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Abstract

It may be optimal from a welfare perspective to use R&D subsidies when the source of R&D distortions originates from the surplus appropriability problem and technological spillovers in the form of knowledge spillovers, creative destruction, and duplication externalities are absent. Hence, R&D subsidies may constitute the optimal policy even when subsidies directly targeted on monopoly pricing could be applied. The result holds when dynamic effects are important relative to static effects and when governments spending is restricted. The latter characteristic arises when a government is unable or unwilling to use the level of spending required to implement the optimum policy. The argument is developed in a semi-endogenous growth model where the only distortion is monopoly pricing of intermediate goods.

Keywords: R&D, policy instruments, welfare, market power
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1 Introduction

This paper argues that it may be optimal from a welfare perspective to directly subsidize R&D activities when the source of R&D distortions mainly originates from the surplus appropriability problem and technological spillovers in the form of knowledge spillovers, creative destruction, and duplication externalities are negligible or absent. The result holds when two conditions are satisfied: (1) dynamic effects are important relative to static effects and (2) government spending is below the required effort for correcting completely for R&D distortions. The surplus appropriability problem means that innovators are unable to appropriate the full social gain associated with innovations even in the case without technological spillovers. Prices are determined as constant mark-up over costs, which distort sales downwards, implying that the R&D incentive is too low from a social point of view.

It is often argued that the decentralized economy underinvests in R&D relatively to what is socially optimal. Jones and Williams (2000) reach this conclusion by evaluating the net-effect of a number of R&D distortions. The analysis is based on calibrations of an endogenous growth model for the US economy. Two groups of imperfections are potentially relevant for R&D activities. These are distortions directly related to the production of ideas (knowledge spillovers in research, externalities associated with duplication, and creative destruction) and distortions related to market power in the sector that captures surplus generated by ownership of innovations (surplus appropriability problem). Moreover, by internalizing individual distortions one at a time, it is found that the main force promoting underinvestment in R&D comes from the surplus appropriability problem.

Underinvestments in R&D call for policy interventions. An important statement in this relation is that governments do not provide enough support for R&D activities to correct fully for distortions. Jones and Williams (1998) link the theoretical models of new growth theory to the empirical literature estimating private and social returns to R&D and argue that the optimal level of R&D expenditures are at least four times higher than the actual level in the US economy. The analysis thus establishes that government policies are unsuccessful in bringing the decentralized economy to the social equilibrium. This suggests that government spending is restricted, which is the case when a government is unable or unwilling to use the level of spending required to implement the optimum policy.

As for the US economy it seems likely that European governments also are unsuccessful in bringing the economies to the social equilibrium. According to the Barcelona objective the average research investment level should be increased from 1.8% of GDP in 2002 to 3% of GDP by 2010, of which 1/3 should be funded by governments. According to OECD (2005), government funding amounted to around one third on average for countries in the European Union for 2002. For comparison, gross domestic expenditure on R&D amounted to 2.6% as a percentage of GDP for the United States of which government funding constituted about 1/3.

To sum up, three characteristics are important for R&D: first, the socially optimal level of R&D investments is above the outcome in the decentralized economy; second, existing R&D policies do not bring economies to the social optimum; and third, the primary cause for underinvestments in R&D comes from the surplus appropriability problem. This motivates the main question addressed in this paper. What are the welfare effects of applying R&D subsidies to correct for distortions created by market power instead of instruments that deals with the market failure as directly as possible when government spending is relatively low compared to the effort required to implement the optimum policy. The analysis is taken to the extreme case where technological spillovers are absent. Consequently, the analysis investigates welfare effects of policy instruments used to remedy distortions from market power in firms that use blueprints developed by R&D activities as input in production activities. The issue is interesting because in contrast to technological spillovers where R&D taxes-cum-subsidies are the direct instruments, the policy instruments that the government should use dealing with market power are not obvious a priori.

As mentioned, the focus is economic policy under restricted government spending. Therefore, the exact mechanisms causing the restriction are not modeled formally and are not expected to change the main result if included. However, one can think of a number causing mechanisms. Restricted government spending may be a consequence of marginal costs of public funds above one, which may be due to distortional income taxes or distributional considerations, see for example Neary (1994). Alternatively, the government may not want to tax voters too heavily because they punish public expenditure, see for example Peltzman (1992).

The analysis is related to the literature on marginal cost of public funds, where alternative taxes for financing the same amount of government spending are compared under the differential analysis, see for example Ballard (1990) and Håkonsen (1998). This type of analysis investigates the efficiency effects of financing public expenditures, while the effects of government spending are of no concern. In this paper, the efficiency effects of government spending is investigated, while the effects of public finance are of no concern.

The applied model is a simple semi-endogenous growth model, see Jones (1995). The production side of the economy is divided into three sectors.

Final goods are produced by a composite of labor and intermediate goods, where the latter input factor is composed of specialized intermediate inputs. Intermediate inputs are produced converting final goods into intermediate varieties, whereas innovation takes place in a separate sector using labor input. To make the analysis as focused as possible, technological spillovers are assumed to be absent.

When a new design is developed, the patent is sold to an intermediate firm. Patents secure property rights, and technological progress is a result of market driven innovation. Market power for intermediate firms is accordingly needed to ensure demand for new designs, and monopolistic competition is assumed to prevail in the intermediate sector. This assumption generates an imperfection that calls for welfare improving policy interventions. Perfect competition takes place in the rest of the economy.

The only distortion in the model is monopoly pricing in the intermediate sector. This distortion implies that the demand for intermediate varieties is below the social optimal level. An indirect consequence is that the incentive to innovate is below the social optimal level because low intermediate demand in the market economy leads to low profits. Since the R&D incentive is related to private profits, low intermediate demand depresses the incentive. This is an important relationship since monopoly pricing, which directly generates static inefficiency in the intermediate sector, indirectly generates dynamic inefficiency.

A subsidy to intermediate goods production is a direct policy instrument to correct for monopoly pricing. This subsidy affects the static distortion only, leaving the R&D incentive unaffected and corrects completely for the monopoly distortion and makes firms price according to marginal costs, provided that the optimal subsidy level can be financed through lump-sum taxation. As a consequence of the dynamic nature of the model, an R&D subsidy is also a relevant policy instrument. Even though this subsidy is not targeted directly on the source of the distortion and affects the market price for patents, the instrument does not introduce new distortions in the economy. The reason is that blueprints for intermediate varieties are a specific input to the intermediate sector.

The government can also use a third instrument; a subsidy to intermediate purchase. This subsidy has an indirect effect on incentive to innovate in addition to the direct effect on the static distortion. Hence, the instrument produces a direct static gain and an indirect dynamic gain in efficiency. It turns out that this instrument can be view as a combination of the two policy instruments mentioned above. By using the optimal level of this instrument, the government is able to simulate the economic outcome a social planner who maximizes the utility of his representative household would choose. Hence, the government can implement the first-best policy using this instrument. However, the level of government spending required to implement the optimal rate of this direct instrument may be high.

Should a government use R&D subsidies, subsidies to intermediate purchase or subsidies to intermediate production when government spending is restricted? To answer this question, the welfare ranking of the subsidies is studied for different levels of government spending. It is established that the R&D subsidy leads to higher welfare effects under restricted government spending when the dynamic gain is sufficiently important compared to the static gain. Hence, it may be optimal to focus entirely on the dynamic inefficiency that arises from monopoly pricing. Also, it is established that the welfare gain from focusing on the static or the dynamic imperfection separately is higher that by using the instrument that have both static and dynamic effects under restricted government spending.

