excludable public inputs if the user fee does not change. To prevent this, the government must increase the user fee. This is the incentive effect of the user fee, as a change in the user fee will have important implication on individual's usage of excludable public inputs.

6. The second-best optimal policies

In this section, we examine the second-best optimum in which individuals make their own decisions, taking the government policies as given. The government, in turn, decides his optimal policies, taking individuals' decisions as given. Moreover, we also follow Barro (1990) and Chatterjee (2007) by assuming that non-distortionary financing instruments (such as lump-sum or consumption taxes) are not available for the government.

Under the second-best optimum, the government of the decentralized economy decides his policies by maximizing economic growth (and thus the social welfare), subject to the following budget constraint:

$$E + G = \tau Y + qE, \tag{26}$$

where the RHS (LHS) is the total government revenue (expenditure). Under the second-best equilibrium, we should determine the fraction of government revenue allocated to excludable and non-excludable public inputs. To do so, denote ν_E $(1-\nu_E)$ as the fraction of the government revenue spent on excludable (non-excludable) public inputs (i.e., $\nu_E = E/(\tau Y + qE)$ and $(1-\nu_E) = G/(\tau Y + qE)$). Moreover, combining eqs. (13c) with (21b), one sees that $q = (1-\phi_e)\epsilon_e \beta y/\bar{e}^d$. Using market equilibrium, $Y = ny$ and $E = n\bar{e}^d$, as well as $q = (1-\phi_e)\epsilon_e \beta y/\bar{e}^d$, we see that

$$E = \nu_E[\tau + (1-\tau)(1-\phi_e)\epsilon_e\beta]Y$$

and

$$G = (1-\nu_E)[\tau + (1-\tau)(1-\phi_e)\epsilon_e\beta]Y.$$

Using these two definitions as well as market equilibrium conditions, eq. (16) implies that

$$\frac{y}{k} = \nu_E^{\frac{\beta}{\alpha}}(1-\nu_E)^{\frac{\gamma}{\alpha}}[\tau + (1-\tau)(1-\phi_e)\epsilon_e\beta]^{\frac{\beta+\gamma}{\alpha}}\bar{n}. \tag{27}$$

Substituting this into eq. (19b), we derive the marginal product of capital as

$$\frac{\partial y}{\partial k} = (\alpha + \beta\phi_e\epsilon_e + \gamma\phi_g\epsilon_g)\nu_E^{\frac{\beta}{\alpha}}(1-\nu_E)^{\frac{\gamma}{\alpha}}[\tau + (1-\tau)(1-\phi_e)\epsilon_e\beta]^{\frac{\beta+\gamma}{\alpha}}\bar{n}. \tag{27a}$$

Finally, substitute eq. (19c) into eq. (15), the growth rate is given as

$$\frac{\dot{c}}{c} = \frac{1}{\sigma}[\underbrace{(1-\tau)}_{A}[\alpha + \beta\phi_e\epsilon_e + \gamma\phi_g\epsilon_g]\nu_E^{\frac{\beta}{\alpha}}(1-\nu_E)^{\frac{\gamma}{\alpha}}\underbrace{[\tau + (1-\tau)(1-\phi_e)\epsilon_e\beta]^{\frac{\beta+\gamma}{\alpha}}}_{B}\bar{n} - \delta - \rho]. \tag{28}$$

The government selects the optimal ν_E (denoted as ν_E^*) and τ (denoted as τ^*_{second}) by maximizing eq.

(28). The optimal second-best user fee (denoted as q^*_{second}) can then be derived by substituting ν^*_E and τ^*_{second} into eq. (13c). We summarize the second-best optimal policies as follows:

Proposition 6. (*Second-best optimal policies*) *The second-best optimal fractions of government revenue that are allocated to excludable and non-excludable public inputs are given as*

$$\nu^*_E = \frac{\beta}{\beta+\gamma} \tag{29a}$$

and

$$1-\nu^*_E = \frac{\gamma}{\beta+\gamma}, \tag{29b}$$

respectively. The second-best optimal tax rate and user fee are given as

$$\tau^*_{second} = \frac{\beta+\gamma-(1-\phi_e)\beta\epsilon_e}{1-(1-\phi_e)\beta\epsilon_e} \tag{29c}$$

and

$$q^*_{second} = \frac{\alpha(1-\phi_e)\epsilon_e}{1-(1-\phi_e)\beta\epsilon_e}, \tag{29d}$$

respectively[19].

An increase in the tax rate, on the one hand, directly reduces the after-tax marginal product of capital and hence lowers the growth rate. This is represented by term A in eq. (28). On the other hand, it also increases the government revenue that can be spent on excludable and non-excludable public inputs. As public inputs result in positive externality to the marginal product of capital, an increase in the tax rate benefits capital investment and hence economic growth. This is captured by term B in eq. (28). The optimal tax rate is then derived by balancing these two opposite effects. As the marginal product of e^d is diminishing, there must have a positive user fee that is equal to the after-tax marginal product of e^d for a given optimal tax rate.

Proposition 6 leads to the following results:

Proposition 7. Under the second-best optimum, (i) the optimal shares of government on excludable and non-excludable public inputs are equal to β and γ, respectively; (ii) an increase in ϵ_e leads to a decrease in the optimal tax rate and an increase in the user fee; (iii) an increase in ϕ_e leads to an increase in the tax rate and a decrease in the user fee.

Note that, under the second-best optimum,

$$E/Y = \nu^*_E[\tau^*_{second}+(1-\tau^*_{second})(1-\phi_e)\epsilon_e\beta] = \beta \tag{30a}$$

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[19] Recall that the incentive effects of excludable public inputs are present if ϕ_e is less than one. Eq. (29c) implies that the optimal tax rate is less than the output elasticity of both types of public inputs ($\alpha+\beta$) if the incentive effects are present. While Barro (1990) has concluded that the optimal tax rate is equal to the output elasticity of public services, many studies, such as Ligthart and Van der Ploeg (1994) and Hung (2005), have found that the optimal tax rate may not be equal to the output elasticity of public services. In this paper, we find that the present of the incentive effects plays an important role in determining whether the second-best optimal tax rate is equal to the output elasticity of public services.

and

$$G/Y = (1-\nu_E^*)[\tau_{second}^* + (1-\tau_{second}^*)(1-\phi_e)\epsilon_e\beta] = \gamma. \tag{30b}$$

Thus, the second-best optimal shares of government expenditure on excludable and non-excludable public inputs are constant and are the same as those under the first-best optimum.

An increase in the overall degree of congestion for excludable public inputs ϵ_e obviously increases the marginal product of private capital (i.e., term B in eq. (28)) in a nonlinear relationship with the tax rate. Since ϵ_e has no effect on $(1-\tau)$ (i.e., term A in eq. (28)), an increase in ϵ_e must lead to a decrease in the optimal tax rate to balance the two opposite effects of the tax rate on economic growth. Recall also that an increase in ϵ_e increases the marginal product of e^d. As such an increase leads to a decrease in τ_{second}^* (and hence an increase in $1-\tau_{second}^*$), the second-best user fee must increase in response to an increase in ϵ_e for eq. (13c) to still hold. Hence, similar to the first-best optimum, an increase in the overall degree of congestion should be associated with an increase in the second-best optimal user fee.

7. Conclusions

This paper studies the optimal government taxation and the user fee policies with the presence of excludable and non-excludable public inputs. We find that the optimal expenditure shares of non-excludable and excludable public inputs are determined by their corresponding productive elasticity, regardless of the first- or second-best optimum. The optimal tax rate and the user fee are derived under the first- and second-best optima. It is found that an increase in the degree of congestion for excludable public inputs, on the one hand, always leads to an increase in the user fee and, on the other hand, leads to an increase in the first-best tax rate but a decrease in the second-best tax rate. Moreover, with the presence of the incentive effect, the second-best optimal tax rate is less than the output elasticity of public inputs. Finally, the revenue generated by the user fee alone is not sufficient to finance excludable public inputs under both first- and second-best optima.

Some extensions of this study are as follows. In our model, both excludable and non-excludable public inputs are flow variables. It may be an interesting issue to treat both types of public inputs are stock variables and examine the dynamics of the economy. Moreover, by focusing on the stock variables, one may incorporate government maintenance spending into the model and explore how the presence of the user fee affects the optimal government spending polices of new investment on pubic inputs as well as maintenance.

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The Second Paper

1. Introduction

Ever since the contribution of Dixit and Stiglitz (1977), considerable attention has been paid to issues concerned with whether free entry in a market with monopolistic competition leads to the over entry or too little entry of firms. Recently, researchers have further incorporated related issues with government policies to investigate optimal fiscal policies in the presence of distortions associated with imperfect competition. A notable contribution along this line of research is Chang et al. (2007) (hereafter, CHSL), who were the first to add monopolistic competition and increasing returns to specialization to a model where the government levies taxes on labor and capital incomes to provide congestible public inputs. They found that optimal tax rates on capital and labor incomes are decreasing in the degrees of monopolistic competition/market power and, more importantly, free entry always leads to over entry relative to the social optimum whenever the congestion is present. This latter conclusion is true even when the market is perfectly competitive.

While CHSL is quite insightful, they use the same parameter to characterize both market power and increasing returns to specialization. As pointed out by Benassy (1996), this type of setting is unable to distinguish the effects caused by monopolistic competition from those caused by increasing returns. The purpose of this paper is to separate monopolistic competition from increasing returns to fully disentangle their corresponding effects. In so doing, we derive conclusions that are significantly different from CHSL.

To be specific, we find that optimal tax rates on capital and labor incomes are independent of the degree of market power. This result is quite intuitive. To restore the social optimum, tax rates on capital and labor incomes must be able to correct distortions between factor incomes and their marginal products. While a higher degree of market power leads to a larger degree of distortions to the individual firm, it also attracts more firms to enter the market under free entry. An expansion in the number of firms, however, tends to ease distortions between factor incomes and marginal products. As a result, market power leads to two opposite effects on the distortion. As a whole, we find that the two effects cancel each other out so that market power has no effect on optimal tax rates.

With respect to the issue of over entry, we find that, depending on the relative strengths of market power, increasing returns, and congestion, free entry may lead to over or too little entry relative to the social optimum. When the market is perfectly competitive, free entry leads to over (too little) entry of firms, provided that the strengths of congestion are greater (less) than those of increasing returns. It is worth noting that increasing returns and market power possess equal strengths but opposite signs in determining whether free entry leads to over or too little entry. As a result, when increasing returns and market power are characterized by the same parameter, such a parameter will not have any effect on issues related to over entry. Hence, in CHSL, the only force that determines whether free entry leads to over entry is the congestion associated with public inputs.

2. Model

Consider an infinite-horizon production economy consisting of firms, households, and a government. There are two types of goods in the economy: a homogeneous final good and differentiated intermediate inputs. Each differentiated intermediate input is produced by a single firm indexed by $i = 1, ..., n_t$, where n_t is the total number of firms producing intermediate inputs at t. The final good is produced by competitive firms using the following production technology:

$$Y_t = [n_t^{\theta(1-\eta)-\eta} \int_0^{n_t} x_{it}^{1-\eta} di]^{\frac{1}{1-\eta}} \quad \theta \in [0,1), \eta \in [0,1), \qquad (1)$$

where x_{it} is the quantity of intermediate input i. Because intermediate inputs are not perfect substitutes in producing final goods, each intermediate-input producer faces a downward-sloping demand curve. This gives firm i some degree of market power and, as will be seen later, the parameter η measures the degree of market power.

