

**GOVERNMENT INVESTMENTS  
IN SCHOOLING AND INFRASTRUCTURE:  
RAMSEY VS. PUBLIC CHOICE PATHS IN A  
LIFECYCLE GROWTH MODEL**

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**Resumen:** El financiamiento público de la educación obedece a imperfecciones en los mercados de capital. De manera similar, se cree que el gobierno debe mantener un nivel adecuado de capital público que facilite la producción privada. En este artículo, se examina la implicación de bienestar y de política de estas inversiones en una versión del modelo de Diamond (1965). Se argumenta que en un esquema donde la generación actual es decisiva, se observa una subinversión significativa en infraestructura y educación con respecto al equilibrio Ramsey.

**Abstract:** Government financing of schooling is necessitated by capital market imperfections. Governments are also responsible for maintaining a stock of public capital that enters private production function. In this paper the welfare implications and politics of these investments are examined in a version of Diamond (1965) growth model. It is argued that in decentralized environments where the working generation is decisive each period significant underinvestment in both schooling and infrastructure will be observed relative to the Ramsey equilibrium.

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## 1. Introduction

The declining quality of US schools and the deterioration of the nations infrastructure are among the most important public policy concerns in the US today. Schooling is supposed to provide younger generations with the skills necessary to compete in the labor market. Investments in public capital are required to boost the productivity of private factors of production. Both may be necessary to sustain US economic growth and enhance the countrys international competitiveness.

Government investments in both schooling and public (infrastructure) capital in the US are substantial. State, local and federal spending for schools amounts to over 5 percent of GNP, and spending for infrastructure is even higher (about 7 percent of GNP). In the case of schooling, some argue that government intervention is necessitated by capital market imperfections, externalities, and redistribute considerations. In particular, it is well known that capital constrained families underinvest in the human capital of their children (see Becker, 1991 and Friedman, 1982). These families underinvest even if schooling has no external effects; however, the magnitude of underinvestment is more pronounced if, as argued by Lucas (1988), the social returns to human capital accumulation exceed the private returns by a substantial margin. In the case of public capital, the role of the government emerges from the need to establish the rules of political and economic interactions (national defense, property rights, rules for bankruptcy, legal enforceability of contracts, etc.). These government services and some private goods traditionally provided by governments (highways, fire stations, etc.) are best modeled as inputs in production and raise the productivity of privately owned factors.<sup>1</sup>

One of the most important questions in growth economics is the relative contribution of each of these two types of government invest-

<sup>1</sup> The basic argument for government provision of private goods is that there may be certain benefits that are not appropriable; that is, producers may not be able to exclude some agents from consuming these services. Another argument suggests that there may be economies of scale and, efficient provision of the services may require a monopolist; perhaps the government is an entity that could be easily monitored (Aschauer, 1989). Empirical studies have shown no conclusive evidence that government provision of services is inefficient (Stiglitz, 1988, Chp. 7). For example, Aschauer (1990) found a positive effect on output from government non-military investment spending.

ment in the growth process. Existing models of endogenous growth have either addressed government investments in human and public capital separately (see e.g. Lucas, 1988) or have combined the two concepts of capital in a single concept of generalized capital (see e.g. Barro, 1990). This is appropriate if the aim of the analysis is to obtain broad qualitative conclusions about the effects of government investment on economic growth. The distinction between the two is important when implementing of these theories and, in particular, in assessing the relative size of taxes required to finance each type of public investment. Both types of public investments reallocate resources away from current private consumption and capital accumulation and impose substantial burdens on a generation already weary of high taxes, large deficits and large taxpayer bailouts. This view is best described in Meltzer (1992): "Looking at the budget deficit alone makes it seem that federal investment in infrastructure has the same effect as hiring more regulators". However, as Meltzer (1992) adds: "The effects on the economy of these two ways of spending money are, however, quite different. If the governments investment is effective, private sector productivity is enhanced".