2 The Model

2.1 Final Goods

The underlying framework of the model follows Romer (1990) and Jones (1995). Final goods are produced according to:

$$Y = \left[\int_0^N {x_j}^{\alpha} dj \right] L_y^{1-\alpha} \ , \ \ 0 < \alpha < 1, \tag{1}$$

where $j \in [0, N]$.[1] Y is the quantity of final goods, x_j is the intermediate quantity of variety j, L_y is labor input in final goods production, N is the stock of specialized intermediate inputs, and $1 - \alpha$ is the value share of labor. The aggregate quantity of intermediate goods equals $\int_0^N x_j dj$, whereas effective intermediate input is given by the square bracket in (1). This specification implies that the productivity of a given aggregate quantity of intermediate goods increases with the number of specialized varieties.

Given the assumptions of perfect competition and profit-maximizing firms, the demand for the j'th intermediate variety and labor are determined by:

$$\begin{aligned} x_j &= (\alpha / p_j)^{1/(1-\alpha)} L_y \quad &(2) \\ L_y &= (1 - \alpha) Y / w, \quad &(3) \end{aligned}$$

[1] To keep the analysis as simple as possible we use the production function from Romer (1990). This function implicitly restricts the link between the markup, the capital share, and consumer surplus, see Jones and Williams (2000) and Alvarez-Pelaez and Groth (2005).

where p_j is the price of intermediate variety j and w is the wage rate. The price of final goods is used as numeraire, i.e. $p_Y = 1$.

2.2 Intermediate Goods

To start business activities, the intermediate firm issues shares in order to finance the patent that is required for production. Patents secure property rights and monopolistic competition prevails in the intermediate goods sector. Profits are accordingly paid to shareholders as dividends.

The intermediate firm possesses the property right to intermediate variety j, and produces the specific variety by transforming final goods into intermediates one-to-one. Hence, intermediate goods are perishables goods that are depreciated fully within the period of production. This is different from Jones (1995) and Romer (1990) that treat intermediates as capital goods but follows Grossman and Helpman (1991). This formulation is applied to make the analysis more tractable. The producer of variety j maximizes profits

$$\pi_{x_j} = (p_j - 1)\, x_j,$$

subject to (2), and the price of intermediate variety j is accordingly determined by $p_j = \bar{p} = 1/\alpha$. Hence, the price of intermediate goods is the same across varieties, which implies symmetric market clearing quantities for intermediate goods

$$\bar{x} = \alpha^{2/(1-\alpha)} L_y. \tag{4}$$

Profits are thus identical for all producers of intermediate goods,

$$\pi_j = \bar{\pi} = (1-\alpha)\, \alpha^{(1+\alpha)/(1-\alpha)} L_y.$$

The usual non-arbitrage condition for shares in intermediate firms applies:

$$r = \frac{\dot{p}_N}{p_N} + \frac{\bar{\pi}}{p_N},$$

where p_N is the patent price, and a dot above a variable indicates the time derivative. The return to shares in intermediate firms is equal to the dividend plus capital gains.

2.3 Innovation

New designs are produced using labor:

$$\dot{N} = \delta L_N, \tag{5}$$

where L_N is labor input in innovation. According to this formulation the model is a semi-endogenous growth model, see Jones (1995). The applied technology in innovation is simpler than that applied by Jones and Williams (2000), which incorporates both replication effects, creative destruction, and knowledge spillover. To keep the analysis as clear-cut as possible, I only introduce one distortion in the model.

Profit in innovation is zero due to perfect competition, implying that the patent price equals:

$$p_N = w/\delta. \tag{6}$$

Consequently, the non-arbitrage condition equals:

$$r = \frac{\bar{\pi}}{p_N} + g_N = \frac{\alpha\delta L_y}{N} + g_N \tag{7}$$

where g_N indicates the growth rate of N.

2.4 Household Sector

The household sector is characterized by a representative household with an infinite time horizon. Intertemporal preferences are described by the isoelastic utility integral:

$$U = \int_0^\infty e^{-(\rho-g)t}\frac{c^{1-\theta}-1}{1-\theta}dt. \tag{8}$$

where $\rho > 0$ is the rate of time preference, $\theta > 0$ is the inverse intertemporal elasticity of substitution, g is exogenous population growth, and c is consumption of final goods per capita, which equals aggregate consumption divided by the population, i.e. $c = C/L$. Utility is maximized subject to the dynamic budget constraint:

$$\dot{F} = wL + rF - C, \tag{9}$$

where F is aggregate financial capital.

The growth rate in consumption per capita is derived from the first-order conditions with respect to c and $f = F/L$ and is determined by:

$$g_c = (r-\rho)/\theta \tag{10}$$

where g_c indicates the growth rate of c. Finally, the transversality condition $\lim_{t\to\infty}[a_t f_t] = 0$ implies that $r > 2g$.

2.5 Market Clearing

The equilibrium conditions for the N intermediate markets are already imposed on the model. The labor and final goods markets also have to clear. The market clearing condition for final goods is derived from (9) using $F = Np_N$, (1), (3), (4), and (7):

$$C = \left(1 - \alpha^2\right) \alpha^{2\alpha/(1-\alpha)} N L_y \tag{11}$$

It is assumed that a share u of labor is employed in the final goods sector, whereas the remaining share $(1-u)$ is employed in innovation, i.e. $L_y = uL$ and $L_N = (1-u)\,L$. Finally, the market for patents clears according to Walras' Law.

3 Government Policy

Monopoly power generates a distortion in pricing of intermediate goods, which calls for welfare improving policy interventions. In the following, welfare effects of policy interventions financed through domestic tax collection are investigated. Especially, I focus on the case of restricted government spending. Hence, for some reason the government is unable or unwilling to use the level of spending required to implement the optimum policy.[2] In the following, I analyze welfare effects of subsidies to production and R&D subsidies.

3.1 Instruments

The direct instrument to correct for monopoly power is a production subsidy that covers a share of production costs, S_X. For a given subsidy level, the instrument lead to an intermediate price of:

$$\bar{p} = (1 - S_X)/\alpha. \tag{12}$$

The effect of this instrument is an increase in the demand for intermediates. This is a direct static effect. The higher demand increases profits for intermediate producers, and thereby the incentive to investments in innovation activities. However, the higher intermediate demand also increases labor demand and thereby the wage rate and patent price, see (6). The higher patent price reduces the incentive to invest in innovations. The two opposite

[2] In a more subtle setup distorting taxes could be introduced. To make things as simple as possible, I use the described *ad hoc* tax distortion.

effects on the incentive to innovate exactly cancel out, implying that direct instrument does not affect the allocation of labor between sectors. In other words, the subsidy generates no R&D dynamic effects.

The optimal subsidy level of production subsidy is $S_X = (1 - \alpha)$. For this subsidy level, the distortion from monopoly pricing is fully eliminated and the purchasing price for intermediates equals the marginal cost of production.

An R&D instrument is an R&D subsidy. This subsidy covers a cost share, S_I, of labor used in innovation activities and changes the price of patents in (6) to:

$$p_N = (1 - S_I)\, w/\delta. \tag{13}$$

This subsidy is targeted on the incentive to invest in R&D and therefore leads a direct dynamic effect. It is clear that this subsidy is an R&D instrument, since it does not affect the distortion from monopoly pricing directly but distorts the patent price. Usually, R&D policy responses introduce unintended distortions of incentives in other sectors of the economy. This is not the case in the present setting because the stock of blueprints developed by R&D is a sector-specific production factor implying that a changing patent price does not affect distortions in other parts of the economy.