Since intermediate-input firms are symmetric, each firm will produce the same amount of intermediate inputs in equilibrium (i.e., $x_{it} = x_t$). Using this result, the aggregate production function can be derived from eq. (1) as

$$Y_t = n_t^{1+\theta} x_t. \tag{2}$$

The technology in eq. (2), as in Ethier (1982) and Benassy (1996), displays aggregate increasing returns to specialization in the sense that the larger the number of intermediate inputs n_t, the higher the amount of final goods produced for a given amount of x_t. It is obvious that the parameter θ determines the degree of increasing returns to specialization.

From eqs. (1) and (2), the degree of market power is separated from the degree of increasing returns to specialization. In the CHSL model, the production function in eq. (1) is given as $Y_t = [\int_0^{n_t} x_{it}^{\rho} di]^{\frac{1}{\rho}}, \rho \in (0,1)$ and, under the symmetric equilibrium, $Y_t = n_t^{\frac{1}{\rho}} x_t$. Obviously, both market power and increasing returns to specialization are characterized by the same parameter ρ.

The producer of intermediate input i at t employs capital k_{it} and labor l_{it} to produce intermediate input x_{it} and sells it to final-good producers. Following CHSL, the technology for producing intermediate input i at t is given as

$$x_{it} = k_{it}^{\alpha} l_{it}^{\beta} G_{st}^{\gamma} - \phi, \;\; 0 < \alpha, \beta, \gamma < 1, \;\; \alpha + \beta + \gamma = 1, \tag{3}$$

where G_{st} is the amount of public inputs received by each firm and ϕ is the overhead/fixed cost associated with the production. Following Thompson (1974), Glomm and Ravikumar (1994), and Turnovsky (1996), public inputs are congestible and the amount of public inputs received by each firm is given as

$$G_{st} = \frac{G_t}{\Gamma(n_t, K_t)^{\sigma}}, \;\; \sigma > 0 \tag{4}$$

where G_t is the total amount of public inputs provided by the government and K_t is the aggregate private capital in the economy. The parameter σ is related to the degee of congestion. It is assumed that $G_t = gY_t$, with g being the ratio of government expenditure on public inputs. The function Γ is homogeneous of degree one in the number of firms n_t and the total amount of capital K_t, with $\Gamma_{n_t} > 0$ and $\Gamma_{K_t} > 0$. Because $k_{it} = k_t = K_t/n_t$ in a symmetric equilibrium, $\Gamma(n_t, K_t) = n_t \varphi(k_t)$. Defining ε as the elasticity of congestion with respect to per-firm capital k_t, we see that $\varepsilon = d\ln\Gamma(n_t, K_t)/d\ln k_t = k_t \varphi'/\varphi$, where $\varepsilon \in [0, 1]$.

Households as a whole are endowed with one unit of labor at any point of time. They accumulate capital and provide labor to maximize the following lifetime utility function:[20]

$$\int_0^{\infty} [\ln C_t + \Lambda \ln(1 - L_t)] e^{-\xi t} dt, \;\; \Lambda > 0, \xi > 0, \tag{5}$$

where C_t is total consumption (final goods) and L_t is total labor supplied to firms. By denoting w_t

[20] To facilitate comparison with the centralized economy, we present the households' decision as a whole.

and r_t as the capital rental rate and the wage rate under the aggregate equilibrium at t, the households' budget constraint is given as[21]

$$\dot{K}_t = (1-\tau_l)w_t L_t + (1-\tau_k)(r_t K_t + \Pi_t) - C_t + T_t, \qquad (6)$$

where Π_t is the total profits of firms, τ_k (τ_l) is the tax rate on capital income and profits (labor income), and T_t is a lump-sum transfer from the government. Note that $\Pi_t = \int_0^n \pi_{it} di$, where π_{it} is firm i's profit. In the symmetric equilibrium, households will equally supply their labor and capital to all firms; hence, $L_t = n_t l_t$ and $K_t = n_t k_t$.

The government finances public inputs G_t and lump-sum transfers T_t by taxing income from capital and labor as well as firms' profits. Hence, the government's budget constraint is given as

$$G_t + T_t = \tau_l w_t L_t + \tau_k (r_t K_t + \Pi_t). \qquad (7)$$

3. Competitive Equilibrium

We now present the equilibrium consequences in which private agents make their own decisions by taking the market-determined wage and capital rental rates as well as tax rates as given. To solve the producers' maximization problems, we treat the final good as the numéraire and denote p_i as the price of intermediate input i (in terms of the final good).[22] Then, the representative final-good producer faces the following maximization problem:

$$\text{Max}_{x_i} [n^{\theta(1-\eta)-\eta} \int_0^n x_i^{1-\eta} di]^{\frac{1}{1-\eta}} - \int_0^n p_i x_i di \qquad (8)$$

Taking the number of intermediate inputs n as well as p_i as given, the first-order condition for selecting x_i is derived as

$$p_i = (\frac{Y}{x_i})^{\eta} n^{\theta(1-\eta)-\theta} \qquad (9)$$

Eq. (9) is the demand function for x_i. By taking logs on both sides of eq. (9), one can find that

$$-\frac{d\log x_i}{d\log p_i} = \frac{1}{\eta}.$$

Thus, the parameter η is the inverse of the elasticity of demand for x_i. When $\eta = 0$, the price elasticity is infinite, implying that intermediate inputs are perfect substitutes in producing final goods. In this case, the market for intermediate inputs is perfectly competitive. For $0 < \eta < 1$, the demand function for x_i is negatively sloped and in this case the intermediate-input firm can be exploited by manipulating prices. Moreover, a higher η corresponds to a higher degree of market power for the producer of intermediate input i.

Denote r_i and w_i as the capital rental and wage rates faced by firm i. Then, the intermediate-input firm i's profit can be written as

$$\pi_i = p_i x_i - r_i k_i - w_i l_i. \qquad (10)$$

[21] For simplicity, there is no capital depreciation.
[22] To keep the notation simple, we eliminate time subscripts from now on.

Taking r_i and w_i as given, the firm chooses k_i and l_i to maximize its profit, subject to eqs. (3), (4) and (9). The first-order conditions for selecting k_i and l_i are derived as

$$r_i = (1-\eta)\alpha(\frac{x_i+\phi}{k_i})p_i \tag{11}$$

$$w_i = (1-\eta)\beta(\frac{x_i+\phi}{l_i})p_i \tag{12}$$

Note that $\alpha(\frac{x_i+\phi}{k_i})p_i$ and $\beta(\frac{x_i+\phi}{l_i})p_i$ are the marginal products of capital and labor faced by firm i, respectively. Thus, the capital rental and wage rates are less than their corresponding marginal products in the case of imperfect competition (i.e., $1 > \eta > 0$). In response to this fact, households will accumulate less capital and provide less labor, leading to inefficiency in production compared with the case of perfect competition. This is consistent with Judd (1997) in the case where the number of firms is constant. In this model, the number of firms in equilibrium is endogenously determined by the free-entry condition. For this reason, the degree of market power leads to another effect on marginal products, as we will state below.

Under the symmetric equilibrium, $p_i = p$. Combining $p_i = p$, $k_i = k = K/n$, and $l_i = l$ with eqs. (2) and (9), we have

$$p = n^{\theta}. \tag{13}$$

In this model, new firms will enter the market and produce a new intermediate input in each period, until incumbent firms have zero profits. Substituting eqs. (11)-(13) into eq. (10) and setting $\pi_i = \pi = 0$, we derive

$$x_i = x = \frac{(1-\eta)(\alpha+\beta)\phi}{1-(1-\eta)(\alpha+\beta)}. \tag{14}$$

It is easy to verify that $\partial x/\partial\eta < 0$. By substituting eq. (14) into eq. (2), the equilibrium number of firms is determined as

$$n = [\frac{1-(1-\eta)(\alpha+\beta)}{(1-\eta)(\alpha+\beta)\phi}Y]^{\frac{1}{1+\theta}}. \tag{15}$$

Thus, a higher degree of market power will lead to a larger number of firms. Intuitively, a higher degree of market power raises the incumbent firm's profit and hence induces more new firms to enter the market. As shown in eq. (13), an expansion in the number of firms increases the price of the intermediate inputs and hence increases the marginal products of capital and labor (i.e., $\alpha(\frac{x_i+\phi}{k_i})p_i$ and $\beta(\frac{x_i+\phi}{l_i})p_i$). As a result, while market power η directly creates distortions between the capital rental and wage rates and the corresponding marginal products faced by each individual firm, free entry that leads to an expansion in the number of firms in the aggregate equilibrium raises the marginal product and thus eases these distortions. As a whole, these two opposite effects cancel each other out and hence market power has no effect on the distortions between the factor incomes and marginal products under the competitive equilibrium of the economy. To verify this, by substituting eqs. (13) and (14) into (11) and (12), we find that the capital rental and wage rates are given as

$$r = (\frac{\alpha}{\alpha+\beta})\frac{Y}{K} \tag{11'}$$

$$w = (\frac{\beta}{\alpha+\beta})\frac{Y}{L}, \tag{12'}$$

where $(\frac{\alpha}{\alpha+\beta})\frac{Y}{K}$ and $(\frac{\beta}{\alpha+\beta})\frac{Y}{L}$ are the marginal products under the aggregate equilibrium.

Households as a whole maximize their lifetime utility in eq. (5) subject to eq. (6). By denoting λ as the shadow price associated with the budget constraint $\dot{K}$ in eq. (6), the first-order conditions for the maximization are listed as follows:

$$\frac{1}{C} = \lambda \tag{16}$$

$$\frac{\Lambda}{1-L} = \lambda(1-\tau_l)w \tag{17}$$

$$\lambda(1-\tau_k)r = -\dot{\lambda} + \xi\lambda, \tag{18}$$

where r and w are given by eqs. (11') and (12').

4. Optimal Fiscal Policies and Entry

We next consider a centralized economy in which a social planner maximizes eq. (5), subject to the following aggregate production function for final goods:

$$Y^s = n^{1+\theta}[K^\alpha L^\beta G^\gamma \varphi(k)^{-\gamma\sigma} n^{-(\alpha+\beta+\gamma\sigma)} - \phi] \tag{19}$$

and aggregate resource constraint for the planner:

$$\dot{K} = Y - G - C. \tag{20}$$

Eq. (19) is derived by combining eq. (2) with (3), while eq. (20) is derived by substituting eqs. (10)-(13) into eq.(6) without the presence of tax rates and lump-sum transfers. Note that, by disentangling market power and increasing returns, the aggregate production function in eq. (19) is not directly related to market power η.

The social planner accomplishes his goal by selecting C, G, K, L, and n. By letting μ be the shadow price associated with the budget constraint $\dot{K}$ in eq. (20), the first-order conditions for the social planner's maximization are

$$\frac{1}{C} = \mu \tag{21}$$

$$\frac{\Lambda}{1-L} = \mu \underbrace{\beta(\frac{1+\theta}{\theta+\alpha+\beta+(1-\varepsilon)\gamma\sigma})\frac{Y^s}{L}}_{MPL^s} \tag{22}$$

$$\underbrace{\mu(\alpha-\sigma\gamma\varepsilon)[\frac{1+\theta}{\theta+\alpha+\beta+(1-\varepsilon)\gamma\sigma}]\frac{Y^s}{K}}_{MPK^s} = -\dot{\mu} + \xi\mu \tag{23}$$

$$n^s = [\frac{[1-\alpha-\beta+\theta-(1-\varepsilon)\gamma\sigma]}{\phi[\alpha+\beta+(1-\varepsilon)\gamma\sigma]}Y^s]^{\frac{1}{1+\theta}} \tag{24}$$

$$\frac{G}{Y^s} = \frac{(1+\theta)\gamma}{\alpha+\beta+(1-\varepsilon)\gamma\sigma}, \tag{25}$$

where the superscript 's' represents the equilibrium values under the centralized economy.