This paper addresses the public finance problem of providing funds for schooling and for public capital in a lifecycle growth framework which makes explicit the choices faced by the current generation of taxpayers. Diamond's (1965) model is extended to incorporate both decisions about human capital accumulation and investment in infrastructure capital. Three factors of production —labor, private capital and public capital— and three generations per period —students, workers, and retirees— are distinguished. Labor skills are determined by investments in schooling. These investments require the student's own time and schooling services (mainly those of teachers and instructional capital). If the capital markets were perfect or students could compensate their parents for the cost of these services, investments in human capital would be undertaken up to the point where the marginal return of human capital equals the cost of funds. These alternatives are not feasible in today's society, so that in absence of government financing of schooling there would be underinvestment in human capital. Government funds for schooling are intergenerational transfer from workers and retirees to students. These funds are typically raised via distortionary taxes. This distortion is independent from —and can be traded

against— the capital market distortion described above. The level of subsidies to schooling is determined by the social welfare function of the government.

Provision of funds for schooling can be modeled as an intergenerational transfer from wage and capital income earners to students. The size of this transfer depends on the nature of intergenerational politics in the society. Becker and Murphy (1988), for example, adopt the view that the expansion of public funding of schools and the institution of social security are components of a social compact between generations—an arrangement in which the working generation pays for educating the young and in exchange receives old age support in the form of social security. They argue that this arrangement mimics patterns of intergenerational cooperation that formerly existed within families in more traditional societies. These patterns in essence represented implicit contracts between generations and were enforced by social custom or pressure that are no longer present in today's highly mobile society (see Becker, 1991). Becker and Murphy view the government's ability to levy taxes as substitute to these social customs. Therefore, in a world in which capital markets cannot be relied on by capital-constrained families to obtain adequate funds for schooling, this type of government intervention is welfare-improving.

While the Becker-Murphy view of government intervention in education and social security as substitute of older arrangements within families is in some respects appealing, it does presuppose the existence of perfect precommitment of future governments to the intergenerational social compact. In practice, intergenerational cooperation is probably limited to some extent by the sequential nature of generational exchange and the self-interested nature of governments. It seems at least as reasonable to suppose, for example, that the current administration cannot commit future ones to the level of old-age support specified by the optimal social contract. In that case the only transfers which seem possible are those dictated by the selfish interests of the decisive generation. For the purposes of this paper this is taken to be the generation of workers—if students are not enfranchised and population grows, workers will be more numerous than retired owners of capital. In this world there is still a selfish motive for voluntary intergenerational transfers to the young. This motive is provided in a closed economy by the fact that labor and capital are cooperating factors so that the return to

physical capital initially rises with investments in the schooling of the young. The same logic can be used to determine current rates of investment in the human capital of the young and in the stock of public capital.

The rest of the paper is organized as follows: Section 2 presents the model. Section 3 analyzes golden rule investments in human capital, private physical capital and public capital. Section 4 derives second-best optimal tax rules in a decentralized setting in which the government must raise flat-rate taxes on all income in order to provide funds for schools and for investments in public capital. In section 5 these Ramsey rules are contrasted with endogenous taxes which a self-interested government would levy. Section 6 presents some concluding remarks.

## 2. The Model

Consider an economy of three-period lived overlapping generations defined over discrete time periods  $t = 1, 2, 3, \dots$ . The size of generation  $t$  is  $N(t)$ . Population grows at the rate  $n \geq 0$ :

$$N(t+1) = (1+n)N(t)$$

In the first period of life individuals specialize in schooling. In the second they supply to the labor market the skills acquired, receive labor income, pay taxes, consume, and save by acquiring physical assets. The raw time endowment in each of the first two periods of life is one. In the final period of life they retire and rely on accumulated assets to finance their consumption. The government collects taxes that are used to provide public education and public capital free of charge.

