PUBLIC PENSIONS AND CAPITAL ACCUMULATION: THE CASE OF BRAZIL

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Abstract

We use an OLG model to study the effects of the generous public sector pension system in Brazil. In our model there are two types of workers, one working in the private sector, the other working in the public sector. Public workers produce infrastructure or education services. We find that reducing generosity of the public sector pensions has large effects on capital accumulation and steady state income.

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1 Introduction

Brazil runs two very different pension systems for the public and the private sector. The public sector system is very generous. "Integrality" ensures that pension payments are 100% of the highest income of a public sector employee. "Parity" makes sure that these pension payments are indexed to wages paid to current civil servants. Overall, the public sector pension system accounts for 50% of all retirement payments, whereas public sector retirees only account for 5% of all retirees in Brazil. The average contribution rate of civil servants towards their pension fund is 11%. In the private sector the contribution rates are much higher, roughly 27% (7.6% employees contribution and 20% employer contribution) in the manufacturing and service sector. In the agricultural (rural) sector contribution rates are somewhat lower and range around 16%. The average pension paid to private sector retirees amounts to 70% to 80% of their wage income.[1] According to Souza et al. (2004) the deficit of the pension system amounts to roughly 4.5% of GDP, 3.5% is caused by the public sector, the remaining 1% comes from the private sector.

The generosity of the public sector pension system has led to concerns about its sustainability. These concerns inspired the original bill of the Constitutional Amendment 40 (Lula Reform 2003) which had two main objectives. First, it aimed at reducing the huge deficit in the civil sector pension system. Second, it aimed at making the public system more similar to the private sector system to improve equity. The changes that were actually approved fell short of the original goals and mainly affect future public servants.[2]

This paper studies the effects of public sector pension reforms on capital accumulation. We do this using an OLG framework, which is described in detail in section 2, in which the government hires workers and invests in a public capital to provide services to households and firms. These services are made available free of charge. We can think of these as being services flowing from the stock of roads and highways.

The government also finances public expenditures on education and social security payments to the private sector workers. In our model financing generous public sector pensions implies the opportunity cost of lower public expenditures on public education and/or on public capital accumulation. We focus on reduction of public sector pensions. The extra resources freed up by cutting public sector pensions can be used to (*i*) increase private sector pension, (*ii*) increase public education expenditure, or (*iii*) increase investment in the public capital stock.

Section 3 contains the definition of competitive equilibrium. In section 4 we solve the model. In section 5 we calibrate the model to Brazil and in section 6 we conduct policy experiments. In all of the policy experiments conducted we focus on steady state outcomes. We find that steady state income is completely unaffected by shifting from public to private sector pensions. This is due to homogeneity of the utility function assumed here. Decreasing generosity of public sector pensions and increasing either public education expenditures or investment in public capital has sizeable effects on

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[1] See Bonturi (2002) for more detailed information about the Brazilian pension system.
[2] Souza et al. (2004) contains further details of the pension reform in Brazil.

steady state income. We find that the direct effects of public pension reform through influencing savings are small. However, using the resources that become available through reduction in public pensions on public investment in infrastructure or on public education has large effects on steady state income. We conduct extensive sensitivity analysis for these policy reform experiments. Section 7 concludes.

2 The Model

In order to study the economic effects of the generosity of public sector pensions we employ a model in which recipients of public sector pensions, civil servants, play a meaningful economic role. In our model civil servants work in two sectors, public education and public provision of infrastructure. This set-up allows us to not only study the costs of public sector compensation including pension benefits but also the benefits of public sector employment.

There is a large number of individuals who live for two periods in an OLG set-up. Each period accounts for roughly 30 years. For reasons of simplicity we abstract from population growth and normalize the size of the population to one. A fraction N^r of the population is working in the private sector and N^u is the fraction of civil servants. Workers who work in the public sector but do not have the status of a civil servant are counted as private sector workers. Only civil servants have access to generous pension payments. We therefore get

$$N^r + N^u = 1.$$

A fraction N^{ue} of civil servants is working in the public education sector , the others N^{ui} are working in the "public infrastructure" sector. We use the following notation

$$
\begin{aligned}
N^{ue} &= aN^u, \\
N^{ui} &= (1-a)N^u.
\end{aligned}
$$

All civil servants have an identical wage and pension scheme regardless of sector of employment. This scheme differs from private sector workers in contribution rates and also in benefit payments.

Agents value two different types of goods, a privately provided good and a publicly provided good. The utility function of a member of generation t is

$$
\begin{aligned}
&u\left(c_t, G_t, c_{t+1}, G_{t+1}\right) \\
&= \frac{1}{1-\sigma}\left[(c_t^\rho + \Theta G_t^\rho)^{\frac{1}{\rho}}\right]^{1-\sigma} + \beta\frac{1}{1-\sigma}\left[\left(c_{t+1}^\rho + \Theta G_{t+1}^\rho\right)^{\frac{1}{\rho}}\right]^{1-\sigma},
\end{aligned}
$$

where c_s is consumption of the private good, and G_s is a pure public good provided by the government in the two respective periods $s = t, t+1$. We can think of this public good as enforcement of private property, enforcement of contracts, maintenance of law and order. Alternatively, we can think of this good as roads, highways or other elements of core infrastructure which is made available to all households and firms at a zero price. We also assume $\rho \leq 1$ and $\sigma > 0$.

The privately supplied good is produced from three inputs, the publicly provided service G_t, the private capital stock K_t and effective labor (human capital) in the private sector $H_t^r = H_t N_t^r$ according to the production function

$$Y_t = A G_t^{\alpha_1} K_t^{\alpha_2} (H_t^r)^{\alpha_3},$$

where $\alpha_i \in (0,1)$ for $i = 1, 2, 3$, $\alpha_2 + \alpha_3 = 1$, and $A > 0$. Capital K fully depreciates each period. The public good G is provided without charge by the government. If G is made available to firms at a zero price, firms only hire capital and labor. The condition $\alpha_2 + \alpha_3 = 1$ then ensures constant returns to scale in the two hired factors and zero profits. This kind of production function is standard and has been used by Barro (1990), Glomm and Ravikumar (1994), Turnovsky and Fisher (1995), Cassou and Lansing (1998) and many others.

Human capital is produced according to

$$h_{t+1} = B \left[(H_t^{ue})^{\eta_1} + \chi_1 E_t^{\eta_1} \right]^{\frac{\gamma_1}{\eta_1}} h_t^{\gamma_2}, \tag{1}$$

where H_t^{ue} is public educational human capital (teachers), E_t is public education expenditure, h_t is the parental human capital, $B > 0$, $\eta_1 \leq 1, (\gamma_1, \gamma_2) \in (0,1)$, and $\gamma_1 + \gamma_2 \leq 1$.

Most models of human capital accumulation such as Loury (1981), Benabou (1996), Fernandez and Rogerson (1998) or Blankenau and Simpson (2004) only allow for one public input into human capital production. Here we find it useful to disaggregate public education inputs into teachers H_t^{ue} and material inputs E_t such as textbooks, computers and buildings.