There are three different types of distortions in the economy: imperfect competition, increasing returns, and the congestion of public inputs. In general, private agents in the decentralized economy make their decisions without taking these distortions into account. By contrast, the social planner takes these distortions into account and hence derives optimal conditions in eqs. (21)-(25). It is well known that the government in the competitive equilibrium (the decentralized economy) can induce private agents to behave like the social planner and restore the first-best outcome. To do so, the government in the decentralized economy sets up tax rates (τ_k and τ_l) and the ratio of expenditure g to equalize the decisions made by private agents (eqs. 16-18) and the social planner (eqs. 21-23). In so doing, the total output in the decentralized economy (i.e., Y) will be identical to that in the centralized economy (i.e., Y^s) under the equilibrium.[23] We then derive the following result.

Proposition 1. With the presence of an imperfect market, increasing returns to specialization, and congestion, the optimal tax rates and the fraction of government expenditure are given as

$$\tau_l = \frac{(1-\varepsilon)\gamma\sigma - \theta(\alpha+\beta)}{\alpha+\beta+(1-\varepsilon)\gamma\sigma} \tag{26}$$

$$\tau_k = \frac{(1-\varepsilon)\gamma\sigma + (\alpha+\beta)[(1+\theta)\frac{\gamma\sigma\varepsilon}{\alpha} - \theta]}{\alpha+\beta+(1-\varepsilon)\gamma\sigma} \tag{27}$$

$$g = \frac{(1+\theta)\gamma}{\alpha+\beta+(1-\varepsilon)\gamma\sigma}. \tag{28}$$

The striking result from Proposition 1 is that optimal policies are related to increasing returns and congestion, but are independent of market power. This is significantly different from CHSL who find that optimal income tax rates on both labor and capital are decreasing in terms of market power. Intuitively, to restore the social optimum, fiscal policies must be able to correct any distortion in factor incomes and marginal products. As already stated, when the number of firms is endogenously determined by the free-entry condition, market power will not create distortions between factor incomes and marginal products in the aggregate equilibrium. As a result, optimal tax rates are independent of market power in our model. By contrast, when market power and increasing returns are characterized by the same parameter, the conclusion of CHSL may be misleading. Indeed, it is easy to see from eqs. (26) and (27) that optimal tax rates are decreasing in the degree of increasing returns. In other words, the conclusion of CHSL that optimal tax rates are decreasing in market power is, in fact, driven by the degree of increasing returns.

By equating eq. (15) with eq. (24), we have the following result:

Proposition 2. Free entry in the competitive economy leads to over (too little) entry relative to the social optimum when

$$\frac{1-(1-\eta)(\alpha+\beta)}{(1-\eta)(\alpha+\beta)} > (<) \frac{1+\theta-(\alpha+\beta)-(1-\varepsilon)\gamma\sigma}{\alpha+\beta+(1-\varepsilon)\gamma\sigma}.$$

Obviously, free entry in the competitive economy may lead to over or too little entry relative to the social optimum. This is also significantly different from CHSL who find that free entry always leads to over entry. In our model, a higher degree of market power leads to a higher number of firms; hence, market power tends to induce excessive entry. On the other hand, since private agents do not take increasing returns into account, the presence of increasing returns tends to result in too little entry. When market power and increasing returns are characterized by the same parameter, as in CHSL, both effects cancel each other out in determining whether free entry leads to over or too little entry. Hence, CHSL find that market power plays no role in determining the issue related to over entry.[24] By disentangling market power from increasing returns, we find that whether or not free entry leads to over or too little entry depends on the relative strengths of the effects of market

[23] λ is also equal to μ.

[24] From page 149 of CHSL, one can verify that the parameter ρ does not have an effect on whether $N_t^c > N_t^s$ or $N_t^c < N_t^s$ when optimal policies are implemented (and hence $Y_t^c = Y_t^s$).

power, increasing returns and congestion.

5. Conclusion

This paper extends Chang et al. (2007) by disentangling market power and increasing returns to specialization. In so doing, we arrive at conclusions that are significantly different from Chang et al. (2007). In particular, market power does not affect optimal tax rates and free entry may lead to over or too little entry even when the intermediate input market is perfectly competitive.

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附件二

國科會補助專題研究計畫成果報告自評表

請就研究內容與原計畫相符程度、達成預期目標情況、研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）、是否適合在學術期刊發表或申請專利、主要發現或其他有關價值等，作一綜合評估。

1. 請就研究內容與原計畫相符程度、達成預期目標情況作一綜合評估

■ 達成目標

□ 未達成目標（請說明，以 100 字為限）

　□ 實驗失敗

　□ 因故實驗中斷

　□ 其他原因

說明：

2. 研究成果在學術期刊發表或申請專利等情形：

論文：■已發表 □未發表之文稿 □撰寫中 □無

專利：□已獲得 □申請中 □無

技轉：□已技轉 □洽談中 □無

其他：（以 100 字為限）

3. 請依學術成就、技術創新、社會影響等方面，評估研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）（以 500 字為限）

此一兩年期計畫，共完成兩篇與政府最適財政政策有關的文章。雖然兩篇文章的結論與現存文獻都有很大的不同，但兩篇文章的模型設定都比現存文獻合理，結論也比現存文獻符和經濟直覺。基於此，個人認為者兩篇文章的學術貢獻顯著。

附件四

國科會補助專題研究計畫移地研究心得報告

日期：102 年 2 月 21 日

計畫編號	NSC 99－2410－H－004－055－MY2		
計畫名稱	政府公共支出、維修支出、與貨幣融通：局部不確定性與經濟成長		
出國人員姓名	洪福聲	服務機構及職稱	政治大學經濟系
出國時間	1. 101 年 04 月 04 日至 101 年 04 08 日 2. 101 年 08 月 20 日至 101 年 08 月 24 日	出國地點	香港

一、 移地研究過程

I went to Hong Kong twice during this project. In the first trip, I went to Hong Kong from 04/04/2012 to 04/08/2012 to discuss a research project with Professor Yong Wang, who is affiliated with Department of Economics and Finance, City University of Hong Kong. During this trip, we have launched a project that is intended to examine the optimal government fiscal policies with the presence of asymmetric information in capital markets. Basically, this project is an extension of Ho and Wang (2005). In the second trip, I went to Hong Kong from Aug. 20, 2012 to Aug. 24, 2012. During the second trip, we have established a model and reached some results. Below, I briefly state this project.

In their previous paper, Ho and Wang (2005) examined the optimal tax rate in an endogenous growth model with asymmetric information in credit markets. One important contribution of this study is that, due to the existence asymmetric information, an increase in the tax rate exacerbates the problem of asymmetric information and hence is harmful to economic growth. With the presence of asymmetric information, screening becomes a mechanism to separate different types of borrowers. As in Barro (1990), an increase in the tax rate, on the one hand, enables the government to increases its spending that is beneficial to economic growth. On the other hand, it also creates distortion to capital investment and hence is detrimental to economic growth. By incorporating asymmetric information into Barro (1990), Ho and Wang (2005) found that an increase in the tax rate acerbates the problem of asymmetric information to a larger extent. Given this, they argued that the optimal tax rate should be lower for economies whose problem of asymmetric information is more severe.

While Ho and Wang's (2005) conclusion is quite insightful, their model does not consider the possibility that the government may subsidize capital borrowers when asymmetric information is present. Indeed, it is well recognized that the presence of market imperfection call a need for the government to intervene the market. As asymmetric information is a type of market imperfection, a country who suffers a larger extent of asymmetric information may need to subsidize capital borrowers more extensively. Our project is intended to extend Ho and Wang (2005) by consider this possibility. Potentially, this consideration may alter Ho and Wang's (2005) result. Specifically, a country who suffers a larger extent of asymmetric information may also subsidize capital borrowers to a larger extent. As the government need to tax output for subsiding, this also implies that a country suffered a larger extent of asymmetric information may need to increase its tax rate to raise revenue for subsidizing.

During my trip, we have found some basic results. Specifically, we found that a country who suffers a larger extent of asymmetric information should subsidize capital borrowers. However, once the magnitude of the problem of asymmetric information is reduced to a critical level, subsidy is not beneficial to economic growth. Given this, we further found that if the magnitude of the information problem is relatively, a the optimal tax is increasing in the magnitude of information problem. This contradicts to Ho and Wang (2005).

The above conclusion is derived by using a model with asymmetric information where lenders must screen borrowers in ex ante. We plan to verify where our results still hold if we consider the model with costly state verification. This should be finished in a few months.

二、 研究成果

見次頁

三、建議

無。

四、其他

無。

移地研究成果

Asymmetric Information, Government Credit Subsidy, and Economic Growth

Preliminary version

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Abstract

This paper examines the effects of tax-financed government credit programs in a simple endogenous growth model with the presence of asymmetric information. We find that government credit programs are able to alleviate the problem of asymmetric information and hence reduce the incidence of credit rationing, even though the associated taxation exacerbates this problem. Nevertheless, taxation also crowds out capital investment. We derive optimal ratio of government credit subsidies. Interestingly, optimal ratios of credit subsidies may be negative, implying that the government should tax credit and use the proceeds to subsidize output production.

1. Introduction

It is well documented in the literature that market failures create a need for the government intervention. One of most important type of market failures is asymmetric information in credit markets. With the presence of asymmetric information, borrowers are usually credit rationed and hence it is believed that credit markets do not provide adequate funds for capital investment. In models of endogenous growth where capital investment is the key impetus to economic growth, asymmetric information and the resulting credit rationing could be the key impediment to economic growth. In response to this, many governments in the world have provided credit subsidy programs intended to alleviate the problem of asymmetric information and hence facilitate capital investment.[25]

Numerous studies have examined the effects of government credit programs. Smith and Stutzer (1989), for example, evaluate government loan programs, such as loan guarantees, direct loans and equity participation loans, with the presence of asymmetric information and credit rationing. They show that some government programs, such as loan guarantee programs, might improve the efficiency of credit markets. However, direct loans may distort borrowers' incentive to a further extent and lead to an increase in the incidence of credit rationing. Similarly, Williamson (1994) examines the effects of government credit programs such as loan guarantees and direct loans in two types of informational frictions: one that frictions are caused by the costly state verification, and the other one that frictions are due to an adverse selection problem. In the model of costly state verification, he shows that direct government lending on the same terms offered by the private sector does not relieve any of the rationing that exists prior to the government intervention. Moreover, with the presence of credit rationing the effects of government loan guarantees could deteriorate all participants of credit markets if loan guarantees lower the interest rate faced by lenders while increase the interest rate faced by borrowers. In the second model of adverse selection, direct loans to borrowers who are credit rationed may act to alter incentives in possibly useful ways if the interest rate of government loans is set sufficiently low. Moreover, he finds that government loan guarantees are not a Pareto improvement.

While the above mentioned studies are quite insightful to the effects of government credit programs, they ignore the possibility that government relies on taxation to finance its spending on credit programs. For example, Smith and Stutzer (1989) assume that the government utilizes foreign aids to finance its spending on credit programs. Similarly, in Williamson (1994), government charges interests on the direct loans and utilizes insurance premium paid by lenders to finance loan guarantees. If the government imposes a tax on output production to finance its spending on credit programs, there may have two opposite effects on

[25] See Gale (1990) and Li (2002) for government credit programs in U.S. and Khatkate (1982), Besley (1994) and McKinnon (1973) for discussions on credit interventions of developing countries.

government credit programs. First, credit subsidies may be able to alleviate the problem of asymmetric information and hence reduce the incidence of credit rationing. Second, as in Ho and Wang (2005), taxation also creates additional distortions to credit markets which lead to an increase in the incidence of credit rationing. As a consequence, allowing the government to finance its spending of credit programs may have profound effects on the effectiveness of government credit programs.