The production technology for human capital accumulation is of the form:

$$h(t+1) = \phi(e(t), gh(t)) \quad \phi(0)=0, \phi' > 0, \phi'' < 0 \quad (1)$$

In (1),  $e(t)$  is the effort put by the individual and  $gh(t)$  is the per student level of government expenditure on human capital accumulation at time  $t$ . Assuming the young do not care about leisure, they

$$\phi'(\tilde{g}h) \bullet \{f(k_p, k_g) - (1 + n) \bullet [k_p + k_g]\} = (1 + n) \quad (6)$$

The Golden Rule consumption profile  $(\tilde{C}_p, \tilde{C}_p)$  satisfies  $MRS(\tilde{C}_p, \tilde{C}_p) = (1 + n)$ , for given  $(\tilde{k}_p, \tilde{k}_g, \tilde{g}h)$ .

PROPOSITION 1. *Steady State Utility is maximized if the MRS of consumption and the gross return of human and private and public physical capital are each equal to  $(1 + n)$ , the gross rate of population growth. That is, welfare is maximized at:*

$$f_1(\tilde{k}_p, \tilde{k}_g) = \phi'(\tilde{g}h) \bullet \{f(\tilde{k}_p, \tilde{k}_g) - (1 + n) \bullet [\tilde{k}_p, \tilde{k}_g]\} = f_2(\tilde{k}_p, \tilde{k}_g) = (1 + n).$$

#### 4. Decentralized Equilibrium: the Ramsey Problem with Uniform Income Taxes

In general a member of generation  $t$  has preferences over consumption bundles  $(c_1(t), c_2(t+1), c_3(t+2))$ , where  $c_i(t-1+i)$  denotes the consumption of an individual belonging to generation  $t$  in periods  $i = 1, 2, 3$  of her life. It is assumed that the consumption of young agents at  $t$ ,  $c_1(t)$ , is zero. While simplifying things considerably, this assumption is in no way crucial for the results of this paper. Furthermore, assuming log-linear preferences, the utility function becomes  $u(c_2, c_3) = \log(c_2) + B \bullet \log(c_3)$ , with  $B > 0$ .

The production function is assumed to exhibit constant returns to scale (CRS); specifically,

$$Y(t) = k_p(t)^\alpha \bullet k_g(t)^\beta \bullet L(t)^\delta, \quad (7)$$

where  $\alpha + \beta + \delta = 1$  and  $\alpha, \beta, \delta \geq 0$ .  $L(t) = N(t-1) \bullet h(t)$  is the stock of effective labor,  $h(t)$  is human capital,  $N(t-1)$  is the labor force that equals the population of generation “ $t-1$ ” in this model. The constant returns to scale formulation has been tested by Aschauer (1989) and Munnell (1990). They have found that the sample data 1947-1985 for the US and 1970-1986 for the states of the US do not reject this hypothesis and, as such, we employ this specification.

In the absence of lump-sum taxation the government must levy distortionary taxes. Here we assume that the government finances its

expenditure on human capital with revenues from taxation of all income. At any time  $t$ , the government collects revenue to buy a flow of goods which are invested in public capital; also it does provide schooling to the generation just born. Given the length of a “period”, we assume that all inputs to production depreciate completely, i.e. human capital cannot be “bequeathed” to future generations. Thus the government budget constraint at any  $t$  is:

$$G(t) = \{\tau_h(t) + \tau_k(t)\} \cdot Y(t), \quad (8)$$

where  $\tau_h(t)$  and  $\tau_k(t)$  are the shares of government expenditure in human and physical capital respectively. Define  $G^h(t)$  as the expenditure carried on generating human capital and  $G^k(t)$  the expenditure dedicated to provide public physical capital. Using these definitions, it is easy to show that

$$gh(t) \equiv G^h(t) / N(t) = \tau_h(t) \cdot k_p(t)^\alpha \cdot k_g(t)^\beta \cdot gh(t-1)^\gamma / (1+h), \text{ and} \quad (9)$$

$$k_g(t+1) \equiv G^k(t) / N(t) \cdot h(t+1) = \tau_k(t) \cdot k_p(t)^\alpha \cdot k_g(t)^\beta \cdot (gh(t-1) / gh(t))^\gamma \quad (10)$$

where equation (10) represents the public physical capital per effective labor. By substituting (9) into (10) we obtain

$$\begin{aligned} k_g(t+1) = & [\tau_k(t) \cdot k_p(t)^{\alpha/(1-\gamma)} \cdot gh(t-1)^{\gamma(1-\gamma)} \cdot k_g(t)^{\beta/(1-\gamma)}] \\ & / (1+n)^{1-\gamma} \cdot \tau_h(t)^\gamma \end{aligned} \quad (11)$$