The government uses effective labor (human capital) of civil servants employed in the non-educational sector $H_t^{ui} = H_t N_t^{ui} = H_t (1 - a) N_t^u$ and public capital K_t^G to produce services according to

$$G_t = Y_t^G = Z \left[\left(K_t^G \right)^{\eta_2} + \chi_2 \left(H_t^{ui} \right)^{\eta_2} \right]^{1/\eta_2}, \tag{2}$$

where $Z > 0$ and $\eta_2 \leq 1$. Public capital evolves according to

$$K_{t+1}^G = (1 - \delta_{K^G}) K_t^G + I_t^G. \tag{3}$$

The government collects two kinds of labor income taxes in the public sector, the standard tax on labor income τ_{Lt}^u and an additional social security contribution rate τ_{Lt}^{ssu}. Workers in the private sector pay the tax rates τ_{Lt}^r and τ_{Lt}^{ssr}. In addition, capital income is taxed at rate τ_{Kt}. The stock of debt that the government can issue in period t is B_t. In period t the government faces the following expenditures (where we will express expenditures for government program i as fixed share $\Delta_{i,t}$ of output Y_t):

1. public education expenditures

$$E_t = \Delta_{E,t} Y_t, \tag{4}$$

2. investments in public capital

$$I_t^G = \Delta_{G,t} Y_t, \tag{5}$$

3. transfer payments to the old who were employed in the private sector

$$T_t^r = \Delta_{T^r,t} Y_t, \tag{6}$$

4. wage payments of the current civil servants $w_t^u H_t N_t^u$,

5. pensions of last period's civil servants $\Psi w_t^u H_t N_{t-1}^u$,

6. payments of public debt $(1 + r_t) B_t$.

Public pensions are indexed to this period's public sector wages, where $w_t^u H_t$ is an individual public employee's wage income. The total wage bill of the public sector in a given period is $w_t^u H_t N_t^u$. Since $w_t^u H_t$ is the average wage of an individual agent in a period (which is roughly 30 years long), the question arises what fraction of this current wage is paid out to retirees. In order to capture different levels of generosity of a pension system we express the amount of pensions paid to public sector retirees as

$$T_t^u = \Psi w_t^u H_t N_{t-1}^u, \tag{7}$$

where $\Psi > 0$. If $\Psi \in (0, 1)$ then pensions paid are only a fraction of the current average wage. The larger Ψ becomes the more generous the public pension system becomes. As $\Psi > 1$ the pensions paid are actually higher than current average wages.[3] In order to calculate the total amount of public pensions paid to retired civil servants we multiply the individual wage of a current civil servant $w_t^u H_t$ by the number of public sector retirees (the public employees of the previous period) N_{t-1}^u and by the generosity factor Ψ. The government budget constraint can be written as

$$(1 + r_t) B_t + \Delta_{E,t} Y_t + \Delta_{G,t} Y_t + \overbrace{\Delta_{T^r,t} Y_t}^{\text{private pension } T^r} + \overbrace{w_t^u H_t N_t^u}^{\text{public wages}} + \overbrace{\Psi w_t^u H_t N_{t-1}^u}^{\text{public pension } T^u}$$
$$= B_{t+1} + \left(\tau_{L,t}^{ssu} + \tau_{L,t}^u\right) w_t^u H_t N_t^u + \left(\tau_{L,t}^{ssr} + \tau_{L,t}^{ssrf} + \tau_{L,t}^r\right) w_t^r H_t N_t^r + \tau_{K,t} r_t K_t. \tag{8}$$

We assume that government behavior is exogenous, that is labor taxes $\tau_{Lt}^u, \tau_{L,t}^r, \tau_{L,t}^{ssu}, \tau_{L,t}^{ssr}$, a contribution rate to social security paid by the firm $\tau_{L,t}^{ssf}$, capital taxes $\tau_{K,t}$, the fraction spent on education $\Delta_{E,t}$, the fraction spent on increasing the public capital stock $\Delta_{G,t}$, the fraction that goes to retired private sector employees $\Delta_{T,t}$, the parameter of generosity of the public pension system Ψ are all exogenous.

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[3] Since wages in the data are rising with age and in the model wages are constant over the entire period, we will use values of Ψ around 1.5 to capture "integrality".

3 Equilibrium

3.1 Household Problem

We can now state the household problem as

$$\max_{c_t^j, c_{t+1}^j, i_{t+1}^j} \frac{1}{1-\sigma} \left[\left(\left(c_t^j \right)^\rho + \Theta G_t^\rho \right)^{\frac{1}{\rho}} \right]^{1-\sigma} + \beta \frac{1}{1-\sigma} \left[\left(\left(c_{t+1}^j \right)^\rho + \Theta G_{t+1}^\rho \right)^{\frac{1}{\rho}} \right]^{1-\sigma} \quad (9)$$

$$s.t.$$

$$c_t^j + i_t^j \leq \mathcal{I}_t^j \quad (10)$$

$$c_{t+1}^j \leq R_{t+1} i_t^j + \frac{T_{t+1}^j}{N_t^j}$$

where, $j = u$ if it is a public sector worker, $j = r$ if it is a private sector worker, $i_t = k_{t+1} + b_{t+1}$ is the agent's savings in form of physical capital or government bonds,

$$\mathcal{I}_t^j = \left(1 - \tau_{Lt}^{ssj} - \tau_{Lt}^j \right) w_t^j h_t \quad (11)$$

is after-tax wage income of agent j when young, R_{t+1} is the gross rate of return on investments, and T_{t+1}^j is a government transfer received when old.[4] Household j takes the level of the public good G_t as well as all tax rates and prices as given.

3.2 Firm Problem

The firm's problem is standard. Note, however, that the firm takes the level of the public good as given so that the firm only chooses to hire physical capital and human capital. Note also that the government collects a social security tax from the firm at the rate τ_t^{ssrf}. Thus the firm's problem is

$$\max_{(H_t^r, K_t)} F \left(G_t, K_t, H_t^r \right) - \left(1 + \tau_t^{ssrf} \right) w_t^r H_t^r - r_t^k K_t.$$

3.3 Definition of Equilibrium

Given the government policy $\left\{ \tau_{Lt}^r, \tau_{Lt}^u, \tau_{Lt}^{ssr}, \tau_{Lt}^{ssu}, \tau_{Lt}^{ssrf}, \tau_{Kt}, \Delta_{E,t}, \Delta_{K^G,t}, \Delta_{T,t}, w_t^u, N_t^u, \Psi \right\}_{t=0}^{\infty}$, a competitive equilibrium is a collection of sequences of decisions of privately employed households $\left\{ c_t^r, c_{t+1}^r, k_{t+1}^r, b_{t+1}^r, h_{t+1}^r \right\}_{t=0}^{\infty}$, sequences of decisions of publicly employed households $\left\{ c_t^u, c_{t+1}^u, k_{t+1}^u, b_{t+1}^u, h_{t+1}^u \right\}_{t=0}^{\infty}$, sequences of aggregate stocks of private physical capital and private human capital $\left\{ K_t, H_t^r \right\}_{t=0}^{\infty}$, sequences of aggregate stocks of public physical capital and public human capital $\left\{ K_t^G, H_t^u \right\}_{t=0}^{\infty}$, sequences of factor prices $\left\{ w_t^r, r_{t+1}^k, r_{t+1}^b \right\}_{t=0}^{\infty}$ such that

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[4]The wage of an agent of group j is $w_t^j h_t$. We assume that human capital in the public and private sector is the same, only the fraction employed will differ, so that in the aggregate we will have $h_t = H_t$ and the fraction employed by the private sector is $H_t N_t^r$ and the fraction employed by the public sector is $H_t N_t^u$.