It is worth noting that Li (2002) develops a dynamic general equilibrium model with infinitely lived agents whose saving behaviors and occupational choice are influenced by precautionary saving motives and borrowing constraint. Without explicitly modeling asymmetric information, tax-financed government credit programs in this model have two opposite effects to the economy. On the benefit side, tax-financed credit programs that provide additional means of smoothing consumption and loosen borrowing constraint enhance the liquidity of agents. On the cost side, the associated taxation crowds out capital and have adverse incentive effects. Interestingly, the study finds that income subsidy, instead of the subsidy on loan repayment, are more effective in promoting entrepreneurial activity and improving total output.

Though tax-financed government credit programs have been analyzed by Li (2002), asymmetric information and credit rationing disappear in this model. Moreover, the primary focus of this model is how government credit programs influence agents' decisions on savings and occupational choice. The effects of tax-financed government credit programs on capital investment and economic growth in a model with asymmetric information and credit rationing, however, are not analyzed in the literature. The purpose of this paper is to present a simple theoretical analysis that is able to shed lights on the effects of tax-financed government credit programs in a model of endogenous growth with the presence of asymmetric information.

It is important to consider tax-financed government credit programs in a model of endogenous. To see this, note that government announces its credit programs at current period and the actual payment of credit programs takes place at future period (when loan payments are due). This implies that the government can impose a tax on output at the future period to finance its credit programs on loans at the current period. As a result, if the government credit programs are so effective that capital investment is increased and hence economic growth is enhanced, then the actual tax rate can be lower. Recent studies that do not take this channel into account cannot fully capture the effects of tax-financed government credit programs.

We develop a model in which asymmetric information gives rise to both problems of adverse selection and costly state verification. Under the separating equilibrium of credit markets, some borrowers are credit rationed. We consider three types of subsidies: the interest rate subsidy, loan guarantees and the monitoring cost subsidy. We find that all of these three tax-financed government credit programs are able to alleviate the problem of asymmetric information and decrease the incidence of credit rationing, even though the associated taxation exacerbates it. Note that taxation on output also reduces the size of each capital loan and hence reduces capital investment. As a result, government credit programs have two opposite effects on capital investment and economic growth. First, they are able to alleviate the problem of asymmetric information and reduce the incidence of credit rationing. This is beneficial to economic growth. Second, the associated taxation crowds out capital investment and hence reduces economic growth. These two opposite effects imply that there are optimal ratios of government credit subsidies. We also characterize the optimal subsidy ratios. One important finding of our study is that if the extent of credit rationing is not so severe before the presence of government credit programs, it may be optimal for the government to impose a tax on credit and use the proceeds to finance a subsidy on output production. In other words, the optimal ratios of government credit subsidies can be negative.

The plan of this paper is as follows. In Section 2, we present the theoretical model. In Section 3, we obtain the equilibrium contracts under the separating equilibrium. Section 4 derives economic growth and social welfare under the balanced growth path. Optimal ratios of government credit subsidies are analyzed in Section 5. Section 6 concludes.

2. Model

Consider a model economy inhabited by two-period lived overlapping generations of agents. Time is discrete and indexed by t=0, 1, 2, …. All generations are identical in size and composition, with each generation consisting of a continuum of agents with unit mass. Each generation consists of two different groups of young agents with equal size, referred to as borrowers and lenders. Both borrowers and lenders care only consumption in the old period.

Lender

Each lender is endowed with one unit of labor at the young age and nothing at the old age. Young lenders' labor is inelastically sold to firms at t in return for the after-tax real wage rate $(1-\tau)w_t$, where τ is the tax rate and w_t is the wage rate. Each young lender can lend $(1-\tau)w_t$ to a borrower in exchange for consumption in the next period. Alternatively, young lender has an access to a storage technology that can convert one unit of time-t output into x units of time-t+1 capital. Each old lender becomes a firm operator that can produce output by renting capital from old borrowers (capital producers) and young lenders.

Capital producing borrowers

Each young borrower is endowed with a project and a unit of labor. With his own labor, the project of each young borrower can convert consumption goods (borrowed from lenders) into capital goods. Borrowers' projects are of either type-L or type-H and a fraction λ of borrowers' projects are of type- H. With probability p_i, the borrower with a type-i $(i=H,L)$ project can convert one units of time-t consumption good into Q units of time-t+1 capital. With probability $1-p_i$, the operation of the project is failed and nothing is produced. It is assumed that $1 \geq p_L > p_H > 0$ so that a type-L (-H) project is a low (high) risk project. For loans between lenders and borrowers to be mutual desirable, it must be the case that $p_i Q > x$. Hence, we assume that $x = Q\varepsilon$, where $\varepsilon < p_i$ $(i=H,L)$. Moreover, since the capital producing technology of each investment project is linear, we must impose a condition to limit the size of each loan. For this purpose, we follow Bencivenga and Smith (1993) and Ho and Wang (2005) by assuming that a borrower can only contact with a lender.

As a variety of informational imperfection exists in credit markets, we impose two additional assumptions. First, the type of the project for each borrower, ex ante, is private information. Second, the information related to whether the borrower's project is successful, ex post, is private information. While the former assumption leads to an adverse selection problem, the latter gives rise to a moral hazard problem. To verify the true outcome of the project, any other agent must incur δ units of capital per unit lent (monitoring costs). As in the literature of costly state verification, this implies that each lender must monitor the borrower when a failure of investment project is claimed by the borrower.

Credit markets are operated in a way similarly to Bencivenga and Smith (1993), Bose and Cothren (1996), and Ho and Wang (2005). At the beginning of each period, each young lender at *t* announces a set of loan contracts, denoted as C^i, $i = H, L$, with C^H (C^L) being intended for type *H* (*L*) borrowers, taking other lenders' offers as given. If these announced contracts are not dominated by those of other lenders', the lender will be approached with borrowers. The borrower can accept either of the two contracts on the menu or reject both. We focus on the separating equilibrium in which the announced contracts are able to induce self selection of borrowers. As in the literature, self selection of borrowers can be achieved if the offered contracts specify a probability that the borrower is denied credit and different type of borrowers has different opportunity cost of being denied. For this latter purpose, we follow Bencivenga and Smith (1993) by assuming that borrowers who are denied with credit at *t* can provide his labor to firms and earn the wage rate w_t. Borrowers who earn the wage rate must store for old-age consumption.[26] One unit stored by a type *i* borrower yields β_i units of the consumption good at time *t*+1. Moreover, $\beta_L > \beta_H = 0$ so that type *H* borrowers have higher opportunity costs than type *L* ones when their loan applications are rejected.

Output producing firms

Any agent who provides his labor to firms and earns the wage rate becomes a firm operator at the old age. Each firm can rent capital from borrowers and hire labor from young agents according to the following production technology:

$$y_t = A\bar{k}_t^{\theta} k_t^{\alpha} l_t^{1-\alpha} \tag{3}$$

where y_t is output, $\bar{k}_t$ is the average per firm capital stock in the economy, k_t is the capital stock employed and l_t is per firm labor employment. Following the literature of endogenous growth, it is assumed that $\theta = 1 - \alpha$. All agents behave competitively in labor and capital markets at any period *t*; thus, they take the wage rate w_t and renal rate of capital (denoted as ρ_t) as given. Moreover, competition among firms ensure that

$$w_t = A\bar{k}_t^{\theta} k_t^{\alpha}(1-\alpha) l_t^{-\alpha} = A(1-\alpha) k_t l_t^{-\alpha} \tag{4}$$

and

[26] Implicitly, it is assumed that credit markets are closed after borrowers receive the wage rate. Hence, they cannot contract with other borrowers.

$$\rho_t = A\bar{k}_t^{\theta} \alpha k_t^{\alpha-1} l_t^{1-\alpha} = A\alpha l_t^{1-\alpha}, \qquad (5)$$

where the last equalities in eqs. (4) and (5) are derived by using the equilibrium conditions of $\bar{k}_t = k_t$.

Government

Informational imperfection in credit markets usually places considerable strains on the operations of these markets. To resolve this, government usually provides a variety of credit programs. Government credit programs, however, needs additional taxation, which may create additional distortions to credit markets. The optimal subsidy-taxation policy should take this issue into account. To evaluate the effects of government credit programs with needed taxation, we consider three types of government subsidy: interest rate subsidy, loan guarantee, and intermediation cost subsidy. Denote s_1, s_2, and s_3 as the subsidy ratio for interest rate, the subsidy ratio for the interest payments to lenders for those borrowers with failed projects (loan guarantee), and the subsidy ratio to the monitoring cost. Also, let τ be the tax rate on time $t+1$ output imposed by the government to finance its spending on credit subsidy programs. Note that the government announces credit programs at time t, while actual payments for these programs take place at time $t+1$. The government budget constraint will be given after the equilibrium loan contracts are derived.

3. Equilibrium Contracts under the Separating Equilibrium

As in Rothschild and Stiglitz (1976), the equilibrium of credit markets features that any equilibrium displays self-section and yields zero expected profit to the lender. To induce self-selection, each young lender announces a set of contracts C^i (*i*=*H, L*), each consisting of a triple (π_t^i, R_t^i, q_t^i), where π_t^i is the probability that the type-*i* borrower obtains the loan, R_t^i is the real rate of interest, and q_t^i is the loan quantity offered. Then, the expected old-period consumption of a type *L* and type *H* borrower who reveals his risk type and applies for a loan from a lender is given as

$$\pi_t^L p_L[Q(1-\tau)\rho_{t+1} - (1-s_1)R_t^L]q_t^L + (1-\pi_t^L)\beta_L(1-\tau)w_t \qquad (6)$$

and

$$\pi_t^H p_H[Q(1-\tau)\rho_{t+1} - (1-s_1)R_t^H]q_t^H \qquad (7)$$

respectively. With probability π_t^L, the type L borrower derives q_t^L, from which he can produce Qq_t^H units of time-*t*+1 capital with probability p_L and obtain $Qq_t^H(1-\tau)\rho_{t+1}$ units of time-*t*+1 after-tax output (via renting capital to output producing firms). After interest payment, the net payoff (old-age consumption) is $\pi_t^L p_L[Q(1-\tau)\rho_{t+1} - (1-s_1)R_t^L]q_t^L$, where s_1 is the subsidy ratio for interest payment. With the probability $1-\pi_t^L$, loan application is rejected and the type *L* borrower can supply labor to earn $(1-\tau)w_t$ and store it for old-age consumption. This leads to eq. (6). Similar logic applies to derive eq. (7) for a type *H* borrower, except that the type *H* borrowers have no access to storage ($\beta_H = 0$).