Let  $s = B / (1 - B)$  be the savings rate. Then from the loan market equilibrium we have that

$$S^p(t) = K^p(t+1) = s \cdot N(t-1) \cdot [1 - \tau_h(t) - \tau_k(t)] \cdot w(t) \cdot h(t).$$

Using the identity

$$L(t+1) / L(t) \equiv N(t) \cdot gh(t)^\gamma / N(t-1) \cdot gh(t-1)^\gamma$$

into (11) results in:

$$k_p(t+1) = \{s \cdot (1 - \alpha - \beta) \cdot [1 - \tau_h(t) - \tau_k(t)] \cdot [k_p(t)^{\alpha/(1-\gamma)} \cdot gh(t-1)^{\gamma(1-\gamma)} \cdot k_g(t)^{\beta/(1-\gamma)}]\} / (1+n)^{1-\gamma} \cdot \tau_h(t)^\gamma \quad (12)$$

To simplify, define

$$\begin{aligned} B1 &\equiv \tau_h(t) / (1+n) \\ B2 &\equiv \tau_k(t) / (1+n)^{1-\gamma} \cdot \tau_h(t)^\gamma \\ B3 &\equiv s \cdot (1 - \alpha - \beta) \cdot [1 - \tau_h(t) - \tau_k(t)] / (1+n)^{1-\gamma} \cdot \tau_h(t)^\gamma \end{aligned} \quad (13)$$

Using these definitions, equations (9), (11) and (12) become

$$gh(t) = B1 \cdot k_p(t)^\alpha \cdot k_g(t)^\beta \cdot gh(t-1)^\gamma \quad (14)$$

$$k_g(t+1) = B2 \cdot k_p(t)^{\alpha/(1-\gamma)} \cdot gh(t-1)^{\gamma/(1-\gamma)} \cdot k_g(t)^{\beta/(1-\gamma)} \quad (15)$$

$$k_p(t+1) = B3 \cdot k_p(t)^{\alpha/(1-\gamma)} \cdot gh(t-1)^{\gamma/(1-\gamma)} \cdot k_g(t)^{\beta/(1-\gamma)} \quad (16)$$

Equation (14)-(16) depict the equilibrium sequences,  $\{gh(t), k_p(t+1), k_g(t+1)\}$ . Using (14) and (15), we obtain

$$k_p(t+1) = \{gh(t+1)\}^{1/\alpha} \cdot B1^{[\beta(1-\gamma)-1]/\alpha} / \{B2^{\beta/\alpha} \cdot gh(t)^{[\gamma(1-\beta)+\beta]/\alpha}\}$$

Plugging it into (16) we see that expenditure on human capital per student obeys the following equation:

$$gh(t+1) = B3^\alpha \cdot B2^\beta \cdot B1^{\gamma(\alpha+\beta) + (1-\alpha-\beta)} \cdot gh(t)^{\gamma(1-\alpha-\beta) + \alpha + \beta}$$

which converges to the log steady state if  $\gamma(1 - \alpha - \beta) + \alpha + \beta < 1$  and it is satisfied as long as  $\gamma < 1$ . Taking logarithms and evaluating at the steady state, we obtain

$$\begin{aligned} \log(gh) &= \{\alpha \cdot \log(B3) + \beta \cdot \log(B2) + [\gamma(\alpha + \beta) \\ &+ (1 - \alpha - \beta)] \cdot \log(B1)\} / \{(1 - \gamma) \cdot (1 - \alpha - \beta)\} \end{aligned} \quad (17)$$



Similarly  $k_p$  and  $k_g$  become:

$$\log(k_p) = \log(B3) - (1 - \gamma) \cdot \log(B1) + (1 - \gamma) \cdot \log(gh), \text{ and} \quad (18)$$

$$\log(k_g) = \{-\log(B1) - \alpha \cdot \log(k_p) + (1 - \gamma) \cdot \log(gh)\} / \beta \quad (19)$$

Equations (17), (18) and (19) describe the steady state  $(gh, k_p, k_g)$  triplet.