The government could also use a third instrument, a subsidy to intermediate purchase. This subsidy deals directly with the monopoly distortion by reducing the price of intermediate goods by covering a cost share of intermediate purchase. As for the production subsidy, this subsidy generates opposite effects on the incentive to innovate. In this case, however, the positive effect on the rate of return dominates the negative cost effect leading to a higher incentive to invest in innovation. Hence, this version of the direct instrument generates an R&D dynamic effect in addition to the direct static effect. This instrument is a combination of the two above mentioned subsidies with $S_X = S_I$. Hence, this instrument has the same effect on the incentive to innovate as the subsidy to R&D, i.e. the number of intermediate varieties N, and on the mark-up over marginal costs as the production subsidy.

In the following, the analysis is mainly concerned with the production subsidy and the R&D subsidy. In Section 5, welfare effects from subsidizing intermediate purchase is introduced.

3.2 Steady-State Equilibrium

In steady-state equilibrium the number of intermediate varieties grows by g. This implies that $N_j = \delta\,(1 - u_j)\, L/g$ where $j = I,\ X$, denotes the type of subsidy applied, see (5). As mentioned the production subsidy does not affect the allocation of labor and thereby the number of intermediate varieties. This implies that $u_X = (r-g)/(r-g+\alpha g)$ and $N_X = \alpha\delta L/(r-g+\alpha g)$.

Implementing the R&D subsidy and substituting N_I into the non-arbitrage condition in (7) leads to $(r-g) = \pi/p_N = \alpha g\,(u_I/(1-u_I))/(1-S_I)$. Consequently, the steady-state share of labor employed in final goods production equals:

$$u_I = \frac{(1-S_I)(r-g)}{(1-S_I)(r-g)+\alpha g}, \tag{14}$$

and the number of intermediate varieties follows

$$N_I = \frac{\alpha\delta L}{(1-S_I)(r-g)+\alpha g}. \tag{15}$$

It can be shown that $u_I \geq 1/2$. The minimum value of u_I applies when $r \to 2g$ and $S_I = 1-\alpha$.

The optimal R&D subsidy, i.e. $S_I = (1-\alpha)$, implies a steady-state number of intermediate varieties of $N_X = \delta L/r$. By implementing the R&D subsidy, the government ensures the full dynamic gain by correcting for the misallocation of labor between final goods production and R&D. This subsidy, however, leaves the static distortion from monopoly pricing unaffected. I restrict the R&D subsidy to $S_I \in (0, 1-\alpha)$, since the incentive to innovate exceeds the social optimum when the R&D subsidy exceeds $(1-\alpha)$.

Since the optimal level of the production subsidy equals $S_X = (1-\alpha)$ and the optimal level of the R&D subsidy equals $S_I = (1-\alpha)$, a subsidy to intermediate purchase, i.e. a combination of the two subsidies under investigation, equal to $(1-\alpha)$ fully eliminates the distortion from monopoly pricing and increases the number of intermediate varieties to the optimal level. Using this subsidy, the government is thus able to simulate the economic outcome a social planner who maximizes the utility of his representative household would choose. This is the first-best policy of the economy.

Finally, consumption per capita is determined. Under the production subsidy this variable equals

$$c_X = SEu_XN_X \tag{16}$$

where SE measures the static effect on consumption from lower monopoly distortion and

$$SE = \frac{(1-\alpha^2-S_X)}{(1-S_X)}(1-S_X)^{-\alpha/(1-\alpha)}\alpha^{2\alpha/(1-\alpha)}. \tag{17}$$

The subsidy affects consumption through two effects on SE. First, the direct static effect of S_X reduces the intermediate price and gives rise to higher use of the single intermediate variety. Second, a negative effect from increasing S_X is generated through a higher level of government spending required to implement the higher subsidy level.

Under the R&D subsidy, consumption per capita equals

$$c_I = \left(1-\alpha^2\right)\alpha^{2\alpha/(1-\alpha)}u_I N_I. \tag{18}$$

This subsidy has a direct dynamic effect working through a lower patent price. The higher R&D incentive reallocates labor out of the final goods sector and into R&D activities, i.e. u_I falls, leading to a higher stock of intermediate varieties, i.e. N_I increases. The positive effect on the number of intermediate varieties dominates the negative effect on the labor share in final goods production, i.e. $u_I N_I$ increases. Hence, consumption is affected through an increase in $u_I N_I$.[3]

The magnitude of the static gain compared to the magnitude of the dynamic gain can be summarized by:

Proposition 1 *The dynamic effect from a change in S_I*
(i) increases in the inverse intertemporal elasticity of substitution, θ, and the rate of time preferences, ρ, and
(ii) decreases in the population growth rate, g.
The static gain from a change in S_X is not affected by changes in θ, ρ or g.

Proof. The static effect of a change in S_X equals

$$\frac{\partial \ln SE}{\partial \ln S_X} = \frac{1}{(1-\alpha)(1-S_X)} - \frac{1}{(1-\alpha^2-S_X)},$$

which is positive for $S_X < (1-\alpha)$ and independent of g, θ, and ρ.

The elasticity of $u_I N_I$ with respect to S_I equals

$$\frac{\partial \ln u_I N_I}{\partial \ln S_I} = \frac{S_I}{(1-S_I)}\frac{(1-S_I)(r-g)-\alpha g}{(1-S_I)(r-g)+\alpha g},$$

which is positive for $S_I < (1-\alpha)$. This elasticity depends positively on the inverse intertemporal elasticity of substitution,

$$\frac{\partial^2 \ln u_I N_I}{\partial \ln S_I \partial\theta} = \frac{2S_I\alpha g^2}{\left((1-S_I)(r-g)+\alpha g\right)^2} > 0,$$

[3] There is no static effect on consumption from increasing tax revenue because the larger tax payment is exactly offset by the fall in the investment cost for intermediate firms. This can be shown using the household budget constraint, see (9).

positively on rate of time preference

$$\frac{\partial^2 \ln u_I N_I}{\partial \ln S_I \partial \rho} = \frac{2S_I \alpha g}{\left((1-S_I)(r-g)+\alpha g\right)^2} > 0,$$

and negatively on population growth

$$\frac{\partial^2 \ln u_I N_I}{\partial \ln S_I \partial g} = -\frac{2S_I \alpha \rho}{\left((1-S_I)(r-g)+\alpha g\right)^2} < 0.$$

This proves Proposition 1.□

The higher is the rate of time preferences, ρ, or the inverse intertemporal elasticity of substitution, θ, the larger is the dynamic effect of a subsidy. Furthermore, the higher is population growth, the lower is the dynamic effect. The relationships follow from the non-arbitrage condition mentioned above. $(r-g) = \pi/p_N$ can be reformulated to $\theta - 1 + \rho/g = (u_I/(1-u_I))/(1-S_I)$. Hence, a one percent increase in S_I that results in a x-percent fall in $(1-S_I)$ reduces $u_I/(1-u_I)$ by x percent. Hence, the share of labor employed in final goods production falls, whereas the share increases in the R&D sector. The higher is ρ or θ and the lower is g, the higher is the initial $u_I/(1-u_I)$.