Competition induces each lender to offer C^i that maximize eqs. (6) and (7), subject to the following incentive constraints

$$\pi_t^L p_L[Q(1-\tau)\rho_{t+1} - (1-s_1)R_t^L]q_t^L + (1-\pi_t^L)\beta_L(1-\tau)w_t \geq$$
$$\pi_t^H p_L[Q(1-\tau)\rho_{t+1} - (1-s_1)R_t^H]q_t^H + (1-\pi_t^H)\beta_L(1-\tau)w_t \quad (8)$$
$$\pi_t^H p_H[Q(1-\tau)\rho_{t+1} - (1-s_1)R_t^H]q_t^H$$
$$\geq \pi_t^L p_H[Q(1-\tau)\rho_{t+1} - (1-s_1)R_t^L]q_t^L, \quad (9)$$

the zero-profit condition for each lender from lending to a type *i* borrower

$$[p_i R_t^i + (1-p_i)s_2 R_t^i - (1-p_i)(1-s_3)\delta\rho_{t+1}]q_t^i$$
$$= q_t^i Q\varepsilon(1-\tau)\rho_{t+1}, i = H, L, \quad (10)$$

and the following resource constraints[27]

$$q_t^L \leq (1-\tau)w_t \quad (11)$$
$$q_t^L \leq (1-\tau)w_t. \quad (12)$$

The first part of eq. (8) is the expected payoff to a type *L* borrower who reveals his true type by applying for C^L, while the second part is the expected payoff of a type *L* borrower who pretends as a type *H* borrower by applying for C^H. Similarly, the first part of eq. (9) is the expected payoff of a type *H* borrower who truly reveals his type by applying for C^H and the second part of this equation is the expected payoff when a type *H* borrower applies for C^L. In the separating equilibrium, one of eqs. (8) and (9) must hold in the strict inequality. By lending q_t^i to the borrower, the expected rate of returns is equal to $p_i R_t^i + (1-p_i)s_2 R_t^i$, where the second part is derived from the government loan guarantee program. Since the lender must monitor the borrower when the borrower claims bankruptcy and the government subsidizes s_3 fraction of the monitoring cost, the expected monitoring cost is equal to $(1-p_i)(1-s_3)\delta$ in terms of capital and $(1-p_i)(1-s_3)\delta\rho_{t+1}$ in terms of output. Thus, the LHS of eq. (10) is the expected net returns to the lender via lending q_t^i units to a type *i* borrower. On the other hand, the RHS is the expected returns when the lender saves q_t^i through the storage technology. Thus, the equality between these two implies that each lender derives zero economic profit from lending. Note that each investment project is failed with probability $(1-p_i)$. Under such a case, the government promises to pay a s_2 fraction of interest payment $R_t^i q_t^i$ to the lender. Moreover, when the borrower claims bankruptcy, the lender must incur δq_t^i units of capital to verify the true outcome. Since the subsidy ratio of the monitoring cost is equal to s_3, the expected monitoring cost to each lender is equal to $(1-p_i)(1-s_3)\delta\rho_{t+1}q_t^i$. Finally, because one borrower can only contact with a lender, the amount of each loan is bounded by the lender's after-tax wage income, leading to eqs. (11) and (12).

To solve for the equilibrium contracts, we can first derive R_t^L and R_t^H from eq. (10) as follows:

[27] We may impose an assumption that some fraction of resources may be lost during the contracting process between the lender and borrower. With the presence of this ex ante cost, the resource constraint may be rewritten as $q_t^L \leq (1-\tau)(1-\delta_F)w_t$, where δ_F is the cost per unit lent that is lost during the contracting process. In this case, the presence of δ_F will not alter the borrowers' incentive so that the probability of obtaining a loan π_t^i (see below) does not depend on δ_F.

$$R_t^L = \frac{Q\varepsilon(1-\tau) + (1-p_L)(1-s_3)\delta}{p_L + (1-p_L)s_2}\rho_{t+1} \tag{13}$$

$$R_t^H = \frac{Q\varepsilon(1-\tau) + (1-p_H)(1-s_3)\delta}{p_H + (1-p_H)s_2}\rho_{t+1}. \tag{14}$$

From eqs. (13) and (14), $R_t^H > R_t^L$, because $p_L > p_H$. Second, $Q(1-\tau)\rho_{t+1} - (1-s_1)R_t^H$ must be positive; otherwise, type *H* borrowers have no incentive to borrow. Similarly, $[Q(1-\tau)\rho_{t+1} - (1-$ *s1RtLqtL* must be greater than *βLwt*. Since *Q(1−τ)ρt+1−1−s1RtH* and *Q(1−τ)ρt+1−1−s1RtL* are increasing in ε, it is assumed that ε is sufficiently small so that both condition hold. Given this condition, the expected payoff to both types of borrowers (i.e., $[Q(1-\tau)\rho_{t+1} - (1-s_1)R_t^i]q_t^i$) is increasing in q_t^i, making eqs. (11) and (12) binding.

Finally, since $R_t^H > R_t^L$, a type *H* borrower has incentive to pretend as a type *L* (by applying for C^L). On the contrary, type *L* borrowers will reveal their true type by applying for C^L. With the assumption that type *L* borrowers have lower opportunity cost being denied credit than type *H* ones, the separating equilibrium can be obtained by offering the type *H* borrowers their most preferred contract, while the contract intended to type *L* borrowers (i.e., C^L) is distorted such that type *H* borrowers have no incentive to apply for this contract. Obviously, the most preferred contract to type *H* borrowers (i.e., C^H) will feature that $\pi_t^H = 1$. Moreover, since $[Q(1-\tau)\rho_{t+1} - (1-s_1)R_t^L]q_t^L$ is greater than $\beta_L(1-\tau)w_t$, the expected payoff of a type *L* borrower (i.e., eq. (6)) is increasing in π_t^L. Thus, the probability of obtaining the loan for C^L should be as large as possible, making the incentive constraint in eq. (9) binding. Hence,

$$\pi_t^L = \frac{Q(1-\tau)\rho_{t+1} - (1-s_1)R_t^H}{Q(1-\tau)\rho_{t+1} - (1-s_1)R_t^L}. \tag{15}$$

For future reference, note that $Q(1-\tau)\rho_{t+1} - (1-s_1)R_t^H$ and $Q(1-\tau)\rho_{t+1} - (1-s_1)R_t^L$ are the net rate of returns to a type *H* and a type *L* borrower (in the case when the project is successful), respectively. Hence , under the separating equilibrium the probability of obtaining a loan for a borrower who applies for C^L is equal to the ratio of the net rate of returns for a type *H* borrower over that for a type *L* one.

We summarize the equilibrium contracts in the following proposition.[28]

Proposition 1. *The equilibrium contracts are derived as* $q_t^H = q_t^L = (1-\tau)w_t$,

$R_t^L = \frac{Q\varepsilon(1-\tau)+(1-p_L)(1-s_3)\delta}{p_L+(1-p_L)s_2}\rho_{t+1}$, $R_t^H = \frac{Q\varepsilon(1-\tau)+(1-p_H)(1-s_3)\delta}{p_H+(1-p_H)s_2}\rho_{t+1}$, $\pi_t^H = 1$, *and*

$$\pi_t^L = \pi = \frac{[p_L + (1-p_L)s_2]}{[p_H + (1-p_H)s_2]} \times \frac{\{[p_H + (1-p_H)s_2](1-\tau)Q - (1-s_1)[Q\varepsilon(1-\tau) + (1-p_H)(1-s_3)\delta]\}}{\{[p_L + (1-p_L)s_2](1-\tau)Q - (1-s_1)[Q\varepsilon(1-\tau) + (1-p_L)(1-s_3)\delta]\}}. \tag{16}$$

As is customary in the literature, the presence of informational imperfection in credit markets leads to

[28] Using the equilibrium contracts, one can easily verify that eq. (8) holds with a strict inequality.

credit rationing. In this paper, since $p_L > p_H$ and hence $R_t^L < R_t^H$, the probability of obtaining a loan for type L borrowers (i.e., π) is less than one, implying that some type L borrowers cannot obtain loans in the separating equilibrium. The following proposition characterizes the probability of obtaining a loan for type L borrowers.

Lemma 1. *Other thing being equal, (i) an increase in the tax rate τ reduces π; (ii) an increase in the monitoring cost δ reduces π; (iii) an increase in the ratio of interest rate subsidy s_1 raises π; (iv) an increase in the ratio of loan guarantee s_2 raises π; (v) an increase in the subsidy ratio of the monitoring cost s_3 raises π; (vi) the marginal effect of the ratios of credit subsidies (s_1, s_2 and s_3 respectively) on π is diminishing.*

Intuitively, an increase in the tax rate reduces the net rates of returns to both types of borrowers. However, because $p_L > p_H$, the magnitude of the reduction is higher to type *H* borrowers than to type *L* borrowers. Thus, an increase in the tax rate will induce type *H* borrowers to apply for C^L. To prevent this in the separating equilibrium, the probability of obtaining a loan in C^L should decrease. Similarly, an increase in the monitoring cost increases R_t^i. However, since $p_L > p_H$, the magnitude of the increase in R_t^H is larger than that in R_t^L. This increases the incentive of type *H* borrowers in applying for C^L. To prevent this, the probability of obtaining a loan in C^L should decrease. On the other hand, an increase in either s_1, s_2, or s_3 increases the net rate of returns to both types of borrowers in a disparate way such that the magnitude of the increase is higher to type *H* borrowers than in type *L* ones. This reduces incentives for type *H* borrowers in applying for C^L; hence, the probability of obtaining a loan in C^L can be increased.

Many government credit programs aim at reducing the incidence of credit rationing. While government credit subsidies in this paper are able to reduce the incidence of credit rationing and hence increase π, the associated taxation increases the incidence of credit rationing and reduces π. In other words, government credit subsidies lead to two opposite effects on credit rationing. It is interesting to note that government taxation also leads to another effect on capital investment. An increase in the tax rate reduces the size of each loan ($(1-\tau)w_t$) and thus lowers capital investment. If the overall harmful effects caused by taxation dominate the beneficial effects by government credit programs, the government may impose a tax on credit and use the revenue to subsidize output production. We address this issue in the next section.

4. Economic Growth and Social Welfare under the Balanced Growth Path

To alleviate the problems of asymmetric information, the government provides credit programs. As stated, we consider three types of government credit subsidies. The first one is the interest rate subsidy such that the government subsidizes a fraction s_1 of interest payment. Note that borrowers only need to pay interests when their projects are successful. Recall also that the total populations of type *H* and type *L* borrowers are 0.5λ and $0.5(1-\lambda)$, respectively. As a result, the amount of interest subsidy by the government is equal to $0.5\lambda p_H s_1 R_t^H q_t^H + 0.5(1-\lambda) p_L R_t^L q_t^L$. The second type is the loan guarantee program in which the government guarantees a fraction s_2 of loan repayment when borrowers' projects are failed. The total amount needed for this loan guarantee is equal to $0.5\lambda(1-p_H)s_2 R_t^H q_t^H + 0.5(1-\lambda)(1-p_L)R_t^L q_t^L$. Finally, the government also subsidizes a fraction s_3 of monitoring cost. Since the lender will monitor the borrower when a failure of project is claimed, the total amount of output needed for this subsidy is equal to $0.5\lambda(1-p_H)s_3\delta\rho_{t+1}q_t^H + 0.5(1-\lambda)\pi_L(1-p_L)s_3\delta\rho_{t+1}q_t^L$.

Note that while lending/borrowing occurs at time *t*, loan repayments and hence government credit subsidies take place at time *t*+1. To finance credit programs, the government imposes a tax rate τ on output at time *t*+1. Recall that any agent who supplies his labor to firms becomes a firm operator at the old age. Thus, labor supply includes young lenders and type *L* borrowers who are credit rationed so that total labor is equal to $0.5 + 0.5(1-\lambda)(1-\pi)$, which is also the total number of firms.[29] Given this, the government budget constraint between time *t* and *t*+1 is given as

$$\tau 0.5[1+(1-\lambda)(1-\pi)]y_{t+1} = 0.5\lambda[p_H s_1 + (1-p_H)s_2]R_t^H q_t^H + 0.5\lambda(1-p_H)s_3\delta\rho q_t^H$$
$$+0.5(1-\lambda)\pi[p_L s_1 + (1-p_L)s_2]R_t^L q_t^L + 0.5(1-\lambda)\pi(1-p_L)s_3\delta\rho q_t^L. \quad (17)$$

Note that the amount of government credit subsidies is tied to q_t^i, which is equal to $(1-\tau)w_t$ $(= (1-\tau)(1-\alpha)y_t)$. On the other hand, the government levies a tax on output at time *t*+1 to finance its credit subsidies. Thus, for given ratios of credit subsidies, if the growth rate between time *t* and *t*+1 is higher, then the tax rate needed to finance credit subsidies could be lower. Substituting $q_t^i = (1-\tau)(1-\alpha)y_t$ into eq. (17), we obtain

$$g^g = \frac{y_{t+1}}{y_t} = \frac{(1-\tau)(1-\sigma)}{\tau[1+(1-\lambda)(1-\pi)]}\{\lambda[p_H s_1 + (1-p_H)s_2]R_t^H + \lambda(1-p_H)s_3\delta\rho$$
$$+(1-\lambda)\pi[p_L s_1 + (1-p_L)s_2]R_t^L + (1-\lambda)\pi(1-p_L)s_3\delta\rho\}, \quad (18)$$

where g^g refers to the growth rate of per firm output between time *t* and *t*+1 derived from the government budget constraint.