#### 4.1. *The Optimal Taxation Problem*

Let  $V(t - 1)$  be the indirect utility function of generation “ $t - 1$ ” (disregarding any constants):

$$\begin{aligned} V(t - 1) = & \log\{[1 - \tau_h(t) - \tau_k(t)] \cdot w(t) \cdot h(t)\} \\ & + B \cdot \log\{[1 - \tau_h(t) - \tau_k(t)] \cdot [1 - \tau_h(t + 1) \\ & - \tau_k(t + 1)] \cdot w(t) \cdot h(t) \cdot r(t + 1)\} \end{aligned}$$

In steady state  $V, \tau_h, \tau_k, w, h, r, k_p, k_g$  are all constant and  $V$  can be written as

$$V(t - 1) = \log[(1 - \tau_h - \tau_k) \cdot w \cdot h] + B \cdot \log[(1 - \tau_h - \tau_k)^2 \cdot w \cdot h \cdot r] \quad (20)$$

Individuals maximize (20) by choosing  $\{\tau_h, \tau_k\}$  subject to:

$$w = (1 - \alpha - \beta) \cdot k_p^\alpha \cdot k_g^\beta$$

$$h = gh^\gamma$$

$$r = \alpha \cdot k_p(t)^{\alpha - 1} \cdot k_g^\beta$$

(17), (18), (19), and the set of definitions (13).

The solution to this problem leads to the following proposition:

PROPOSITION 2. *Suppose public investments on education and physical capital are financed by a proportional tax on income and the government budget is balanced each period. Then:*

- (a) *The optimal tax rate that maximizes steady state utility is:*  

$$\tau^* = \gamma \cdot (1 - \alpha - \beta) + \beta.$$
- (b) *The shares of human and (public) physical capital investments to output are:  $\tau_h^* = \gamma \cdot (1 - \alpha - \beta)$  and  $\tau_k^* = \beta$ .*

PROOF: See appendix.

Note that the optimal tax rates are independent of the discount factor. In the Ramsey equilibrium the fraction of national income allocated to public schooling and public physical capital is  $\tau^*$ . Nations with higher savings rates optimally invest a greater fraction of their income in human capital and public physical capital and enjoy higher standards of living both because their workforces are better educated and because non-human capital (private and public) per unit of effective labor is greater.

## 5. Endogenous Provision of Schooling and Public Capital

This section investigates the tax rates selected and investments in schooling and public capital chosen by a self-interested government representing the middle-aged workers. Each middle-aged and each old individual in this economy has one vote. By assumption, the young are not enfranchised. Thus, the electoral process involves only the middle aged and the older generations. Since we assume that the rate of population growth is positive, the decisive voters are the middle-aged individuals. The government will impose taxes only in order to raise the lifetime utility of the generation it represents. In the absence of altruism or intergenerational social contracts, the only reason for such transfers to the young is that the productivity of physical capital which the decisive generation depends on during retirement to finance consumption rises with investments in human and public capital. At any "t",  $w(t)$ ,  $h(t)$ ,  $k_g(t)$ ,  $k_p(t)$  are known to these individuals. Moreover, although  $\tau_h(t+1)$  and  $\tau_k(t+1)$  are unknown at "t", the decisive generation does not have

control over these tax rates (i.e. they are fixed). At  $t + 1$  the next generation (born at “ $t$ ”) will set the optimal values of  $\tau_h(t + 1)$  and  $\tau_k(t + 1)$ . The decisive generation only chooses how much to tax to themselves and the old at “ $t$ ”. Thus, individuals maximize

$$V = (1 + B) \cdot \log(1 - \tau_h(t) - \tau_k(t)) + B \cdot \log(r(t + 1))$$

$$\{\tau_k(t), \tau_h(t)\}$$

s. t.  $\log(r(t + 1)) \propto (\alpha - 1) \cdot \log(k_p(t + 1)) + \beta \cdot \log(k_g(t + 1))$  and equations (13), (15) and (16).