(*i*) the sequence $\left\{ c_t^r, c_{t+1}^r, k_{t+1}^r, b_{t+1}^r, h_{t+1}^r \right\}_{t=0}^{\infty}$ solves the maximization problem of the privately employed household (9) with $j = r$ and the sequence $\left\{ c_t^u, c_{t+1}^u, k_{t+1}^u, b_{t+1}^u, h_{t+1}^u \right\}_{t=0}^{\infty}$ solves the maximization problem of the publicly employed household (9) with $j = u$;

(*ii*) factor prices are determined by

$$r_{t+1}^k = \alpha_2 \frac{Y_{t+1}}{K_{t+1}}, \tag{12}$$

$$w_t^r = \frac{\alpha_3}{\left(1 + \tau_t^{ssrf} \right)} \frac{Y_t}{H_t^r} = \frac{\alpha_3}{\left(1 + \tau_t^{ssrf} \right)} \frac{Y_t}{(1 - N_t^u) H_t}, \tag{13}$$

$$R_t = r_t^b = \left(1 - \tau_t^k \right) r_t^k + 1 - \delta^k,$$

(*iii*) capital markets clear, so that aggregate capital stocks are given by

$$I_t = i_t^r (1 - N_t^u) + i_t^u N_t^u = K_{t+1} + B_{t+1},$$
$$H_t = H_t(1 - N_t^u) + H_t N_t^u = H_t^r + H_t^u,$$

(*iv*) commodity markets clear

$$C_{t-1}^r + C_t^r + C_{t-1}^u + C_t^u + K_{t+1} + I_t^G + E_t = Y_t,$$
$$G_t = Y_t^G,$$

(*vi*) and the government budget constraint (8) holds.

4 Solving the Model

We assume that the government indexes public worker wages to private worker wages as following

$$w_t^u = \xi w_t^r. \tag{14}$$

We typically restrict ξ to be sufficient large so that we can assume that the government can directly set the fraction of the workforce N_t^u it wants to employ. Then total human capital employed by the public sector is $H_t^u = H_t N_t^u$. All other workers $(1 - N_t^u)$ will work in the private sector, that is $H_t^r = H_t N_t^r = H_t (1 - N_t^u)$. We justify this by assuming that agents would prefer to work for the government if lifetime income from working in the public sector exceeds lifetime income from working in the private sector.

Households can invest in two assets, physical capital and government issued bonds. In equilibrium both assets have to pay the same rate of return due to non-arbitrage conditions. If we denote $R_{t+1}^k = (1 - \tau_{Kt+1}) r_{t+1}^k + 1 - \delta$ as the after-tax return on capital investment and $R_{t+1}^b = \left(1 + r_{t+1}^b \right)$ as the net return on bonds, we get

$$(1 - \tau_{Kt+1}) r_{t+1}^k + 1 - \delta = 1 + r_{t+1}^b = R_{t+1}.$$

If we assume full depreciation, $\delta = 1$ this becomes

$$(1 - \tau_{Kt+1}) \, r_{t+1}^k = R_{t+1}. \tag{15}$$

After substituting the budget constraints into the utility function we get the following maximization problem for the households:

$$\max_{\{i_t^j\}} \left\{ \begin{array}{c} \frac{1}{1-\sigma} \left[\left(\left(\mathcal{I}_t^j - i_t^j \right)^\rho + \Theta G_t^\rho \right)^{\frac{1}{\rho}} \right]^{1-\sigma} \\ + \beta \frac{1}{1-\sigma} \left[\left(\left(R_{t+1} i_t^j + T_{t+1}^j \right)^\rho + \Theta G_{t+1}^\rho \right)^{\frac{1}{\rho}} \right]^{1-\sigma} \end{array} \right\}. \tag{16}$$

The first order condition for this problem is

$$\left[\left(\mathcal{I}_t^j - i_t^j \right)^\rho + \Theta G_t^\rho \right]^{\frac{1-\sigma}{\rho}-1} \left(\mathcal{I}_t^j - i_t^j \right)^{\rho-1}$$

$$= \beta R_{t+1} \left[\left(R_{t+1} i_t^j + \frac{T_{t+1}^j}{N^j} \right)^\rho + \Theta G_{t+1}^\rho \right]^{\frac{1-\sigma}{\rho}-1} \left(R_{t+1} i_t^j + \frac{T_{t+1}^j}{N^j} \right)^{\rho-1}.$$

We cannot get any closed form solution for i_t^j unless we make some more assumptions about parameters ρ and σ.

4.1 Cobb-Douglas within Period ($\rho = 0$) and no Government Debt

When $\rho \to 0$ then expression (9) reduces to a Cobb-Douglas form and after substituting the budget constraint this problem becomes

$$\max_{\{i_t^j\}} \left\{ \frac{1}{1-\sigma} \left[\left(\mathcal{I}_t^j - i_t^j \right)^\theta G_t^{1-\theta} \right]^{1-\sigma} + \beta \frac{1}{1-\sigma} \left[\left(R_{t+1} i_t^j + \frac{T_{t+1}^j}{N_t^j} \right)^\theta G_{t+1}^{1-\theta} \right]^{1-\sigma} \right\},$$

where $\theta \equiv \frac{1}{1+\Theta}$. We can now derive first order conditions and get

$$\left(\mathcal{I}_t^j - i_t^j \right)^{\theta(1-\sigma)-1} = \beta R_{t+1} \left(R_{t+1} i_t^j + \frac{T_{t+1}^j}{N_t^j} \right)^{\theta(1-\sigma)-1} \left(\frac{G_{t+1}}{G_t} \right)^{(1-\theta)(1-\sigma)}.$$

The optimal decision rules for savings and consumption are

$$i_t^j = \frac{\mathcal{I}_t^j - \mathcal{C}_t \frac{T_{t+1}^j}{N_t^j}}{1 + \mathcal{C}_t R_{t+1}},$$

$$c_t^j = \frac{\mathcal{C}_t R_{t+1} \mathcal{I}_t^j + \mathcal{C}_t \frac{T_{t+1}^j}{N_t^j}}{1 + \mathcal{C}_t R_{t+1}},$$

$$c_{t+1}^j = \frac{R_{t+1} \mathcal{I}_t^j + \frac{T_{t+1}^j}{N_t^j}}{1 + \mathcal{C}_t R_{t+1}},$$

where, $\mathcal{C}_t = \left[\beta R_{t+1}\left(\frac{G_{t+1}}{G_t}\right)^{(1-\theta)(1-\sigma)}\right]^{\frac{1}{\theta(1-\sigma)-1}}$. We now impose the steady state. The expressions for savings by private and public sector workers become

$$i^r = \frac{(1-\tau_L^{ssr}-\tau_L)\frac{\alpha_3}{\left(1+\tau_t^{ssrf}\right)(1-N^u)}Y - \mathcal{C}\frac{\Delta_{Tr}}{1-N^u}Y}{1+\mathcal{C}R},$$

$$i^u = \frac{(1-\tau_L^{ssu}-\tau_L^u)\xi\frac{\alpha_3}{\left(1+\tau_t^{ssrf}\right)(1-N^u)}Y - \mathcal{C}\Psi\xi\frac{\alpha_3}{\left(1+\tau_t^{ssrf}\right)(1-N^u)}Y}{1+\mathcal{C}R}.$$