Steady state consumption under the R&D subsidy can be formulated as a positive function of $u_I(1-u_I)$. It is easy to show that the percentage increase in $u_I(1-u_I)$ that follows from a percentage fall in $u_I/(1-u_I)$ is larger for high $u_I/(1-u_I)$ values when $u_I \geq 1/2$, which is always the case. Consequently, the total percentage effect on $u_I(1-u_I)$ from a change in S_I and thereby the effect on $u_I N_I$ intensifies in θ and ρ, and diminishes in g.

3.3 Government Spending

Government spending per capita equal

$$\begin{aligned} B_X/L &= S_X N_X x/L \\ &= \alpha^2 S_X \alpha^{2\alpha/(1-\alpha)} (1-S_X)^{-1/(1-\alpha)} u_X N_X \end{aligned} \tag{19}$$

under the production subsidy, whereas it equals

$$\begin{aligned} B_I/L &= S_I w (1-u_I) \\ &= S_I (1-\alpha) \alpha^{2\alpha/(1-\alpha)} (1-u_I) N_I \end{aligned} \tag{20}$$

under the R&D subsidy. B_X and B_I denote levels of government spending under the two policy instruments.

Proposition 2 *The level of government spending required to implement $S_X = (1-\alpha)$, measured in relation to final goods output equals $B_X/Y_X = \alpha(1-\alpha)$. The level of government spending required to implement $S_I = (1-\alpha)$, measured in relation to final goods output equals $B_I/Y_I = (1-\alpha)^2 g/(r-g)$.*

Proof. Final goods production equals

$$Y_X/L = (1-S_X)^{-\alpha/(1-\alpha)}\,\alpha^{2\alpha/(1-\alpha)} u_X N_X,$$

after S_X is implemented. The levels of government spending appear from (19). Final goods production equals

$$Y_I/L = \alpha^{2\alpha/(1-\alpha)} u_I N_I,$$

after S_I is implemented. The level of government spending appears from (20). Using $S_I = (1-\alpha)$ and $S_X = (1-\alpha)$ prove Proposition 2.□

The implication of Proposition 2 is that $B_I/Y_{I|S_I=1-\alpha} < B_X/Y_{X|S_X=1-\alpha}$ for $r/g > 1/\alpha$. Hence, the required level of government spending to implement the optimal subsidy level of the production subsidy exceeds that of the R&D subsidy that completely correct for the dynamic inefficiency when dynamic effects are sufficiently important.[4] When the subsidy to intermediate purchase equals the optimal level, the government has implemented the first-best policy. This policy is equivalent to $S_X = S_I = (1-\alpha)$. The spending requirement in relation of output for this policy equals $(1-\alpha)$. This implies that the required level of government spending may be very large.

This proposition motivates the question as to whether the steady-state welfare effect from a changing number of intermediate varieties under the R&D subsidy can be larger than the effect from moderating the monopoly distortion under the production subsidy. If the answer is in the affirmative, it is relevant to analyze whether the total welfare effect, i.e. when the transitional dynamics are incorporated in the analysis, may be larger under the R&D subsidy than the production subsidy. In the following sections these two questions are addressed.

[4] The steady-state value of r is determined by θ, g, and ρ, see (10). Instead of tracing the results back to ρ and θ, I simply treat r as an exogenous parameter in the steady state analysis.

4 Steady-State Welfare

In this section I investigate whether the R&D subsidy can lead to higher steady-state welfare than the production subsidy under restricted government spending. The analysis is performed by comparing steady-state welfare effects of two experiments. In Experiment 1, the production subsidy is implemented with no R&D subsidy, i.e. $S_X > 0$, $S_I = 0$, and the R&D subsidy is implemented with no production subsidy in Experiment 2, i.e. $S_X = 0$, $S_I > 0$. The analysis is carried out under the restriction that levels of government spending in the two experiments are equal.

The requirement that the steady-state levels of government spending are of similar magnitude in the two experiments, i.e. $B_I/B_X = 1$, implies

$$\frac{(1-\alpha)\, g S_I}{\left((1-S_I)(r-g)+\alpha g\right)^2} = \frac{\alpha S_X (1-S_X)^{-1/(1-\alpha)} (r-g)}{(r-g+\alpha g)^2}. \tag{21}$$

(21) are derived using (14), (15), (19), and (20). Furthermore, the steady-state consumption levels are equal across the two experiments, i.e. $c_I/c_X = 1$, if

$$\frac{1-S_I}{\left((1-S_I)(r-g)+\alpha g\right)^2} = \frac{(1-S_X)^{-1/(1-\alpha)}}{(r-g+\alpha g)^2} \frac{1-\alpha^2-S_X}{1-\alpha^2}, \tag{22}$$

holds. (22) is derived using (14), (15), (16), and (18). (21) and (22) are complex function of S_I and S_X. When a S_X-value is chosen, the values of S_I that ensure similar levels of government spending or consumption levels under the two experiments are determined.

The two relationships are used to investigate whether the R&D subsidy can lead to a higher steady-state welfare effect than the production subsidy under restricted government spending. More precisely, I investigate whether $c_I/c_X > 1$ is a possible outcome for $B_I/B_X = 1$ and $S_I < (1-\alpha)$. To do this (21) and (22) are expressed as graphs in the (S_X, S_I)-space. $c_I/c_X > 1$ holds for $B_I/B_X = 1$ if the $B_I/B_X = 1$-curve is located above the $c_I/c_X = 1$-curve. Below I show that this is a possible outcome for the two cases; $S_X = S_I \to 0$ and S_I and $S_X > 0$.

In the following steady-state consumption per capita is used interchangeably for steady-state welfare even though consumption is not synonymous with welfare. It can be the case that the sacrifice in consumption that the households have to suffer in the short- to median-run is too large for what is socially optimal. The analysis, however, is carried out for relatively low subsidy levels, implying that an increase in the subsidy will lead to an increase in welfare. Furthermore, the transitional dynamics are determined in the welfare evaluation in Section 5.

4.1 Analysis for $S_X = S_I \to 0$

The $B_I/B_X = 1$-curve is possibly located above the $c_I/c_X = 1$-curve for $S_X = S_I \to 0$:

Proposition 3 (a) *The $B_I/B_X = 1$-curve and the $c_I/c_X = 1$-curve pass through the origin.*
(b) *For $(S_X, S_I) = (0,0)$, the slope of the $B_I/B_X = 1$-curve is steeper that the $c_I/c_X = 1$-curve when $r/g > \overline{\gamma}$ where*

$$\overline{\gamma} = 1 + \frac{1 + \alpha(1+\alpha) + \sqrt{(1+\alpha(1+\alpha))^2 + 4\alpha(1+\alpha)}}{2(1+\alpha)}$$

Proof. It is easy to verify that the $c_I/c_X = 1$- and the $B_I/B_X = 1$-curves pass through origin by setting $S_X = 0$ in (21) and (22). This proves Proposition 3(a). Proposition 3(b) is proved in Appendix A4.□

The main insight from Proposition 3 is that the introduction of a small R&D subsidy may imply a larger impact on steady-state consumption than the comparable production subsidy. In Figure 1, the condition from Proposition 3b is illustrated for $\alpha \in (0,1)$.

[Figure 1 about here]

The curve shows critical values of $\gamma = r/g$. When γ attains a value above this limit, the steady-state welfare effect of the R&D subsidy is above that of the production subsidy for small subsidy levels. The production subsidy generates a higher steady-state welfare effect than the R&D subsidy below the limit.