This problem has an interior solution with  $\tau_h(t) + \tau_k(t) < 1$  and  $\tau_h(t), \tau_k(t) > 0$ . Proposition 3 establishes this result:

**PROPOSITION 3.** *Suppose public investment in education and physical capital are financed by a proportional tax on income and the government budget is balanced each period. Then:*

a) *The optimal tax rate that maximizes the lifetime utility of the decisive or median voter is:*

$$\tau^*(t) = B[\gamma(1 - \alpha - \beta) + \beta] / [1 + B \cdot \gamma \cdot (1 - \alpha - \beta) + B \cdot (\alpha + \beta)]$$

b)  $\tau_h(t)^* = B \cdot \gamma \cdot (1 - \alpha - \beta) / [1 + B \cdot \gamma \cdot (1 - \alpha - \beta) + B \cdot (\alpha + \beta)]$  and  $\tau_k(t)^* = B \cdot \beta / [1 + B \cdot \gamma \cdot (1 - \alpha - \beta) + B \cdot (\alpha + \beta)]$ .

**PROOF.** See appendix.

The model allows us to estimate and simultaneously for both, the Ramsey and the Endogenous cases. The calibration of the model follows from the assumption that the observed shares of government expenditures on human and physical capital to Gross National Product, GNP, are drawn from an environment where a majority voting rule is followed and each individual casts a single vote (excluding the young). The observed average shares of these expenditures for the Consolidated Government are 5% for the public investment on human capital formation (encompassing only education) and 7% for public physical provision for the period 1965-1989 (US Department of Commerce, 1986).

Public physical investment is defined as a residual. From the total government expenditure we deducted the expenditures on welfare, interest payments, education, health, and hospitals, labor training, veterans and national defense. We take a value of  $\alpha = 0.33$  and  $B = 1$ . Thus, solving the pair of equations in proposition 3 for  $\beta$  and  $\gamma$  under the above assumptions yield:  $\gamma = 0.135$  and  $\beta = 0.106$ . The optimal tax rates for the Ramsey problem under these values of the parameters gives us:  $\tau_h^* = 0.076$  and  $\tau_k^* = 0.106$ . These optimal tax rates also indicate the optimal shares of government investments on human and physical capital respectively. The underprovision amounts up to 2.6 percentage points of the GNP for human formation and up to 3.6 percentage points for public physical capital provision.

Under the assumption that the observed shares of government expenditure are drawn from a Ramsey type economy, the estimated values of  $\gamma$  and  $\beta$  are:  $\gamma = 0.083$  and  $\beta = 0.07$ . The endogenous optimal tax rates under these parameters are  $\tau_h^* = 0.048$  and  $\tau_k^* = 0.034$ .

Independent estimates of  $\gamma$  and  $\beta$  have been obtained in the literature. Using data from the Panel Study of Income Dynamics on white men between the ages of 30 and 55, Akin and Garfinkel (1977) found that school quality (as measured by average school expenditures in the states the person grew up) contributes significantly to earnings. They report an elasticity of earnings with respect to school expenditures of 0.2038, that is,  $\gamma = 0.2038$ . Aschauer (1989), on the other hand, reports that the elasticity of output with respect to the stock of public capital, ( $\beta$  in our notation) ranges between 0.36 and 0.39 for the US from 1949 to 1985, while Munnell (1990) reports  $\beta = 0.15$  using US regional data.