Adding private and public investment we get an expression for aggregate capital (assuming no public debt)

$$
\begin{aligned}
K &= N^u i^u + (1-N^u)i^r \\
&= \frac{Y}{1+\mathcal{C}R}\left\{\left(\frac{N^u}{1-N^u}\right)\frac{\xi\alpha_3}{1+\tau_t^{ssrf}}\left[(1-\tau_L^{ssu}-\tau_L^u)-\mathcal{C}\Psi\right]+(1-\tau_L^{ssr}-\tau_L^r)\frac{\alpha_3}{1+\tau_t^{ssrf}}-\mathcal{C}\Delta_{Tr}\right\}.
\end{aligned}
$$

We next use the expression $R = \alpha_2(1-\tau_K)\frac{Y}{K}$ from the firm's first order condition (12) and replace the left hand side to get

$$
\alpha_2(1-\tau_K)\frac{1}{R} = \frac{1}{1+\mathcal{C}R}\left\{
\begin{array}{c}
\frac{N^u}{1-N^u}\xi\frac{\alpha_3}{1+\tau_t^{ssrf}}\left[(1-\tau_L^{ssu}-\tau_L^u)-\mathcal{C}\Psi\right] \\
+(1-\tau_L^{ssr}-\tau_L^r)\frac{\alpha_3}{1+\tau_t^{ssrf}}-\mathcal{C}\Delta_{Tr}
\end{array}
\right\}, \qquad (17)
$$

where we know that $\mathcal{C} = [\beta R]^{\frac{1}{\theta(1-\sigma)-1}}$ is a function of steady state R. Then we solve this equation for R. We can now calculate the remaining steady state values.

From (1) we get an expression for output in terms of human capital

$$h_{t+1} = B\left[(H_t^{ue})^{\eta_1}+\chi_1 E_t^{\eta_1}\right]^{\frac{\gamma_1}{\eta_1}}h_t^{\gamma_2}.$$

In the steady state this becomes

$$\left(\frac{H^{1-\gamma_2}}{B}\right)^{\eta_1/\gamma_1} = (aN^cH)^{\eta_1}+\chi_1(\Delta_E Y)_t^{\eta_1},$$

which can be solved for[5]

$$\bar{Y}(H) = \frac{1}{\Delta E}\left[\frac{\left(\frac{H^{1-\gamma_2}}{B}\right)^{\eta_1/\gamma_1}-(aN^uH)^{\eta_1}}{\chi_1}\right]^{\frac{1}{\eta_1}}. \qquad (18)$$

---

[5] Note, due to this formulation we can only solve for cases where $\eta_1 \geq 0$, since then $\left[\left(\frac{H^{1-\gamma_2}}{B}\right)^{\eta_1/\gamma_1}-(aN^uH)^{\eta_1}\right] \geq 0$. If η_1 becomes negative, that is H^{ue} and E are complements, the term $\left[\left(\frac{H^{1-\gamma_2}}{B}\right)^{\eta_1/\gamma_1}-(aN^uH)^{\eta_1}\right]$ becomes negative and solutions do not exist.

Given R we have

$$\bar{K}(H,R) = \frac{(1-\tau_K)\,\alpha_2}{R}\bar{Y}(H).$$

(19)

Since at steady state $K_{t+1}^G = K_t^G = K^G$, and using (5) in the law of motion for capital (3) we have

$$K^G = \frac{\Delta_G}{\delta_{K^G}}\bar{Y}(H),$$

and using (18) to substitute for output we have

$$K^G = \frac{\Delta_G}{\delta_{K^G}}\frac{1}{\Delta E}\left[\frac{\left(\frac{H^{1-\gamma_2}}{B}\right)^{\eta_1/\gamma_1} - (aN^cH)^{\eta_1}}{\chi_1}\right]^{\frac{1}{\eta_1}}.$$

(20)

We use (20) in the production function for the public good (2) and get

$$\bar{G}(H) \equiv G = Z\left[\left(\frac{\Delta_G}{\delta_{K^G}}\frac{1}{\Delta E}\left[\frac{\left(\frac{H^{1-\gamma_2}}{B}\right)^{\eta_1/\gamma_1} - (aN^cH)^{\eta_1}}{\chi_1}\right]^{\frac{1}{\eta_1}}\right)^{\eta_2} + \chi_2\left[(1-a)\,N^uH\right]^{\eta_2}\right]^{1/\eta_2},$$

(21)

that expresses the output of the public good G as a function of human capital H. Then the steady state output is given by

$$Y = A\left[\bar{G}(H)\right]^{\alpha_1}\left[\bar{K}(H,R)\right]^{\alpha_2}\left[\bar{H}(1-N^u)\right]^{\alpha_3}.$$

(22)

The six steady state variables H, K^g, G, K, Y, R are determined by the six equations $(17),(18),(20),(21),(19),(22)$.

4.2 The Case of Government Debt with Cobb-Douglas within Period $(\rho = 0)$ Utility Function

Introducing government bonds does not change the household's first order conditions. However, when aggregating over all households we have to include bonds as the additional asset, so that total bonds and capital is

$$
\begin{aligned}
K + B &= N^u i^u + (1 - N^u)\,i^r \\
&= \frac{Y}{1+CR}\left\{\begin{array}{c}\left(\frac{N^u}{1-N^u}\right)\frac{\xi\alpha_3}{1+\tau_t^{ssrf}}\left[(1-\tau_L^{ssu}-\tau_L^u)-C\Psi\right] \\ + (1-\tau_L^{ssr}-\tau_L^r)\frac{\alpha_3}{1+\tau_t^{ssrf}} - C\Delta_{T^r}\end{array}\right\}.
\end{aligned}
$$

We can express $K = \alpha_2\,(1-\tau_K)\frac{Y}{R}$ and $B = \Delta_B Y$ where Δ_B is the debt level set exogenously by the government. Making the substitutions we get

$$\Delta_B + \alpha_2\,(1-\tau_K)\frac{1}{R} = \frac{1}{1+CR}\left\{\begin{array}{c}\frac{N^u}{1-N^u}\xi\frac{\alpha_3}{1+\tau_t^{ssrf}}\left[(1-\tau_L^{ssu}-\tau_L^u)-C\Psi\right] \\ + (1-\tau_L^{ssr}-\tau_L^r)\frac{\alpha_3}{1+\tau_t^{ssrf}} - C\Delta_{T^r}\end{array}\right\}.$$

10

where we know that $\mathcal{C} = [\beta R]^{\frac{1}{\theta(1-\sigma)-1}}$ is a function of steady state R. Simplifying and assuming that $\tau_L^u = \tau_L^r$ we get

$$\Delta_B + \alpha_2 \left(1 - \tau_K\right) \frac{1}{R} = \frac{1}{1 + \mathcal{C}R} \left\{ \begin{array}{c} \frac{\alpha_3}{1+\tau_t^{ssrf}} \left(1 - \tau_L^{ssu} - \tau_L^u\right) \left(1 + \frac{N^u}{1-N^u}\xi\right) \\ - \left(\frac{N^u}{1-N^u}\xi \frac{\alpha_3}{1+\tau_t^{ssrf}}\Psi + \Delta_{T^r}\right)\mathcal{C} \end{array} \right\}. \tag{23}$$

Next we use the government budget constraint in the steady state

$$\frac{\alpha_3}{1+\tau^{ssrf}}\tau_L\left(\xi\frac{N^u}{1-N^u} + 1\right) + \tau_K\alpha_2$$
$$= (R-1)\Delta_B + [\Delta_E + \Delta_G] + \xi\frac{\alpha_3}{1+\tau^{ssrf}}\frac{N^u}{1-N^u} + \Delta_{T^r} \tag{24}$$
$$+ \Psi\xi\frac{\alpha_3}{1+\tau^{ssrf}}\frac{N^u}{1-N^u} - \frac{\alpha_3}{1+\tau^{ssrf}}\left(\xi\frac{N^u}{1-N^u}\tau_L^{ssu} + \tau_L^{ssr} + \tau_L^{ssf}\right).$$

Equations (23) and (24) determine the steady state interest rate R and one endogenized government variable. This government variable can either be a tax rate or one of the four government policy variables $(\Delta_B, \Delta_E, \Delta_G, \Delta_T)$ that can adjust to satisfy the government budget constraint. We can now calculate the remaining six steady state variables H, K^g, G, K, Y using expressions $(18), (20), (21), (19), (22)$.