Since the steay-state rate of return equals $r = \theta g + \rho$, it is clear that $r/g = \theta + \rho/g$. Hence, the higher is θ or ρ and the lower is g, the higher is $\gamma = r/g$ and thereby the more likely is it that a small R&D subsidy results in a larger welfare effect than a production subsidy. This is consistent with the result of Proposition 1, such that a larger $\gamma = r/g$ generates a larger dynamic gain from economic policy. Therefore, it is more likely that a small R&D subsidy will generate a higher steady-state welfare effect than a small production subsidy that is directed at the static effect.

4.2 Analysis for $S_I, S_X > 0$

The $B_I/B_X = 1$-curve is possibly located above the $c_I/c_X = 1$-curve for $S_X, S_I > 0$. The closed form solutions for the two curves are presented in Appendixes A2 and A3. The two curves are positively sloping and are possibly concave or convex. The functions for the two curves are highly complex and it is not possible to describe the characteristics of these analytically. Therefore, the two curves are analyzed using numerical derivations in this section. More precisely, the difference between the R&D subsidies that satisfy $B_I/B_X = 1$ and $c_I/c_X = 1$ for a given value of the production subsidy. If this difference is positive it means that it is more efficient in terms of welfare to subsidize R&D activities.

Three possible outcomes for the difference between the R&D subsidies are presented in Figure 2.

[Figure 2 about here]

Panel a presents the case where the production subsidy always leads to the highest steady-state welfare effect. Proposition 3b does not hold in this case. When Proposition 3b applies, two outcome are possible as shown in Panels b and c. Panel b presents the case where the R&D subsidy leads to a higher steady-state welfare effect for relatively low S_X and the production subsidy leads to a higher steady-state welfare effect for relatively high values of S_X. Finally, Panel c presents the case where the R&D subsidy leads to a higher steady-state welfare effect for $S_I \in (0, (1-\alpha))$.

The main result established in this section is that the dynamic gain from policy intervention is high compared to the static gain for a relatively high rate of return, i.e., the dynamic gain is high when r/g is high. This implies that R&D subsidies increase steady-state consumption more than production subsidies under restricted government spending. The natural next step is to investigate whether the R&D subsidy can generate higher welfare effects that the production subsidy when the transitional dynamics is taken into account. This issue is addressed in the next section.

5 Total Welfare

To measure total welfare effects under the different policy instruments, the transitional dynamics of the model is simulated using the "Time-Elimination Method", see Mulligan and Sala-i-Martin (1991 and 1993). Furthermore, the dynamic equivalent variation, EV, is applied to measure welfare effects. For a derivation of EV see Appendix $A5$.

The transitional dynamics of the two subsidies are presented for the parameter values g= 0.5%, ρ = 0.055, θ = 2, and α = 0.5. The baseline parameters are chosen in line with existing literature on economic growth, see for example Mulligan and Sala-i-Martin (1993) and Barro and Sala-i-Martin (1995, Chapter 5). The level of government spending is assumed to equal 1% of initial final goods production. Hence, the analysis is carried out under the restriction that levels of government spending in the two experiments are equal. The effect on consumption $\left(c'_j = c_j/L\right)$, the share of labor in final goods production (u_j), the interest rate (r_j), patent price $\left(p_{N_j}/L\right)$, the subsidy level (S_j), and the number of intermediate varieties $\left(N'_j = N_j/L\right)$ are shown. j indicates the applied subsidy.

[Figure 3 about here]

The figure confirms that the production subsidy generates static effects only. Panel b shows that the allocation of labor across sectors are unaffected by the subsidy. The reason is that the incentive to invest in innovations are unaffected implying an unchanged rate of return to investments, see Panel c. Consequently, the consumption profile of this subsidy is described as a one time increase in consumption at time zero.

The R&D subsidy generates dynamic effects because the incentive to investing in R&D increased. It is evident from Panel c, that rate of return increases on impact. This reflects that the patent price falls when R&D is subsidized, see (7). The higher incentive to innovate implies reallocation of labor out of final goods production and into R&D implying that u_X falls. Consumption falls on impact when labor is reallocated to R&D activities but increases over time to a new and higher consumption level in the medium and long run as a consequence of the increasing number of intermediate varieties.

The issue of interest is whether the consumption profile of the subsidy to R&D leads to higher welfare than the production subsidy. To evaluate whether this may be the case, the dynamic equivalent variation is presented in Table 1 for combinations of the parameter values g = 0.5%, 1%, and 2%, ρ = 0.03, 0.055, and 0.08, θ = 1.001 and 2, and α= 0.333 and 0.5.

[Table 1 about here]

It is evident that the subsidy to R&D may generate a larger effect on total welfare than the R&D subsidy when the spending equals one percent of final output. For the baseline experiment (g = 0.5%, ρ = 0.055, θ = 2 and α = 0.5), the total welfare effect of the R&D subsidy is 4.29, i.e. EV_{SI}. This welfare effect is 1.70 times larger than the welfare effect for the production subsidy, i.e. EV_{SI}/EV_{SX}.

According to Proposition 1, the R&D subsidy leads to relative large steady-state welfare effects for low g, high ρ and high θ values. It is seen from Table 1 that the total welfare effect is relatively large for high values of ρ and low values of g. For these parameters, the result from the steady-state analysis carries over to the total welfare analysis. However, the steady-state effect of θ does not carry over. Based on the steady-state analysis, it is expected that an increase in θ increases EV of the R&D subsidy in relation to the production subsidy. However, a higher θ tend to reduce the relative size of EV for the R&D subsidy. The understanding of this result is that households are less willing to vary consumption for high θ. This implies that the sacrifice in consumption that the households have to suffer in the short- to median-run under the R&D subsidy lead to relatively a large negative effect on welfare. An exemption is for $g = 0.02$ and $\rho = 0.03$ where the steay-state effect of changing θ as mentioned above dominates.

The last column in Table 1 presents the total welfare effect of the subsidy to intermediate purchase. This subsidy is a combination of the production subsidy and the R&D subsidy. It is evident that this combined subsidy always lead to a lower welfare effect that the two focussed instruments. This suggests that the government should concentrate on correcting one distortion at a time. This result is surprising since by using the subsidy to intermediate purchase, the government could implement the first-best policy under unrestricted government spending.

Table 2 presents the welfare effects for different spending levels. The welfare effects are presented for two scenarios, the baseline scenario and $g = 0.5\%$, $\rho = 0.08$, $\theta = 1.001$, and $\alpha = 0.5$.

[Table 2 about here]

For the baseline scenario, it is seen that the total welfare effect of the R&D subsidy exceeds that of the production subsidy by most when the government spending is low. When government spending increases, the advantage of using the R&D subsidy is reduced. When the government spending is equal to or above 3% the government should use the production subsidy. For the second scenario, the government should use the R&D subsidy, even when the government spending is as high as 5% of final output.

6 Concluding Remarks

This paper argues that it may be optimal from a welfare perspective to directly subsidize R&D activities when the source of R&D distortions mainly originates from the surplus appropriability problem. This result holds when two conditions are fulfilled: (1) dynamic effects are important relative to static effects and (2) governments spend less resources than the required effort for correcting completely for R&D distortions.

The applied model is a simple semi-endogenous growth model, see for example Jones (1995). Monopoly power generates a distortion in pricing of intermediate goods, which calls for policy intervention. Subsidies to the production of intermediate goods and subsidies to R&D activities are analyzed. The former has a direct effect on the distortion of monopoly pricing. The other instrument is direct support of R&D activities and covers part of R&D costs. This instrument has no direct effect on the distortion of monopoly pricing.