Clearly, the values of the parameters estimated in the first case are much closer to those provided by the empirical evidence just mentioned. The value of  $\gamma = 0.135$  from the endogenous case compares well with Akin and Garfinkels estimate. The estimated values of range from 0.083 to 0.106. These appear to be low compared to the values estimated by Aschauer (1989). However, we should note two things: a) to the extent that his formulation did not include a measure of human capital (or effective labor), his estimation may be biased upward; this is so since labor force productivity would be underestimated, and b) he assumes that the flow of government physical capital or services can be represented by the stock of public capital. If, as Barro (1990) argues, the flow of government productive services is proportional to the stock of

public capital, then the estimated range of  $\beta$  by Aschauer (1989) provides an upper bound (with the constant of proportionality equal to one). Indeed, we argue that taking into account these two observations would significantly reduce  $\beta$ . Moreover, it is closer to the estimated value presented by Munnell (1990).

The above discussion can be summarized by the following tables.

**Table 1**  
*Uniform Income Taxation*  
*Endogenous environment:  $B = 1, \beta = 0.106, \gamma = 0.135, \alpha = 0.33$*

	<i>Ramsey</i>	<i>Endogenous</i>
$\tau_h^*$	0.076	0.05
$\tau_k^*$	0.106	0.07

\* Indicates optimal tax rate.

**Table 2**  
*Uniform Income Taxation*  
*Ramsey environment:  $B = 1, \beta = 0.07, \gamma = 0.083, \alpha = 0.33$*

	<i>Ramsey</i>	<i>Endogenous</i>
$\tau_h^*$	0.05	0.034
$\tau_k^*$	0.07	0.048

\* Indicates optimal tax rate.

The underprovision result presented in tables 1 and 2 are described in proposition 4.

**PROPOSITION 4.** *A democratic society that finances government expenditures by means of a uniform tax on income and that keeps a balanced budget, may be underinvesting in human and public physical capital formation relative to the second best.*

From the optimal tax rates found in the last two sections, which are reproduced here for comparison:

$$\begin{aligned}\tau_h^{e*} &= B \cdot \gamma \cdot (1 - \alpha - \beta) / [1 + B \cdot \gamma \cdot (1 - \alpha - \beta) + B \cdot (\alpha + \beta)], \tau_k^{e*} \\ &= B \cdot \beta / [1 + B \cdot \gamma \cdot (1 - \alpha - \beta) + B \cdot (\alpha + \beta)], \\ \tau_h^{R*} &= \gamma \cdot (1 - \alpha - \beta) \text{ and } \tau_k^{R*} = \beta\end{aligned}$$

The superscripts  $e$  and  $R$  refer to the endogenous and the Ramsey (second best) cases respectively. By simple examination, the statements  $\tau_h^{e*} < \tau_k^{R*}$  and  $\tau_k^{e*} < \tau_k^{R*}$  are always true.

## 6. Concluding Remarks

This paper provided an assessment of the intergenerational impacts of public expenditures for education and infrastructure capital in an integrated general equilibrium model. These impacts are important because they shape future living standards and the growth performance of the economy and because there is a presumption that capital market imperfections and externalities result in underprovision of both schooling and infrastructure capital by the private sector and (in modern times) by capital-constrained families.

The paper provides an analysis of both a cooperative view of the politics of intergenerational exchange and public choice perspective. The former view argues that government intervention forces an implicit social contract among generations. This contract results in the implementation of (second best) Ramsey taxes which raise welfare over levels achieved via selfish generational behavior. The second view assumes that the decisive generation cannot be effectively punished in the future if it violates the social compact and that it provides public funds for schooling and infrastructure only to the extent motivated by selfish considerations.

Calibration of the model implies that the selfish view seems to generate parameters that are more in line with labor estimates of the importance of school quality on earnings than the optimal contract view. Observed patterns of public expenditures on schools and infrastructure were thus interpreted as having been derived from the noncooperative regime. Using these values of the productivity of each type of public expenditure along with the Ramsey taxation rule results in a recommen-

dation to raise public spending on schools and infrastructure from about 12 percent of GNP to slightly more than 18 percent. Such an expenditure will raise growth and living standards even if no externalities due to schooling or public capital are present.