5   Data and Calibration

In this section we calibrate the model to the economy of Brazil. Table 1 reports the preference and technology parameters. The preference parameters are perhaps non controversial. The discount factor is a standard one year estimate. Since one period is roughly 30 years long, we scale the discount factor accordingly. The parameter $\theta = 0.95$, so that the weight consumers place in their utility function on publicly provided goods is small.

Note that for the parameters for the consumption goods technology we are imposing constant returns to scale in the two private factors. Note also that capital's share of 0.5 is large relative to the estimates reported in Gollin (2002), but this relatively large parameter value is consistent with estimates for Brazil in Elias (1992) and with values used by Barro and Sala-i-Martin (2004).

The value for the elasticity of output with respect to infrastructure capital, α_1 lies between estimates by Holtz-Eakin (1994) and Ai and Cassou (1995). For the parameter η_2 in the government technology we use a value of 0.5 as a benchmark, but we will use other parameter values in our sensitivity analysis. We are not aware of any estimates of η_2. We set the parameter χ_2, which measures the labor intensity of this technology, equal to unity.

We use a value of 0.1 for the learning elasticity with respect to public expenditure. This is consistent with an estimate by Card and Krueger (1992) and values used by Fernandez and Rogerson (1996) and by Rangazas (2000). We are also not aware of any estimates of η_1. We thus use $\eta_1 = 0.5$ as a benchmark and perform sensitivity analysis

using a variety of values for η_1. The productivity parameters A, B, Z are chosen so that for the benchmark, output is equal to 100.

The government budget constraint becomes

$$
\overbrace{\Delta_{B,t}Y_t}^{B_{t+1} \text{ new debt}} + \overbrace{\left[\frac{\alpha_3}{1+\tau_t^{ssrf}}\left(\tau_{L,t}^u\xi\frac{N^c}{1-N_t^u}+\tau_{L,t}^r\right)+\tau_{K,t}\alpha_2\right]Y_t}^{\text{tax revenue excl. ear market social sec. contribution rates (27\%)}}
$$

$$
= \overbrace{R_t\Delta_{B,t-1}Y_{t-1}}^{R_tB_t \text{ debt service}} + \overbrace{[\Delta_{E,t}+\Delta_{G,t}]}^{\text{Education + Investments (5\%)}}Y_t + \overbrace{\xi\frac{\alpha_3}{1+\tau_t^{ssrf}}\frac{N_t^u}{1-N_t^u}Y_t}^{\text{public wages (10\%)}}
$$

$$
+ \left[\overbrace{\Delta_{T^r,t}}^{\text{private pension } T^r} + \overbrace{\Psi\xi\frac{\alpha_3}{1+\tau_t^{ssrf}}\frac{N_t^u}{1-N_t^u}}^{\text{public pension } T^u} - \overbrace{\frac{\alpha_3}{1+\tau_t^{ssrf}}\left(\xi\frac{N_t^u}{1-N_t^u}\tau_{L,t}^{ssu}+\tau_{L,t}^{ssr}+\tau_{L,t}^{ssf}\right)}^{\text{contribution rate to pension}}\right]Y_t.
$$

with net pension balance (+5.5%) spanning the public pension and contribution rate terms.

Table 2 reports the specific public policy parameters we use for the calibration exercise. The top panel in table 2 contains data on government expenditures, the second panel contains data on tax rates, while the third panel contains data on the relative size of the public and private labor force.

We set public expenditures on education exclusive of teacher salaries equal to 1% of GDP. According to The economist (Feb. 20, 2003), total public education expenditure in Brazil in 1999 was 5.1% of GDP. We subtract 25% which is spent on tertiary education, since only 2% of all students attend college, leaving us with 3.825% of GDP. We assume that about 75% of that is spent on salaries of teachers and administrators, leaving about 1% of GDP for buildings, computers, textbooks, etc.

According to (Calderon, Easterly and Serven, 2003, table 4.1), investment in infrastructure is about 1% of GDP. Wages to current civil servants amount to about 3.5% of GDP. According to the Ministerio de Previdencia e Assistencia Social of Brazil transfers to the old in the private sector amount to 6.6% of GDP, while public sector pensions amount to about 5% of GDP (see Souza et al. (2004)).

In our model public sector wages are higher than private sector wages by a factor ξ. We do not have data on ξ and use $\xi = 1.28$. This may be conservative.

In order to model integrality, we need a measure of wages in the last years of one's career relative to wages averaged over the entire career. We set this number $\Psi = 1.5$.

Basically all of our data on tax rates come from Souza et al. (2004). The social security tax rate levied from both public sector workers is 11% of wage income. In the private sector employers add 10% of the wage bill to the pension fund.[6]

The labor income tax rate for both types of employees net of social security contributions is 9%. The capital tax rate is 9% resulting in tax revenue as a fraction of GDP of

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[6]Since our model does not account for all government expenditure, our tax rate on employers is lower than the 20% reported by (Souza et al., 2004, p. 5).

27% excluding social security contribution rates. Once we include debt financing to the government budget constraint, the capital tax rate is considerably higher and reaches 53%.

According to the Social Security Ministry of Brazil in 2002 there are about 5.2 million civil servants in Brazil; this constitutes 6% out of a labor force of about 85 million. According to the Global Education Database, there are approximately 2.17 million teachers in Brazil. Thus we set $a = 42\%$.

6 Policy Experiments

Initially we assume that the government budget is balanced every period, that is the government does not issue debt. For the following policy experiments we set $\tau_{L,t}^u = \tau_{L,t}^r$, so that the government budget constraint reduces to

$$\frac{\alpha_3}{1+\tau_t^{ssrf}}\tau_{L,t}\left(\xi\frac{N_t^u}{1-N_t^u}+1\right)+\tau_{K,t}\alpha_2$$
$$=\Delta_{E,t}+\Delta_{G,t}+\xi\frac{\alpha_3}{1+\tau_t^{ssrf}}\frac{N_t^u}{1-N_t^u}+\Delta_{T^r,t}+\Psi\xi\frac{\alpha_3}{1+\tau_t^{ssrf}}\frac{N_t^u}{1-N_t^u}-\frac{\alpha_3}{1+\tau_t^{ssrf}}\left(\xi\frac{N_t^u}{1-N_t^u}\tau_{L,t}^{ssu}+\tau_{L,t}^{ssr}+\tau_{L,t}^{ssf}\right).$$

6.1 Public Pensions (Ψ) vs. Private Pensions (Δ_{T^r})

In the first policy experiment we use the extra revenue from making public sector pensions less generous to make private sector social security payments more generous. This policy experiment is motivated by the attempts of Constitutional Amendment 40 to provide for more equity between the public and private sector pension system. (see (Souza et al., 2004, p. 1)). We perform this reallocation in such a way that government's share of GDP remains constant. The results from this experiment are illustrated in figure 1.