Since all type *H* borrowers and a fraction π of type *L* borrowers derive loans, the total amount of capital produced by borrowers is equal to $0.5[\lambda p_H + (1-\lambda)p_L\pi](1-\tau)w_t$. Thus, the total amount of capital stock at time *t*+1 (denoted as K_{t+1}) is give as

$$K_{t+1} = 0.5[\lambda p_H + (1-\lambda)p_L\pi]Q(1-\tau)w_t + 0.5(1-\lambda)(1-\pi)(1-\tau)w_t Q\varepsilon$$
$$-0.5[\lambda(1-p_H) + (1-\lambda)(1-p_L)\pi]\delta(1-\tau)w_t, \quad (19)$$

where the second part of capital is produced by lenders who use his storage technology to convert output into capital and the third part is the monitoring costs needed to induce truthful telling. Dividing both sides of the above equation by the number of firm, we have

[29] Thus, per firm labor employment l is equal to 1. Given this, eqs. (4) and (5) implies that $w_t = A(1-\alpha)k_t$ and $\rho_t = A\alpha = \rho$. Hence, we drop time subscript for the rental rate of capital stock from now.

$$\frac{K_{t+1}}{0.5[1+(1-\lambda)(1-\pi)]} = k_{t+1}$$
$$= \frac{[\lambda p_H + (1-\lambda)p_L\pi + (1-\lambda)(1-\pi)\varepsilon]Q - [\lambda(1-p_H) + (1-\lambda)(1-p_L)\pi]\delta}{[1+(1-\lambda)(1-\pi)]}$$
$$\times (1-\tau)w_t. \qquad (20)$$

Note that k_{t+1} can be viewed as the demand of capital while the last part of eq. (20 is the supply. Hence, eq. (20) is the equilibrium of capital markets.

Using $w_t = A(1-\alpha)k_t$ into the above equation, we derive the growth rate of per firm capital stock from capital markets as

$$g^k = \frac{k_{t+1}}{k_t} = \{[\lambda p_H + (1-\lambda)\pi p_L + (1-\lambda)(1-\pi_L)\varepsilon]Q$$
$$- [\lambda(1-p_H) + (1-\lambda)(1-p_L)\pi]\delta\}\frac{(1-\tau)(1-\sigma)A}{[1+(1-\lambda)(1-\pi)]}. \quad (21)$$

Recall that government credit programs are able to alleviate the problem of asymmetric information so that the probability of obtaining loans π increases. From eq. (21), an increase in government credit policies have two effects on economic growth. First, government subsidy ratios that increase the probability of obtaining a loan π will enhance economic growth. Second, government taxation on output τ that reduces the probability π will decrease economic growth. Moreover, taxation also reduces the size of each loan (i.e., $(1-\tau)w_t$), which is also detrimental to economic growth.

We now can define a balanced growth path for this economy.

Definition. *The equilibrium of the economy under a balanced growth path is defined such that (1) the separating equilibrium contracts in Proposition 1 hold; (2) the government budget constraint between any consecutive periods holds; (3) capital markets are under the equilibrium. Moreover, under the balanced growth path* y_t, k_t, *and* w_t *are all growing at the same, while* τ, s_i $(i = 1, 2, 3)$, π, *and* ρ *remains constant.*

Under the balanced growth path, the growth rate of output y_t is equal to that of per-firm capital stock k_t. To examine the relationship between government credit programs, we first derive the equilibrium tax rate under the balanced growth path by equalizing the growth rate from the government budget constraint (i.e. eq. (18)) to that from capital market equilibrium (i.e., (21)). Due to the complex structure of the model, we are not able to derive the close form solution for the tax rate under the balanced growth path equilibrium. To characterize the equilibrium tax rate, we resort to numerical simulations. Consider an economy with $p_H = 0.36$, $p_L = 0.45$, $\lambda = 0.85$, $\varepsilon = 0.25$, $\alpha = 0.3$, $A = 2.8$, $\delta = 0.$ and $Q = 2$. We then examine the correlation between the equilibrium tax rate and the subsidy ratio s_j for given $s_i = 0$ $(i \neq j)$. We derive the following result.

Lemma 2. *An increase in either* s_1, s_2, *or* s_3 *leads to an increase in the equilibrium tax rate.*

Intuitively, an increase in the subsidy ratio must force the government to increase the tax rate. According to Lemma 2, there are two opposite effects of government credit programs on the probability of obtaining loans π. It is interesting to see the net effect of credit subsidies on π. If the net effect is negative, then the government should not provide any credit subsidy. Using the values of parameters previously given coupled with the equilibrium tax rate, we depict the relationship between the ratios of credit subsidies and the probability of obtaining loans in Figure 1, 2 and 3. As shown, the probability of obtaining loans is increasing in s_1, s_2 and s_3, respectively. Consequently, though the associated taxation leads to further distortions, the net effect of credit subsidies is able to alleviate the problem of asymmetric information and hence the probability of obtaining loans is increasing in the subsidy ratio.

While government credit subsidies are able to alleviate the problem of asymmetric information, it should be noted that the optimal subsidy ratios, in terms of maximizing economic growth and social welfare, is not equal to the one resulting to $\pi = 1$. Indeed, taxation also reduces the size of each loan as well as expected consumption of borrowers. We will derive the optimal ratios of credit subsidies below.

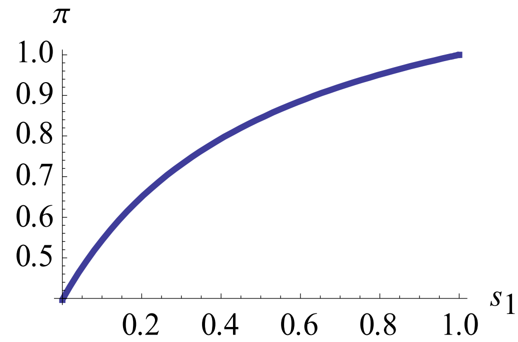

Figure 1. The interest rate subsidy s_1 and π

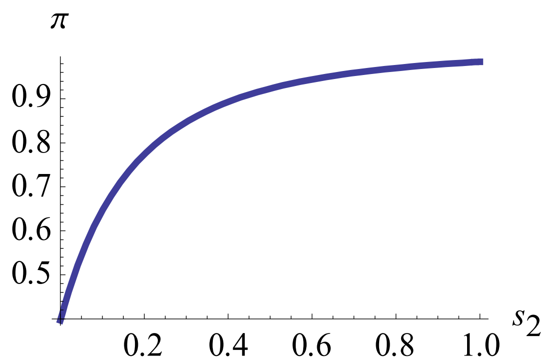

Figure 2. Loan guarantee s_2 and π

It is also interesting to characterize the equilibrium tax rate. To see the effects of Q, p_H, p_L and δ on the equilibrium tax rate, we vary the values of Q, p_H, p_L and δ respectively for given values of s_1, s_2 and s_3 as well as keeping other parameters constant. We summarize these results as follows:

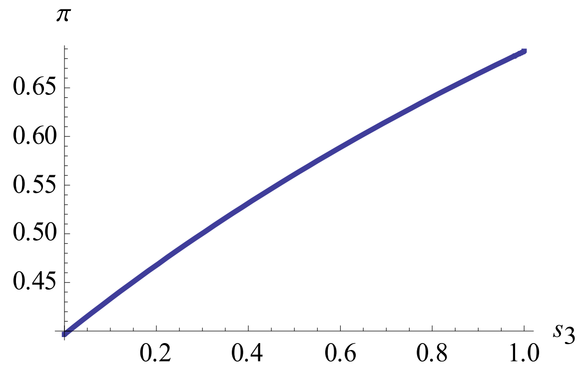

Figure 3. The monitoring cost subsidy s_3 and π

Lemma 3. *Other things being equal, (i) an increase in either Q, p_H or p_L leads to a decrease in the equilibrium tax rate; (ii)an increase in δ leads to an increase in the equilibrium tax rate.*

Recall that the amount of government credit subsidies is directly linked to the wage rate at time *t*, while the government imposes a tax on output at time *t*+1 to finance credit subsidies. Thus, for given ratios of credit subsidies, if the rate of economic growth is higher, the tax rate that is needed to cover credit subsidies will be lower. Consequently, an increase in either Q, p_H or p_L that increases economic growth must be associated with a decrease in the equilibrium tax rate. On the other hand, an increase in the monitoring cost δ that reduces economic growth will lead to an increase in the equilibrium tax rate.

In additional to economic growth, we also examine the effects of credit subsidies on the welfare. The social welfare function (denoted as W) is the summation of the old-age consumption for lenders, type *H* borrowers and type *L* borrowers of all generations. Thus,

$$W = \sum_{t=0}^{\infty} \gamma^t \{0.5(1-\tau) w_t Q \varepsilon (1-\tau)\rho + 0.5\lambda p_H [Q(1-\tau)\rho - (1-s_1) R_t^H](1-\tau) w_t$$
$$+ 0.5(1-\lambda)[\pi p_L [Q(1-\tau)\rho - (1-s_1) R_t^L](1-\tau) w_t$$
$$+ (1-\pi)\beta_L (1-\tau) w_t]\}, \qquad (22)$$

where γ is the discount rate for each generation. By substituting $w_t = A(1-\alpha)k_t$ into the above equation, we further derive the social welfare function in the balanced growth path as

$$W = \frac{0.5A(1-\tau)(1-\alpha)k_0}{1-\gamma(1+g)} \{Q\varepsilon(1-\tau)\rho + \lambda p_H [Q(1-\tau)\rho - (1-s_1) R_t^H]$$
$$+ (1-\lambda)\pi p_L [Q(1-\tau)\rho - (1-s_1) R_t^L] + (1-\lambda)(1-\pi)\beta_L\}, \quad (23)$$

where k_0 is the per firm capital stock for initial old agents and g is the growth rate under the balanced growth path. It is assumed that $\gamma(1+g) < 1$ to ensure the boundedness of the welfare function.

Note that the social welfare function is increasing in the rate of economic growth, but is decreasing in the discount rate γ for each generation. Eq. (23) also implies that, in addition to their effects on economic growth, government credit subsidies have two opposite effects on the social welfare. First, credit subsidies reduce borrowers' interest payments and hence increase borrowers' old-age consumption. Moreover, credit subsidies that increase the probability of obtaining a loan for type L borrowers also raise type L borrowers' consumption. Second, credit subsidies force the government to tax output. Output taxation inevitably lowers agents' consumption and lowers the probability of obtaining a loan. The optimal ratios of credit subsidies can be obtained by balancing these two opposite effects.

Table 1. The Benchmark Case: δ, π, g and W

δ	π	g	W
0.16	0.471	1.116	5.391
0.17	0.453	1.100	4.784
0.18	0.435	1.084	4.293
0.19	0.416	1.068	3.888
0.20	0.396	1.052	3.548
0.21	0.376	1.035	3.258
0.22	0.354	1.019	3.009
0.23	0.332	1.002	2.793

5. Optimal Credit Subsidies and Taxation

Due to the complex structure of the model, the reduced form solutions for the relationships among credit subsidies, economic growth and social welfare are not available. Hence, we perform numerical simulation. Consider an economy with the values of parameters previously given (that is, $p_H = 0.36$, $p_L = 0.45$, $\lambda = 0.85$, $\varepsilon = 0.25$, $\alpha = 0.3$, $A = 2.8$, $Q = 2$). Also, assume that $\gamma = 0.87$, $\beta_L = 0.8$ and $k_0 = 1$ for this economy. As a benchmark case, we first examine the case where there is no government credit programs so that $s_i = 0$ and $\tau = 0$. In this case, the growth rate of the economy can be obtained directly by eq. (21). Note that the monitoring cost δ can be viewed as the efficiency of credit markets. A lower value of δ indicates that credit markets are more efficient. We report results of this benchmark case in Table 1 by varying the values of the monitoring cost that yield reasonable ranges of economic growth. As shown in Table 1, an increase in the monitoring cost that exacerbates the problems of asymmetric information reduces the probability of obtaining loans and hence the growth rate as well as the welfare.