### Appendix

PROOF OF PROPOSITION 2: Uniform Tax on Income: Ramsey Problem.

$$\begin{aligned}
 V = & \{[\alpha \cdot (1 - \beta) + (1 - \gamma) \cdot (1 - \alpha - \beta)(1 + B)] \\
 & / [(1 - \gamma) \cdot (1 - \alpha - \beta)]\} \cdot \log[(1 - \tau_h - \tau_k)] \\
 & + \{[(1 + B) \cdot \beta] / [(1 - \gamma) \cdot (1 - \alpha - \beta)]\} \cdot \log(\tau_k) \\
 & + \{[(1 + B) \cdot \gamma \cdot (1 - \alpha - \beta)] / [(1 - \gamma) \cdot (1 - \alpha - \beta)]\} \cdot \log(\tau_h)
 \end{aligned}$$

Define the coefficient of  $\log[(1 - \tau_h - \tau_k)]$  as  $C$ ; the coefficient of  $\log(\tau_k)$  as  $D$ , and the coefficient of  $\log(\tau_h)$  as  $A$ . The first order condition implies that:

$$-(A + C)\tau_h - A\tau_k + A = 0 \quad (1.1)$$

$$-D\tau_k - (D + C)\tau_h + D = 0 \quad (1.2)$$

After some manipulations,

$$A + C = [(1 + B) \cdot (1 + \beta)] / [(1 - \gamma) \cdot (1 - \alpha - \beta)],$$

$$D + C = (1 + B) \cdot [1 - \gamma \cdot (1 - \alpha - \beta)] / [(1 - \gamma) \cdot (1 - \alpha - \beta)].$$

Using (1.1), (1.2) and the above expressions, the optimal tax rates become:

$$\tau_h^* = \gamma \cdot (1 - \alpha - \beta) \quad \text{and} \quad \tau_k^* = \beta \quad \blacksquare$$

## PROOF OF PROPOSITION 3: Uniform Tax on Income: Endogenous Case.

The problem of the young agent can be rewritten as:

$$\begin{aligned} \text{Max } V = & [(1 + B \cdot \alpha)] \cdot \log[(1 - \tau_h(t) - \tau_k(t))] \\ & + [B \cdot \gamma \cdot (1 - \alpha - \beta)] \cdot \log(\tau_h(t)) + [B \cdot \beta] \cdot \log(\tau_k(t)) \\ & \{\tau_h(t), \tau_k(t)\} \end{aligned}$$

The FONC are:

$$\begin{aligned} - [1 + B \cdot \alpha + B \cdot \gamma \cdot (1 - \alpha - \beta)] \cdot \tau_h(t) - [B \cdot \gamma \cdot (1 - \alpha - \beta)] \\ \cdot \tau_k(t) + [B \cdot \gamma \cdot (1 - \alpha - \beta)] = 0 \end{aligned} \quad (1.3)$$

$$- [1 + B \cdot (\alpha + \beta)] \cdot \tau_k(t) - B \cdot \beta \cdot \tau_h(t) + B \cdot \beta = 0 \quad (1.4)$$

Solving for  $\tau_k(t)$  from (1.4):

$$\tau_k(t) = B \cdot \beta / [1 + B \cdot (\alpha + \beta)] - B \cdot \beta / [1 + B \cdot (\alpha + \beta)] \cdot \tau_h(t) \quad (1.5)$$

and substituting it into (1.3), the optimal tax rate for human capital investment is:

$$\tau_h(t)^* = B \cdot \gamma \cdot (1 - \alpha - \beta) / [1 + B \cdot \gamma \cdot (1 - \alpha - \beta) + B \cdot (\alpha + \beta)].$$

Substituting  $\tau_h(t)^*$  into (1.5), results in:

$$\tau_k(t)^* = B \cdot \beta / [1 + B \cdot \gamma \cdot (1 - \alpha - \beta) + B \cdot (\alpha + \beta)].$$

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