The effect of shifting public funds from public pensions to private pensions on steady state income is nil. This result is not that surprising since this policy is just a reshuffling of expenditures in the government budget constraint and public and private sector have the same propensity to save.

The dashed line indicates the direct effect of making public sector pensions less generous without using the extra funds on the private pensions. This direct effect of reducing generosity of public pensions on output, total saving and savings by sector is positive.

First, public sector workers have a bigger incentive to save as their pensions are reduced. The increase in savings by civil servants causes the interest rate to decrease which causes private sector savings to fall and aggregate output to increase which, through the wage rate, causes private sector savings to rise. The second effect dominates the first effect.

6.2 Public Pensions (Φ) vs. Education (Δ_E)

In the second experiment we use the extra government revenue from making public pensions less generous to finance extra public education expenditures. According to figure 2, this policy reform raises steady state income. There are two effects, a direct

effect on savings and an opportunity cost effect of being able to use the released public funds for some other purpose, in this case more material inputs into education. The intuition is clear: Decreasing Ψ increases public sector savings, which in turn increases steady state capital and output. This direct effect indicated by the dashed line is small. Using the extra revenue to fund higher education increases the steady state level of human capital, hence the rate of return on saving, the capital stock and steady state GDP. This effect is large. Reducing Ψ from 1.5 to 1.25 increases steady state GDP by more than 10%.

Of course the size of these effects depends upon the technology parameters, especially on the size of γ_1, the elasticity of learning output with respect to public expenditures. We summarize the results of this sensitivity analysis in table 3 where we allow γ_1 to vary from 0.05 to 0.15. The effects on steady state income from reducing Ψ from 1.5 to 1.25 vary from almost 6% to over 18%.

In table 4 we illustrate how shifting public funds from public sector pensions to education depends upon η_1, the (inverse of the) elasticity of substitution in the education production function. We see from table 4 that our results are relatively sensitive to sizeable changes in η_1. As η_1 varies from 0.00 to 1 the effect of reducing Ψ from 1.50 to 1.25 varies between 3.87% and 15.95%.

6.3   Public Pensions (Ψ) vs. Public Investment (Δ_G)

In the third experiment the extra revenue from cutting public sector pensions is used to invest in public sector capital. The results are illustrated in figure 3. Qualitatively these results in figure 3 are the same as those in figure 2. The only difference is quantitative. For the base line parameters the effects from using the freed-up resources for public investment generates larger effects on steady state GDP than using these resources for public education. Reducing Ψ from 1.50 to 1.25 causes GDP to increase by approximately 17%. The corresponding increase when these funds are used for education is "only" 12%.

In table 5 we show how sensitive the results are with respect to changes in α_1, the elasticity of output with respect to public capital. We allow α_1 to vary from 0.05 to 0.15. For this range of parameter values reducing Ψ from 1.5 to 1.25 increases steady state output by almost 8% and about 30%. Thus, for realistic parameter values the effects of reallocating funds to public investment can be enormous.

In table 6 we again compare how shifting public funds from public sector pensions into public sector capital depending on η_2, the elasticity of substitution in the public production function. The effects on steady state income of using the extra revenue from public sector pensions for investment in infrastructure are quite sensitive to changes in η_2. As η_2 declines, the effect on output declines as well. If $\eta_2 = -1$, reducing Ψ from 1.50 to 1.25 increases steady state output by "only" 2%.

6.4 Public Pensions (Ψ) vs. Adjustments in Labor Taxes (τ_L) and Capital Taxes (τ_K)

The fourth and fifth experiment describes the effects of cutting public sector pensions and subsequent decreases in either labor taxes τ_L or capital taxes τ_K. Figures 4 and 5 summarize the results. Decreasing the labor tax generates much larger effects on steady state income than decreasing the capital tax.

6.5 Comparison of Policies

The question arises whether the extra revenue from decreasing public sector pensions is more beneficially allocated to public capital investment or to public education. The answer to this question naturally depends upon the productivity parameters $\alpha_1, \gamma_1, \eta_1$ and η_2.

Tables 7 and 8 show the relative steady state output effect from using the extra revenue for education rather than infrastructure. In table 7 negative numbers indicate that using the freed-up resources for infrastructure investment generates higher effects on GDP. It is interesting that basically for the whole range of $\gamma_1 \in [0.05, 0.15]$ investment in public capital dominates investment in education. The same holds true for the range of $\alpha_1 \in [0.05, 0.15]$ in table 8. This result obtains most likely because in our calibrations as in the data public investment in infrastructure is low (1% of GDP) relative to the optimal level.

Once we change the underlying elasticity parameter η_2 to -0.25 we get a range for γ_1 and α_1 where investment in education will dominate investment in public capital. This is illustrated in tables 9 and 10. This is due to the fact that a negative η_2 changes the relation of public sector investments and investments in education from being substitutes to becoming complements. Increases in γ_1 will now not only increase output through the direct channel of increases in human capital (via increased productivity of educational expenses) but also through the indirect channel of increases in output of the public good. The complementarity enhances the effectiveness of public education versus investments into the public capital.

6.6 Government Debt

We now allow for government debt and again equate public and private wage taxes. We then have the following government budget constraint:

$$\frac{\alpha_3}{1+\tau^{ssrf}}\tau_L\left(\xi\frac{N^u}{1-N^u}+1\right)+\tau_K\alpha_2$$
$$=(R-1)\,\Delta_B+\Delta_E+\Delta_G+\xi\frac{\alpha_3}{1+\tau^{ssrf}}\frac{N^u}{1-N^u}+\Delta_{T^r}$$
$$+\Psi\xi\frac{\alpha_3}{1+\tau^{ssrf}}\frac{N^u}{1-N^u}-\frac{\alpha_3}{1+\tau^{ssrf}}\left(\xi\frac{N^u}{1-N^u}\tau_L^{ssu}+\tau_L^{ssr}+\tau_L^{ssf}\right).$$

We interpret $(R-1)\,\Delta_B$ as the interest level on outstanding debt (government bonds) that the government has to service in the steady state.

6.6.1 Experiment 1: Δ_B adjusts

We perform the following policy experiment: We decrease the generosity of the public sector pensions, i.e. Ψ goes down. At the same time we let Δ_B adjust to clear the government budget constraint holding all other government choice variables fixed. Then we see directly from the government budget constraint that Ψ and Δ_B are negatively related.

When government cuts public pensions it has more funds available to service the interest payments of a higher debt level. With lower payments into public pensions, the government can sustain a higher debt level in the steady state.

On the other hand if government would increase the generosity of public pensions, its steady state expenditure goes up. Therefore, government cannot afford high interest payments on outstanding debt and it therefore has to reduce the amount of debt (compare figure 6).

6.6.2 Experiment 2: τ^L or τ^K adjusts

In this policy experiment we decrease the generosity of public pensions Ψ and let the labor tax τ_L or the capital tax rate τ_K adjust. Figure 7 and figure 8 report the respective effects. When Ψ drops from 1.5 to 1.25, and τ_L adjusts downwards, then output increases by 40%. This effect is very large. There are several effects at work here; all effects go in the same direction.