This main question of the paper is whether the R&D subsidy generates a higher welfare effect than a production subsidy under restricted government spending. This is found to be the case, suggesting that the government may be able to generate higher welfare by focusing entirely on the dynamic inefficiency.

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A The Solution to the Model

The solution of the model is given by (5), (7), (10), (11) and the transversality condition $\lim_{t\to\infty}[a_t f_t] = 0$, where a_t is the co-state variable associated to financial capital. Without subsidies, the equilibrium can be expressed as:

$$\begin{aligned} g_c &= (r-\rho)/\theta \\ g_N &= \delta(1-u)L/N \\ c &= \left(1-\alpha^2\right)\alpha^{2\alpha/(1-\alpha)}uN \end{aligned}$$

where

$$r = (1-(1-\alpha)u)\,\delta L/N$$

and L grows with a constant exogenous growth rate, g.

In the main text, two experiments are investigated. In Experiment 1, the direct instrument is implemented with no R&D subsidy, i.e. $S_X > 0$, $S_I = 0$, and the R&D subsidy is implemented with no direct instrument in Experiment 2, i.e. $S_X = 0$, $S_I > 0$. The steady-state equilibria under Experiments 1 and 2 appear from (14), (15), (16) and (18).

A.1 Stability of the Steady State Equilibrium

The Jacobian is derived by linear approximation of system of dynamic equation around the steay-state values of $c' = c/L$ and $N' = N/L$. This results in the following system:

$$\begin{bmatrix} \dot{c}' \\ \dot{N}' \end{bmatrix} = A \begin{bmatrix} c' - c'^* \\ N' - N'^* \end{bmatrix}$$

where:

$$A = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} =$$

$$\begin{bmatrix} \frac{-(1-\alpha)\delta u^*}{\theta N^*} & \frac{(2(1-\alpha)u^*-1)\delta c^*}{\theta N^{*2}} \\ -\delta u^*/c^* & -g+\delta u^*/N^* \end{bmatrix}.$$

The determinant of A can be expressed as:

$$|A| = -\frac{\delta u^*}{\theta N^*}\left(\frac{\delta}{N^*} - (1-\alpha)\left(\frac{\delta u^*}{N^*} + g\right)\right) \tag{23}$$

For stability of the system the determinant of the Jacobian has to be negative. By substituting for steay-state values, the determinant is rewritten to $-(r-g)(r-g+\alpha g)/\theta$. Consequently, the steay-state equilibrium is saddle-path stable. It can be shown that the equilibria with subsidies implemented are saddle-path stable.

A.2 $c_I/c_X = 1$-curve

The function $c_I/c_X = 1$, presented in (22) has two possible solutions:

$$1 - S_I^- = \frac{1 - 2q(S_X)(r-g)\alpha g - (1 - 4q(S_X)(r-g)\alpha g)^{0.5}}{2q(S_X)(r-g)^2}$$

and

$$1 - S_I^+ = \frac{1 - 2q(S_X)(r-g)\alpha g + (1 - 4q(S_X)(r-g)\alpha g)^{0.5}}{2q(S_X)(r-g)^2} \tag{24}$$

where

$$q(S_X) = \frac{(1-S_X)^{-1/(1-\alpha)}}{(r-g+\alpha g)^2}\frac{1-\alpha^2-S_X}{1-\alpha^2}.$$

It can be shown that the relevant solution is $1 - S_I^+$. This is proven by showing that $1 - S_I^- < \alpha$, implying that $S_I > 1 - \alpha$, which is irrelevant in the analysis because R&D is over-subsidized in this case.

The slope of the $c_I/c_X = 1$-curve is derived using (24):

$$\frac{\partial S_I}{\partial S_X} = \frac{(1-S_X)\,q'(S_X)/q(S_X)}{\sqrt{1-4q(S_X)(r-g)\alpha g}} \tag{25}$$

where

$$\frac{q'(S_X)}{q(S_X)} = \frac{1}{1-S_X}\left(\frac{1}{1-\alpha} - \frac{1-S_X}{1-\alpha^2-S_X}\right).$$

The slope of $S_I(S_X)$ is positive for $S_X < (1-\alpha)$.

A.3 $B_I/B_X = 1$-curve

The function $B_I/B_X = 1$, presented in (21) has two possible solutions each:

$$1 - S_I^- = \frac{-(1+2p(S_X)(r-g)\alpha g) - (1+4p(S_X)(r-g)(r-g+\alpha g))^{0.5}}{2p(S_X)(r-g)^2}$$

and

$$1 - S_I^+ = \frac{-(1+2p(S_X)(r-g)\alpha g) + (1+4p(S_X)(r-g)(r-g+\alpha g))^{0.5}}{2p(S_X)(r-g)^2} \tag{26}$$

where

$$p(S_X) = \frac{S_X(1-S_X)^{-1/(1-\alpha)}}{(r-g+\alpha g)^2}\frac{r-g}{g}\frac{\alpha}{1-\alpha}$$

It is clear that the relevant solution is $1-S_I^+$, since S_I would otherwise exceed 1. $1-S_I^+$ can be shown to be positive for all parameter choices.

The slope of the $B_I/B_X=1$ is derived using (26):

$$\frac{\partial S_I}{\partial S_X}=\frac{S_I p'(S_X)/p(S_X)}{\sqrt{1+4p(S_X)(r-g)(r-g+\alpha g)}} \tag{27}$$

since

$$\frac{p'(S_X)}{p(S_X)}=\frac{1}{S_X}+\frac{\alpha}{1-\alpha}\frac{1}{1-S_X}.$$

The slope of $S_I(S_X)$ is always positive.

A.4 Proposition 3

The slope of the $c_I/c_X=1$-curve for $S_X=S_I=0$ equals

$$\frac{\partial S_I}{\partial S_X}_{|c_I/c_X=1}=\frac{\alpha}{1-\alpha^2}\frac{r-g+\alpha g}{r-g-\alpha g},$$

which is derived using (25), whereas the slope of the $B_I/B_X=1$-curve for $S_X=S_I=0$ equals

$$\frac{\partial S_I}{\partial S_X}_{|B_I/B_X=1}=\frac{\alpha(r-g)}{(1-\alpha)g}.$$

The slope is derived from (27) using (21) to solve for the limit value of S_I/S_X.

Define $r=\gamma g$. The slope of the $B_I/B_X=1$-curve is equal to the slope of the $c_I/c_X=1$-curve for

$$(1+\alpha)(\gamma-1)^2-(1+\alpha(1+\alpha))(\gamma-1)-\alpha=0.$$

Two roots solves each of this equation. The lower root is negative and therefore not relevant, since $r>2g$ according to the transversality condition. When $\gamma>\overline{\gamma}$, the slope of the $B_I/B_X=1$-curve larger than the slope of the $c_I/c_X=1$-curve. This proves Proposition 3*b*. The critical γ value, i.e., $\overline{\gamma}$, for which the slopes of the two curves equal is presented in the proposition.