We next consider the optimal credit programs of interest subsidy s_1, the loan guarantee ratio s_2, and the monitoring cost subsidy s_3, respectively. With the values of parameters given previously as well as $\delta = 0.2$, Figures 1 depicts the relationship between s_1 and g by assuming that $s_2 = s_3 = 0$. Similarly, Figure 2 depicts s_2 and g with the case of $s_1 = s_3 = 0$ and Figure 3 depicts s_3 and g when $s_1 = s_2 = 0$. As shown in these figures, there exists an optimal subsidy ratio for s_1, s_2 and s_3, respectively.

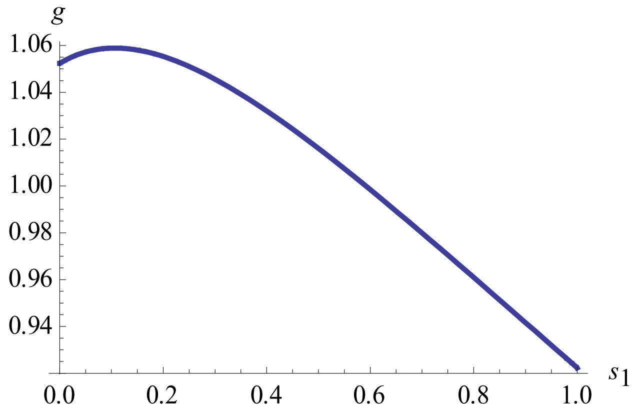

Figure 4: The relationship between s_1 and g: $s_2 = 0$ and $s_3 = 0$

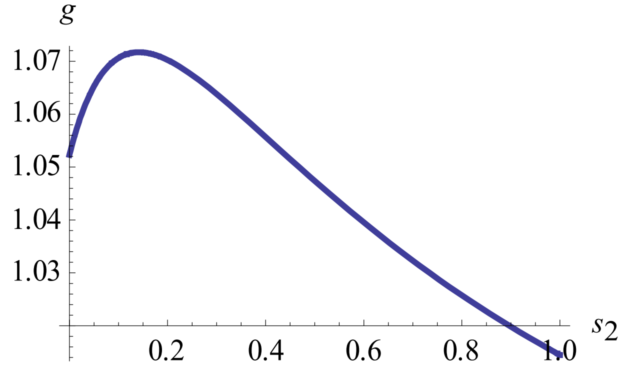

Figure 5. The relationship between s_2 and g: $s_1 = 0$ and $s_3 = 0$

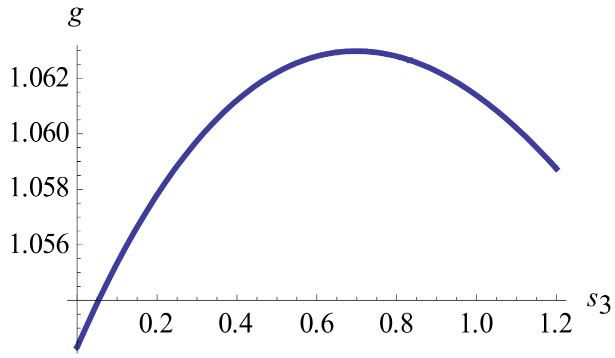

Figure 6. The relationship between s_3 and g: $s_1 = 0$ and $s_2 = 0$

Intuitively, the presence of government credit subsidy creates two opposite effects on economic growth. First, government credit subsidy is able to alleviate the problems of asymmetric information and thereby increases the probability of obtaining a loan. Furthermore, because the government finances its spending on credit subsidies (promised at time *t*) by levying a tax on output at time *t*+1, credit subsidies inevitably lead to output taxation. The presence of taxation exacerbates the problems of asymmetric information and thus reduces the probability of obtaining a loan. The net effect, however, is positive; that is, credit subsidies are able to increase the probability of obtaining loans. Consequently, credit subsidies enhance economic growth. Second, taxation also reduces the size of each loan. This reduces capital investment and hence is harmful to economic growth. Figures 4, 5 and 6 imply that the first effect dominates the second initially. However, once the subsidy ratio is higher than a critical level, the second effect prevails over the first. Hence, there exist optimal subsidy ratios for s_1, s_2 and s_3, respectively. The optimal s_1, s_2 and s_3 are 0.106, 0.141 and 0.698, while the corresponding growth rates are 1.058, 1.071 and 1.062. Compared with Table 1 (with

$\delta = 0.2$), it is clear that government credit programs are able to enhance economic growth.

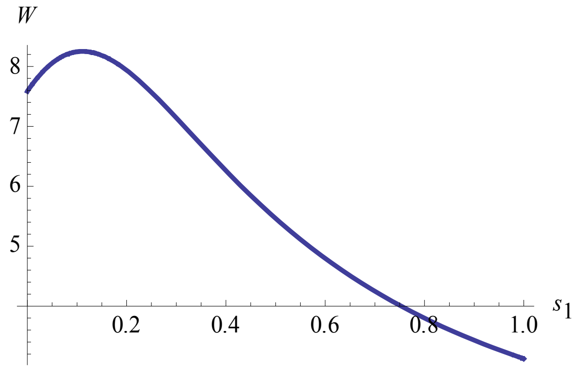

Figure 7. The relationship between s_1 and W: $s_2 = 0$ and $s_3 = 0$

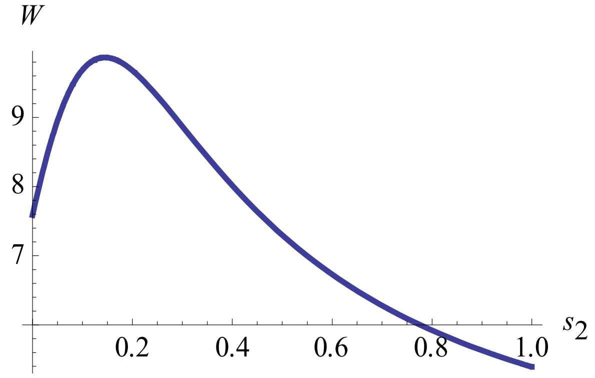

Figure 8. The Relationship between s_2 and W: $s_1 = 0$ and $s_3 = 0$

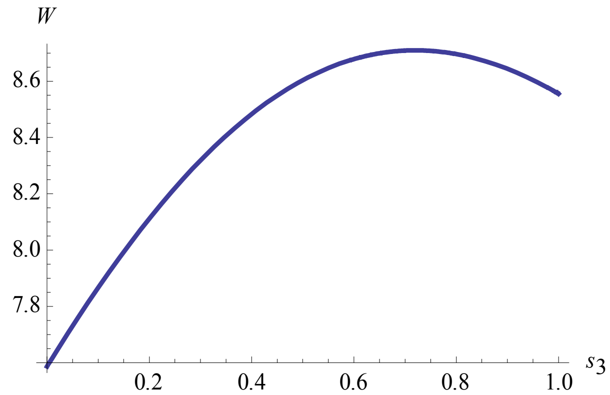

Figure 9. The Relationship between s_3 and W: $s_1 = 0$ and $s_2 = 0$

We also perform similar investigations from the perspective of maximizing social welfare. Results are depicted in Figure 4, 5 and 6, respectively. As shown, there exist optimal ratios of credit subsidies in maximizing social welfare for s_1, s_2 and s_3, respectively. The optimal s_1, s_2 and s_3 in terms of maximizing social welfare W are 0.131, 1.141 and 0.821, while the corresponding levels of social welfare are 2.175, 2.48 and 2.191. Compared with those maximizing economic growth, we find that the optimal level of the subsidy ratio in maximizing social welfare is higher than that in maximizing economic growth. Moreover, regardless of maximizing economic growth or social welfare, the most effective subsidy is the loan guarantee, followed by the monitoring cost subsidy and the interest rate subsidy.

It is interesting to characterize the optimal subsidy ratios. To do so, we vary the value of each parameter in turn while keeping all other parameters constant. Denote s_i^{g*} and τ_i^{g*} $(i = 1, 2, 3)$ as the optimal ratios of credit subsidies and the corresponding tax rate in terms of maximizing economic growth.

Similarly, denote s_i^{W*} and τ_i^{W*} $(i = 1, 2, 3)$ as the optimal ratios of credit subsidies and the corresponding tax rate in terms of maximizing social welfare. Also, let g_i^* and W_i^* be the corresponding growth rate and welfare.

The change of δ

We first focus on the changes on the monitoring cost δ.[30] We report results in Tables 2, 3 and 4. By comparing Table 1 with Tables 2, 3, and 4, we find the following results. First, government credit programs are able to alleviate the problem of asymmetric information and leads to an increase in the growth rate and social welfare, regardless the values of the monitoring cost. This can be derived by comparing the growth rate and the social welfare in these tables for a given value of δ.

Table 2. Interest Rate Subsidy

δ	s_1^{g*}	τ_1^{g*}	g_1^*	s_1^{W*}	τ_1^{W*}	W_1^*
0.16	0.074	0.019	1.119	0.075	0.020	39.35
0.17	0.082	0.022	1.104	0.085	0.023	20.43
0.18	0.090	0.025	1.089	0.094	0.026	13.75
0.19	0.098	0.027	1.074	0.102	0.029	10.33
0.20	0.106	0.030	1.058	0.111	0.031	8.251
0.21	0.114	0.033	1.043	0.118	0.034	6.854
0.22	0.122	0.036	1.028	0.126	0.037	5.850
0.23	0.129	0.039	1.013	0.133	0.040	5.093

Second, Tables 2, 3 and 4 indicate that among these three credit programs, the most effective policy in raising economic growth and welfare is the loan guarantee program, followed by the monitoring cost subsidy and the interest rate subsidy as the last one. Third, an increase in the monitoring cost leads to increases in s_1^{g*}, s_2^{g*} and s_3^{g*}. Recall that an increase in the subsidy ratio leads to two opposite effects on economic growth. On the one hand, an increase in the subsidy ratio alleviates the problem of asymmetric information and increases the probability of obtaining a loan for type L borrowers. On the other hand, such an increase raises the tax rate, which exacerbates the problem of asymmetric information and hence lowers the probability of obtaining a loan. An increase in the monitoring cost intensifies the magnitude of the former effect, leading to higher ratios of credit subsidies.

Similarly, an increase in the monitoring cost leads to increases in s_1^{W*}, s_2^{W*} and s_3^{W*}. Recall that, in addition to economic growth, an increase in the subsidy ratio leads to two opposite effects on social welfare. An increase in the monitoring cost leads the positive effect to slightly outweigh the negative one, leading to an increase in the subsidy ratio.

[30] Except the value of δ, all other parameters are the same as before.