First, there is an income effect due to the lower labor tax rate on the young. Since the young are the only savers in the model, increasing their after tax income increases savings, capital accumulation and steady state income. This effect is reinforced by a simultaneous drop in the real interest rate, which lowers debt service and allows a further reduction in the labor income tax rate. This additional reduction in the income tax rate (which is much smaller in the case when the government does not issue debt as in figure 4) further stimulates capital accumulation and increases steady state income. Notice in figure 7 that for large enough reductions in Ψ the labor tax rate actually becomes negative, i.e. saving is subsidized. There is also the increased savings of civil servants due to the reduction in their expected future pension payments. These effects together cause a massive effect on steady state output.[7]

An adjustment of τ_K has a minor effect on output of roughly 2% when Ψ declines from 1.5 to 1.25 (see figure 8).

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[7]In addition to the steady state equilibrium depicted in figure 7 there is a second type of steady state equilibrium in which a decrease of Ψ causes the interest rate R and the labor tax rate τ_L to rise. An increase in R is then consistent with lower savings, lower investment and hence higher marginal product of capital such that the government budget constraint is still satisfied. All these together result in a decrease of steady state output.

7 Conclusion

In this paper we have used an overlapping generations model to assess the effects of public pension reform on capital accumulation. We have calibrated the model to Brazil. We found (*i*) The direct effects of pension reform through savings of civil servants are small. (*ii*) Shifting government funds from public to private sector pensions leaves steady state GDP unaffected. (*iii*) The indirect effects of reduction of public pensions by freeing resources for public education or investment in public capital are large.

In this paper we have concentrated on one particular channel of how public sector pension reform might influence capital accumulation. Other channels might be: (*i*) The generosity of public sector pensions influences workers' retirement decisions, which in turn has an effect on GDP. (*ii*) The generosity of public sector pensions relative to pensions in the private sector will influence how workers will be allocated across both sectors, which in turn will influence GDP. This would require the introduction of heterogenous agents who make idiosyncratic investment choices into their human capital. This extended framework would allow us to investigate changes in the quality of the public sector labor force, given a specific worker compensation package (wages plus pension plan).

In our model the publicly produced service was made available to all firms and households at a zero price. While this might be a useful assumption for the provision of infrastructure like roads and highways, it clearly does not cover all relevant cases. When governments produce goods like telecommunication services or electricity, they typically charge for these goods/services. Prices charged need not bear any particular relationship to marginal or average costs. This will impact the government budget constraint.

Finally, we restricted our analysis on steady state equilibria. A deeper analysis of policy reform will require emphasis on transition paths from one policy regime to another. We leave these issues for future research.