A.5 Dynamic Equivalent Variation

The intertemporal budget constraint:

$$\int_0^\infty \exp\left(-\int_0^t r_v dv\right) C_t dt = H_0+F_0-B_0$$

is used with the Euler condition for consumption to express:

$$c_0 = \frac{1}{\Omega_0} \left(H_0 + F_0 - B_0 \right)$$

where

$$H_0 = \int_0^\infty w_t L_t \exp\left(- \int_0^t r_v dv \right) dt = \int_0^\infty \frac{w_t}{L_t} \exp\left(- \int_0^t \left(r_v - 2g \right) dv \right) dt$$

$$F_0 = P_{N_0} N_0$$

and

$$B_0 = \int_0^\infty B_t \exp\left(- \int_0^t r_v dv \right) dt = b_0 \int_0^\infty \exp\left(- \int_0^t \left(r_v - 2g \right) dv \right) dt.$$

H_0 is the present value of labor income, F_0 is non-human wealth at time 0, and B_0 is the present value of tax payments.

$$\Omega_0 = \int_0^\infty \exp\left(- \int_0^t \frac{\left(\theta - 1 \right) r_v + \rho - \theta g}{\theta} dv \right) dt$$

By using the expression for c_0 and the Euler condition for consumption, the utility integral, the indirect intertemporal utility function can be formulated as:

$$U = \left(\Omega_0^\theta \left(H_0 + F_0 - B_0 \right)^{1-\theta} - \frac{1}{\rho - g} \right) / \left(1 - \theta \right).$$

The dynamic equivalent variation is defined as follows:

$$\begin{aligned} & \left(\left(\Omega_0^M \right)^\theta \left(H_0^M + F_0^M + EV \right)^{1-\theta} - \frac{1}{\rho - g} \right) / \left(1 - \theta \right) \\ = & \left(\left(\Omega_0^S \right)^\theta \left(H_0^S + F_0^S - B_0^S \right)^{1-\theta} - \frac{1}{\rho - g} \right) / \left(1 - \theta \right). \end{aligned}$$

The superscript S denotes the case when a subsidy is implemented. M denotes the initial situation described by laissez-faire steady-state equilibrium. This yields the equivalent variation:

$$EV = \left(\frac{\Omega_0^S}{\Omega_0^M} \right)^{\theta/(1-\theta)} \left(H_0^S + F_0^S - B_0^S \right) - \left(H_0^M + F_0^M \right)$$

Figure 1: Critical γ as defined in Proposition 3b

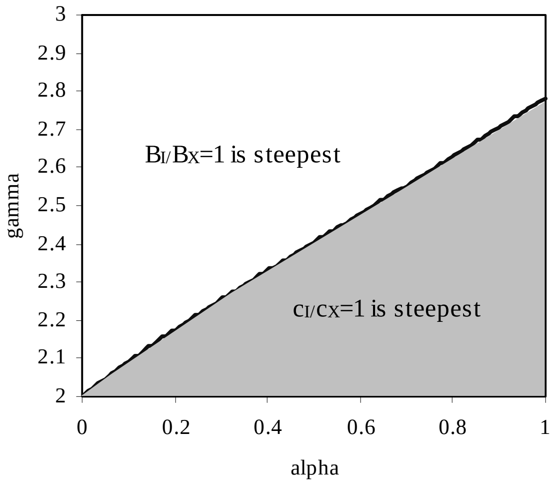
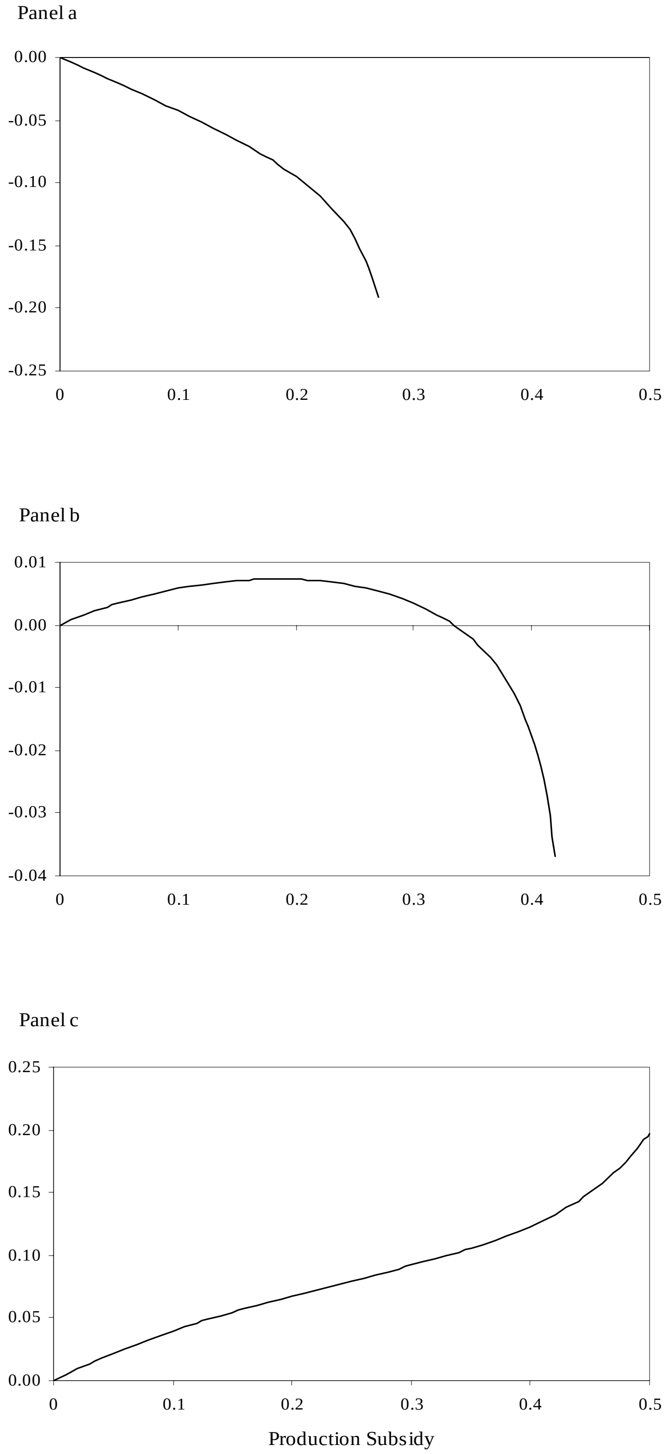
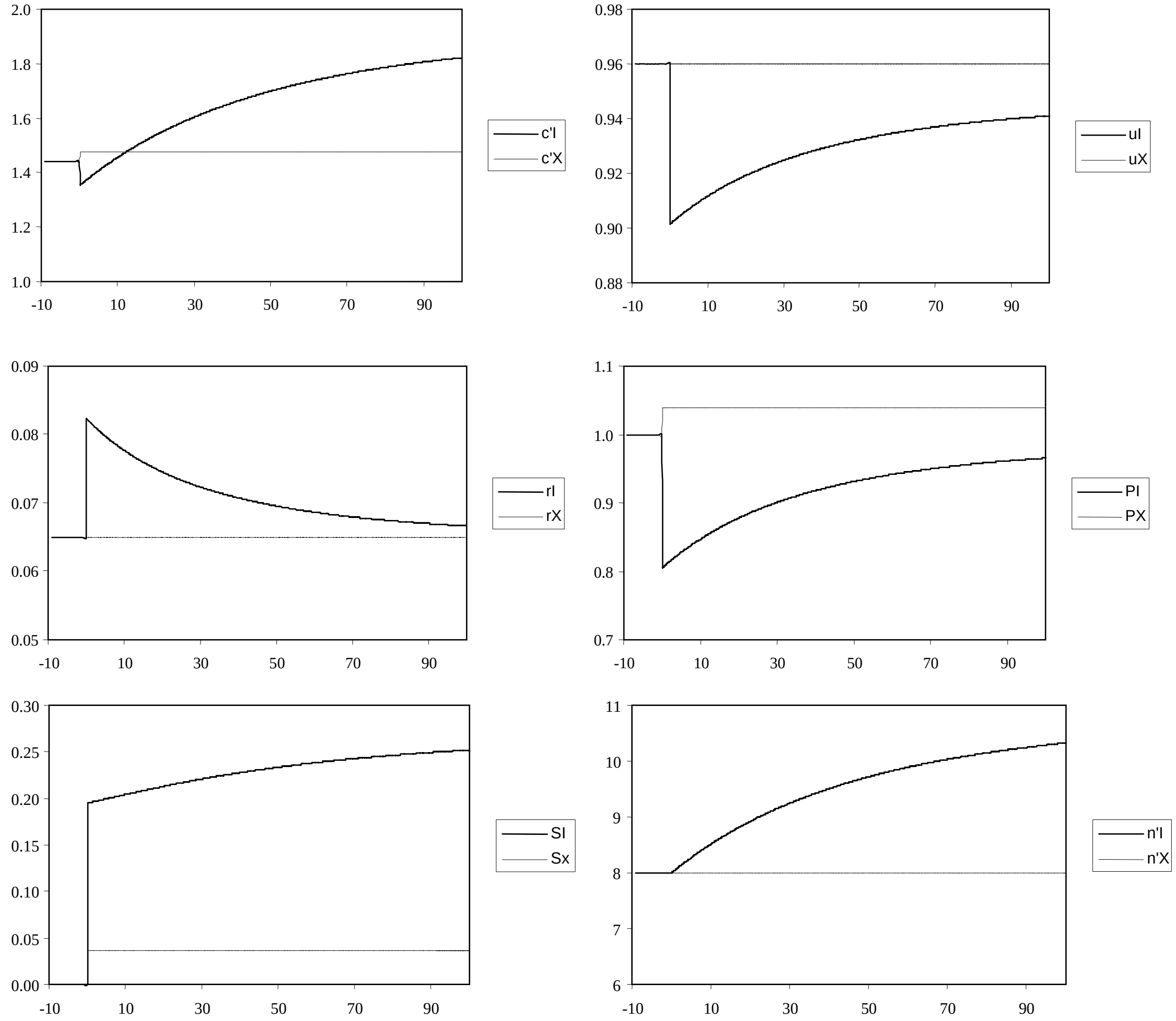