Table 3. Loan Guarantee

δ	s_2^{g*}	τ_2^{g*}	g_2^*	s_2^{W*}	τ_2^{W*}	W_2^*
0.16	0.121	0.045	1.130	0.121	0.045	110.2
0.17	0.126	0.047	1.115	0.127	0.048	31.63
0.18	0.131	0.050	1.101	0.133	0.051	18.34
0.19	0.136	0.052	1.086	0.139	0.053	12.86
0.20	0.141	0.055	1.071	0.144	0.056	9.867
0.21	0.146	0.058	1.057	0.150	0.059	7.978
0.22	0.151	0.060	1.042	0.155	0.061	6.679
0.23	0.157	0.063	1.027	0.159	0.064	5.730

Table 4. Monitoring Cost Subsidy

δ	s_3^{g*}	τ_3^{g*}	g_3^*	s_3^{W*}	τ_3^{W*}	W_3^*
0.16	0.678	0.031	1.122	0.6857	0.031	48.99
0.17	0.683	0.033	1.107	0.6980	0.034	22.97
0.18	0.689	0.036	1.092	0.7075	0.037	14.93
0.19	0.694	0.038	1.077	0.7147	0.040	11.02
0.20	0.698	0.041	1.062	0.7199	0.042	8.709
0.21	0.702	0.044	1.047	0.7232	0.045	7.181
0.22	0.706	0.047	1.033	0.7248	0.048	6.095
0.23	0.709	0.050	1.018	0.7249	0.051	5.283

Table 5. Effect of δ on the optimal subsidy ratios

δ	s_1^{W*}	s_2^{W*}	s_3^{W*} (τ_3^{W*})
0.16	0.206	0.229	1.435(0.0661)
0.17	0.205	0.226	1.349(0.0666)
0.18	0.203	0.224	1.268(0.0670)
0.19	0.200	0.220	1.192(0.0671)
0.20	0.197	0.216	1.119(0.0670)
0.21	0.192	0.210	1.049(0.0665)
0.22	0.186	0.204	0.980(0.0658)
0.23	0.179	0.197	0.912(0.0646)

It is worth noting that the relationship between the monitoring cost and optimal subsidy ratios in terms of maximizing social welfare crucially depends on the discount rate γ. If γ is so small, then an increase in the monitoring cost will lead to a decrease in the optimal subsidy ratio in terms of maximizing social welfare. To see this, we employ values of parameters previously given, except that $\gamma = 0.5$. Results are shown in Table 5. As shown, the optimal subsidy ratios in this case is decreasing in the monitoring cost δ. Again, an increase in the subsidy ratio leads two opposite effects on social welfare. When the government heavily discounts the weights of future generations in the social welfare, an increase in the monitoring cost gives more weights to the negative effect and hence results in a decrease in the optimal ratio of credit subsidies.

The changes on p_H

We now examine the effects of changing p_H. Note that an increase in p_H will raise the rate of economic growth. To keep the boundedness of social welfare, we set $\gamma = 0.5$ in this case. Results are reported in Table 6.[31]

As shown, an increase in p_H, holding other parameters constant, leads to a decrease in the optimal ratios of credit subsidies. An increase in p_H reduces R^H and hence increases the expected consumption of type *H* borrowers. This alleviates the problem of asymmetric information and hence increases π. Due to this, the government should lower the subsidy ratio.

Table 6. Credit Subsidies: the changes in p_H

p_H	s_1^{g*}	s_1^{W*}	s_2^{g*}	s_2^{W*}	s_3^{g*}	s_3^{W*}
0.35	0.144	0.182	0.173	0.204	0.881	1.055
0.36	0.106	0.154	0.141	0.180	0.698	0.928
0.37	0.068	0.119	0.109	0.152	0.503	0.766
0.38	0.027	0.080	0.077	0.119	0.295	0.570
0.39	- 0.014	0.034	0.043	0.083	0.068	0.338
0.40	- 0.059	- 0.015	0.009	0.043	- 0.181	0.067
0.41	- 0.108	- 0.072	- 0.027	0.000	- 0.462	- 0.249
0.42	- 0.163	- 0.136	- 0.066	- 0.046	-0.788	-0.621
0.43	- 0.227	- 0.161	- 0.110	- 0.065	-1.183	-0.775

It is interesting to note that if p_H is higher enough, then both the optimal subsidy ratios and tax rates are negative. This implies that the government should tax credit and subsidize output production. Intuitively, if p_H is higher enough so that the expected consumption in C^L is not much different from that in C^H, then the probability in obtain a loan for type *L* borrowers is close to one. In this case, the problem of asymmetric information is not severe and thus the marginal benefit of an increase in the subsidy ratio is small. Consequently, it may be optimal for the government to tax on credit and use the proceeds to finance a subsidy on output production, leading to an optimal subsidy ratio and an optimal tax rate with negative values.

The changes of p_L

An increase in p_L reduces the expected consumption in C^L. This gives type *H* borrowers more incentive to apply for C^L. To prevent type *H* borrowers applying for C^L, the probability of obtaining a loan in C^L must decrease. In other words, an increase in p_L exacerbates the problem of asymmetric information. To ease this, the government should increase its subsidy ratio.

[31] Note also that s_i^{g*} and s_i^{W*} are derived by assuming $s_j^{g*} = s_j^{W*} = 0\ (i \neq j)$.

Table 7. Credit Subsidies: the changes in p_L

p_L	s_1^{g*}	s_1^{W*}	s_2^{g*}	s_2^{W*}	s_3^{g*}	s_3^{W*}
0.45	0.106	0.131	0.141	0.162	0.698	0.821
0.46	0.117	0.147	0.162	0.187	0.782	0.932
0.47	0.128	0.164	0.183	0.215	0.870	1.048
0.48	0.139	0.181	0.207	0.244	0.963	1.170
0.49	0.150	0.199	0.232	0.275	1.062	1.300
0.50	0.162	0.217	0.259	0.309	1.170	1.438
0.51	0.174	0.236	0.288	0.344	1.286	1.585
0.52	0.187	0.256	0.318	0.382	1.423	1.742
0.53	0.201	0.276	0.351	0.421	1.551	1.909
0.54	0.215	0.298	0.386	0.462	1.702	2.088
0.60	0.319	0.445	0.634	0.748	2.990	3.477

6. Conclusion

This paper evaluates government credit subsidies in a simple endogenous growth model in which asymmetric information is present. In the model, the government imposes a tax on output production to finance its spending on credit subsidies. Three types of credit subsidies are considered: the interest rate subsidy, loan guarantee and the monitoring cost subsidy.

We find that, in general, government credit subsidies can alleviate the problem of asymmetric information and thus enhance economic growth and social welfare. However, if the problem of asymmetric information is not so severe, then the government should impose a tax on credit (taxation on interest payment, taxation on interest payment when the project failed, and taxation on the monitoring activity) and use the proceeds to finance output production.

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Visiting Report to National Science Council of Taiwan, ROC

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Department of Economics, National Chengchi University

I visited Department of Economics and Finance of City University of Hong Kong during 08/20/2012~08/24/2012. In my last trip to Hong Kong (04/04/2012~04/08/2012), I launched a project with Professor Yong Wang to examine the optimal government subsidy with the presence of asymmetric information in credit markets. The basic idea is to extend Ho and Wang (2005, CJE) by considering the possibility of government subsidy. We had derived some results in the last trip. Specifically, we found that the optimal subsidy ratio in general is increasing when the problem of asymmetric information is more severe. As a result, the government size (or tax rate) is increasing with the severity of the problem of asymmetric information. This overturns Ho and Wang (2005). However, we also found that if the magnitude of the problem of asymmetric information is relatively small, the government should not subsidy at all. In such a case, Ho and Wang's (2005) conclusion still holds.

The above results are derived under a model with ex ante adverse selection problems, by which the separating equilibrium is derived by ex ante costly screening. In this trip, we start to work with another model in which the separating equilibrium is derived by rationing a fraction of good borrower. With this model, we find that there always exists an optimal subsidy ratio, regardless the magnitude of the problem of asymmetric information. Because the higher the ratio of government subsidy, the larger the size of government spending, we conclude that government size is increasing with severity of asymmetric information. Since the problem of asymmetric information is more severe in developing countries than in developed ones, our project implies that the government size of developing countries is larger than developed ones. This conclusion contradicts to Ho and Wang (2005).

To better illustrate our conclusion, we plan to collect data to perform some preliminary test. If we can obtain some empirical results that are consistent with our model, we believe that this project can yield a paper that can be published by a good journal.

國科會補助計畫衍生研發成果推廣資料表

日期:2013/02/21

<table>
<tr><td rowspan="3">國科會補助計畫</td><td>計畫名稱: 政府公共支出、維修支出、與貨幣融通：局部不確定性與經濟成長</td></tr>
<tr><td>計畫主持人: 洪福聲</td></tr>
<tr><td>計畫編號: 99-2410-H-004-055-MY2　　　學門領域: 總體經濟學與貨幣經濟學</td></tr>
<tr><td colspan="2">無研發成果推廣資料</td></tr>
</table>

99 年度專題研究計畫研究成果彙整表

計畫主持人：洪福聲			計畫編號：99-2410-H-004-055-MY2				
計畫名稱：政府公共支出、維修支出、與貨幣融通：局部不確定性與經濟成長							
成果項目			量化			單位	備註（質化說明：如數個計畫共同成果、成果列為該期刊之封面故事...等）
			實際已達成數（被接受或已發表）	預期總達成數(含實際已達成數)	本計畫實際貢獻百分比		
國內	論文著作	期刊論文	0	0	100%	篇	
		研究報告/技術報告	0	0	100%		
		研討會論文	0	0	100%		
		專書	0	0	100%		
	專利	申請中件數	0	0	100%	件	
		已獲得件數	0	0	100%		
	技術移轉	件數	0	0	100%	件	
		權利金	0	0	100%	千元	
	參與計畫人力（本國籍）	碩士生	0	0	100%	人次	
		博士生	3	0	100%		
		博士後研究員	0	0	100%		
		專任助理	0	0	100%		
國外	論文著作	期刊論文	2	0	100%	篇	
		研究報告/技術報告	1	0	100%		
		研討會論文	0	0	100%		
		專書	0	0	100%	章/本	
	專利	申請中件數	0	0	100%	件	
		已獲得件數	0	0	100%		
	技術移轉	件數	0	0	100%	件	
		權利金	0	0	100%	千元	
	參與計畫人力（外國籍）	碩士生	0	0	100%	人次	
		博士生	0	0	100%		
		博士後研究員	0	0	100%		
		專任助理	0	0	100%		

其他成果 (無法以量化表達之成果如辦理學術活動、獲得獎項、重要國際合作、研究成果國際影響力及其他協助產業技術發展之具體效益事項等，請以文字敘述填列。)	無

	成果項目	量化	名稱或內容性質簡述
科教處計畫加填項目	測驗工具(含質性與量性)	0	
	課程/模組	0	
	電腦及網路系統或工具	0	
	教材	0	
	舉辦之活動/競賽	0	
	研討會/工作坊	0	
	電子報、網站	0	
	計畫成果推廣之參與（閱聽）人數	0	

國科會補助專題研究計畫成果報告自評表

請就研究內容與原計畫相符程度、達成預期目標情況、研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）、是否適合在學術期刊發表或申請專利、主要發現或其他有關價值等，作一綜合評估。

1. 請就研究內容與原計畫相符程度、達成預期目標情況作一綜合評估

■達成目標

□未達成目標（請說明，以 100 字為限）

□實驗失敗

□因故實驗中斷

□其他原因

說明：

2. 研究成果在學術期刊發表或申請專利等情形：

論文：■已發表 □未發表之文稿 □撰寫中 □無

專利：□已獲得 □申請中 ■無

技轉：□已技轉 □洽談中 ■無

其他：（以 100 字為限）

3. 請依學術成就、技術創新、社會影響等方面，評估研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）（以 500 字為限）

此一兩年期計畫，共完成兩篇與政府最適財政政策有關的文章。雖然兩篇文章的結論與現存文獻都有很大的不同，但兩篇文章的模型設定都比現存文獻合理，結論也比現存文獻符和經濟直覺。基於此，個人認為者兩篇文章的學術貢獻顯著。