Figure 2: The $S_I(c_I/c_X=1)$ - $S_I(B_I/B_X=1)$-curve



Note: Panel a: $\alpha = 0.5$, g = 0.02, $\gamma = 2.2$, Panel b: $\alpha = 0.5$, $g = 0.02$, $\gamma = 2.45$, Panel c: $\alpha = 0.5$, $g = 0.02$, , $\gamma = 2.7$. Critical γ value as defined in Proposition 3*b* equals approximately 2.40

Figure 3: Adjustment to Steady-State Equilibrium with Direct and Indirect Policy Instruments (g = 0.5%, ρ = 0.055, θ = 2, and α = 0.5)



Note: 'I' denotes variables when the subsidy to innovation is implemented; 'X' denotes variables when the subsidy to intermediate production is implemented. c' = c/L and n'=N/L

Table 1: Welfare Effects of Different Scenarios.
(Government budget equals one percent of initial final output).

Parameter values				Equivalent variation		
g	**ρ**	**θ**	**α**	**EV_{SI}**	**EV_{SI}/EV_{SX}**	**EV_{SI}/EV_{SXD}**
0.005	0.03	2	0.5	3.08	1.22	1.86
0.005	0.03	2	0.333	5.48	1.76	2.92
0.005	0.03	1.001	0.5	4.48	1.78	2.47
0.005	0.03	1.001	0.333	7.28	2.34	3.25
0.005	0.055	2	0.5	4.29	1.70	2.61
0.005	0.055	2	0.333	6.74	2.17	3.64
0.005	0.055	1.001	0.5	4.50	1.78	2.51
0.005	0.055	1.001	0.333	9.38	3.02	4.22
0.005	0.08	2	0.5	4.75	1.89	2.90
0.005	0.08	2	0.333	7.35	2.37	3.99
0.005	0.08	1.001	0.5	6.72	2.67	3.74
0.005	0.08	1.001	0.333	7.92	2.55	3.58
0.01	0.03	2	0.5	2.47	0.98	1.46
0.01	0.03	2	0.333	4.11	1.32	2.12
0.01	0.03	1.001	0.5	2.75	1.09	1.50
0.01	0.03	1.001	0.333	4.68	1.51	2.04
0.01	0.055	2	0.5	3.29	1.31	1.98
0.01	0.055	2	0.333	5.34	1.72	2.83
0.01	0.055	1.001	0.5	4.32	1.72	2.38
0.01	0.055	1.001	0.333	7.03	2.26	3.12
0.01	0.08	2	0.5	3.85	1.53	2.33
0.01	0.08	2	0.333	6.12	1.97	3.28
0.01	0.08	1.001	0.5	5.29	2.10	2.93
0.01	0.08	1.001	0.333	8.39	2.70	3.76
0.02	0.03	2	0.5	1.88	0.74	1.09
0.02	0.03	2	0.333	3.14	1.01	1.55
0.02	0.03	1.001	0.5	1.51	0.60	0.81
0.02	0.03	1.001	0.333	2.68	0.86	1.13
0.02	0.055	2	0.5	2.40	0.95	1.42
0.02	0.055	2	0.333	3.99	1.28	2.04
0.02	0.055	1.001	0.5	2.65	1.05	1.44
0.02	0.055	1.001	0.333	4.48	1.44	1.94
0.02	0.08	2	0.5	2.84	1.13	1.70
0.02	0.08	2	0.333	4.68	1.51	2.44
0.02	0.08	1.001	0.5	3.50	1.39	1.92
0.02	0.08	1.001	0.333	5.81	1.87	2.55

Note: EV_{SI} is the dynamic equivalent variation relative to wealth at time zero when the innovation subsidy is implemented; EV_{SX} is the dynamic equivalent variation relative to wealth at time zero when the subsidy to intermediate production is implemented, and EV_{SXD} is the dynamic equivalent variation relative to wealth at time zero when the subsidy to intermediate purchase is implemented.

Table 2: Welfare Effects of Different Scenarios

Parameter values					Equivalent variation	
g	**ρ**	**θ**	**α**	**budget**	**EV_{SI}**	**EV_{SI}/EV_{SX}**
0.005	0.08	1.001	0.5	0.005	4.61	5.05
				0.01	6.72	3.74
				0.02	9.08	2.59
				0.03	10.37	2.02
				0.04	11.09	1.66
				0.05	11.45	1.40
0.005	0.055	2	0.5	0.005	2.82	2.18
				0.01	4.29	1.70
				0.015	5.24	1.42
				0.02	5.88	1.23
				0.025	6.33	1.09
				0.03	6.63	0.97

Note: EV_{SI} is the dynamic equivalent variation relative to wealth at time zero when the innovation subsidy is implemented, and EV_{SX} is the dynamic equivalent variation relative to wealth at time zero when the subsidy to intermediate production is implemented. budget denotes government budget as a percent of initial final output.