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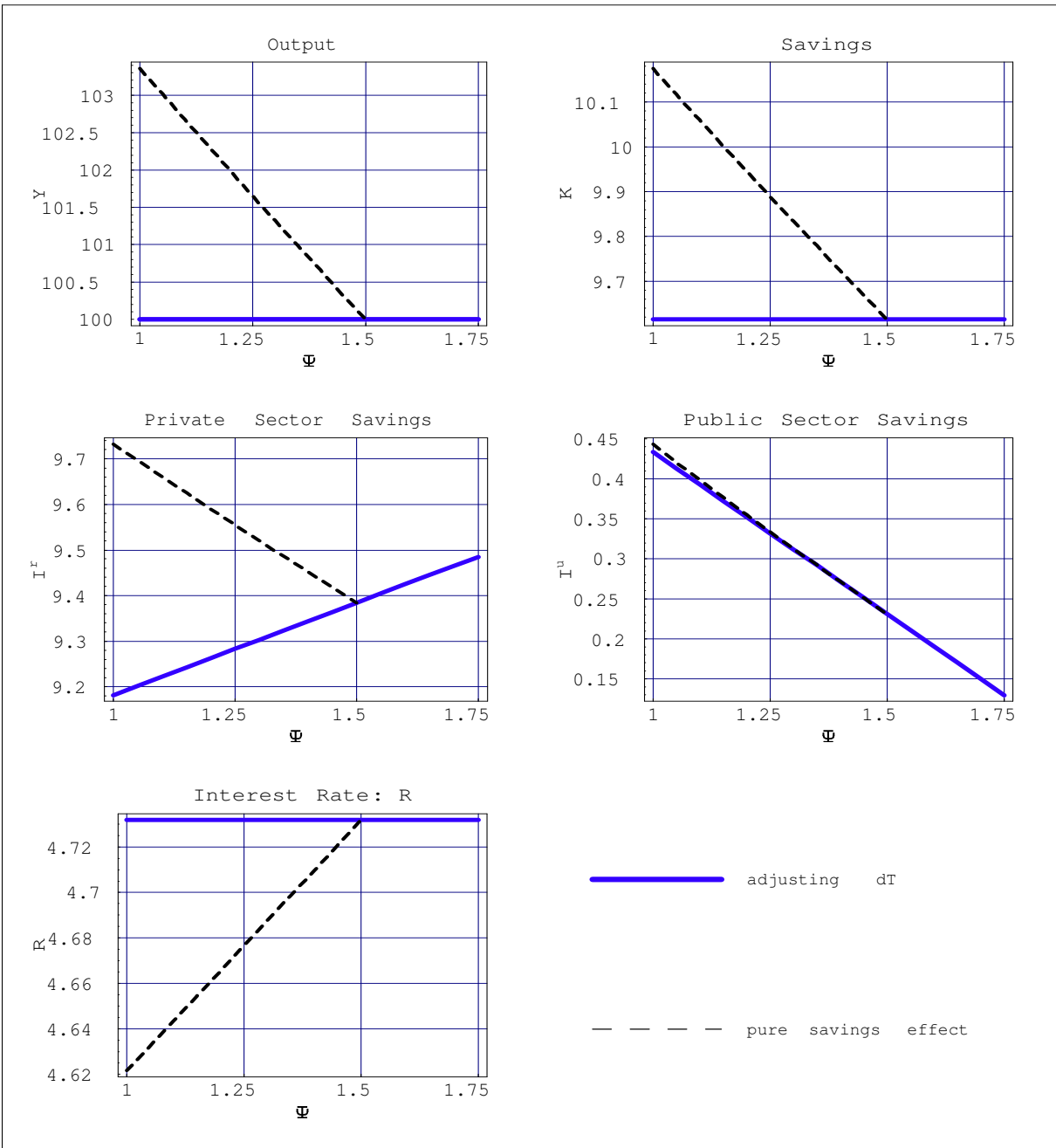
Figure 1: Effect of decreasing public sector pensions Ψ and increasing private sector pensions Δ_T
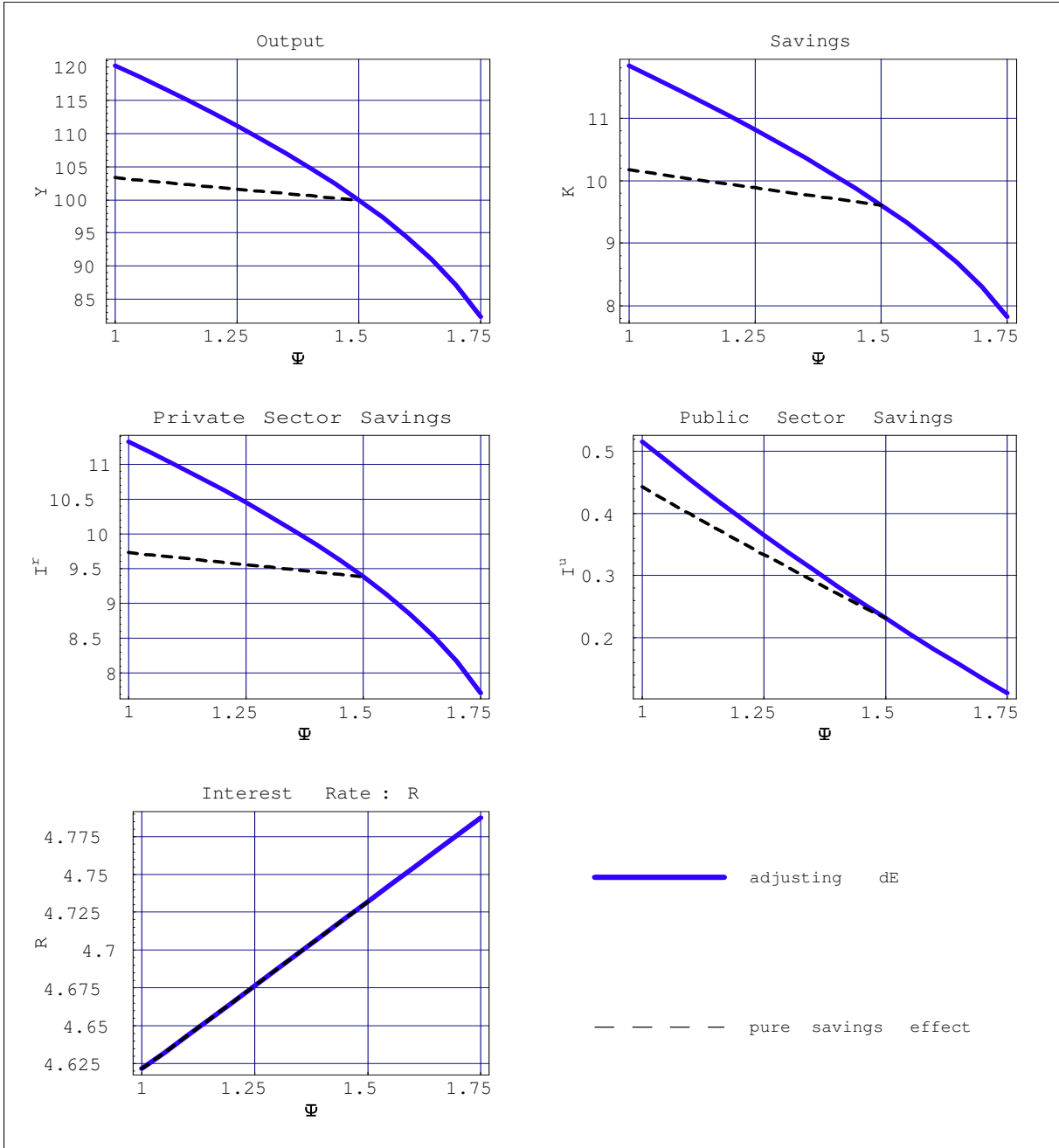
Figure 2: Effect of decreasing public sector pensions Ψ and increasing public education expenditures Δ_E
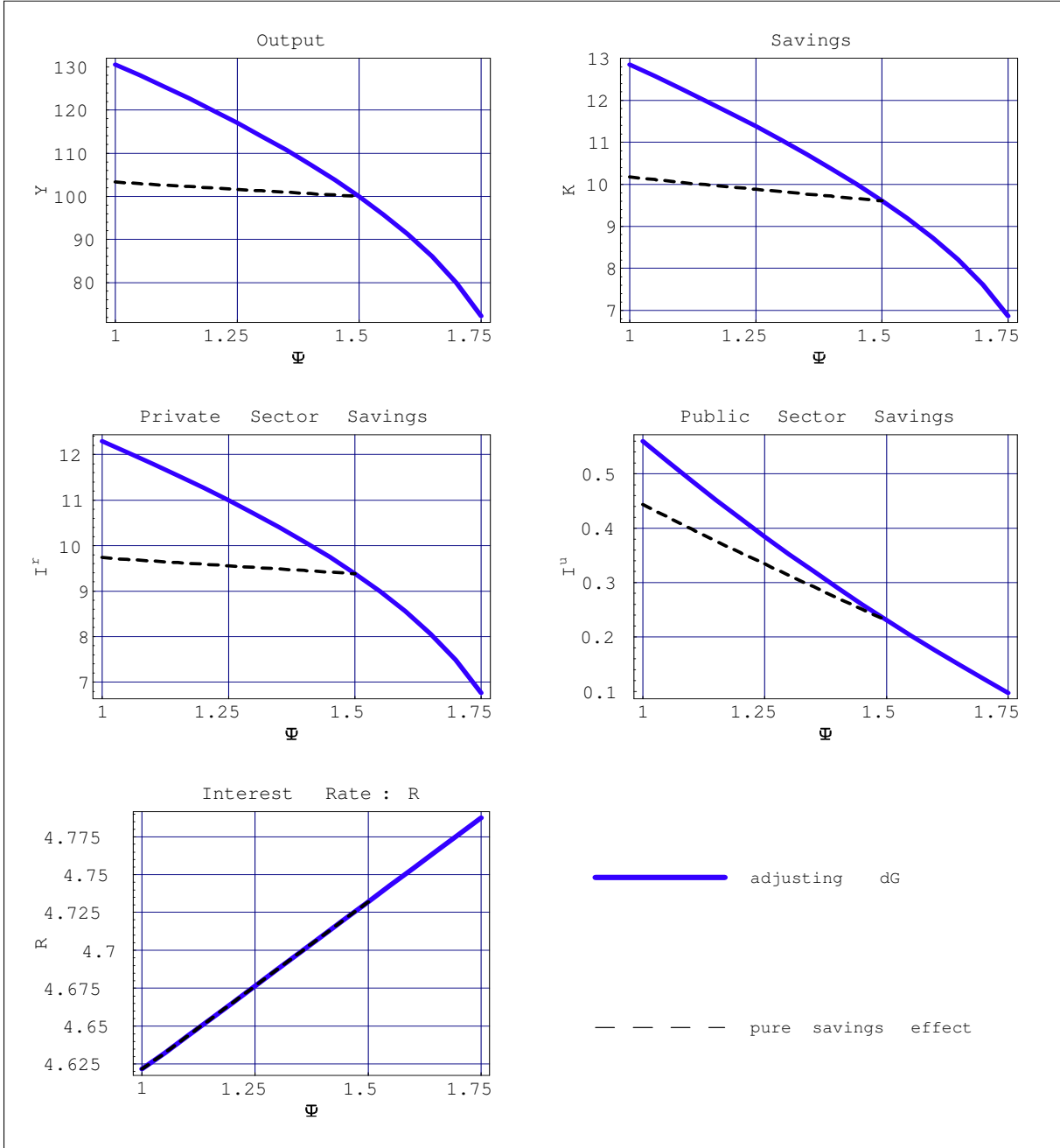
Figure 3: Effect of decreasing public sector pensions Ψ and increasing public capital investments Δ_G
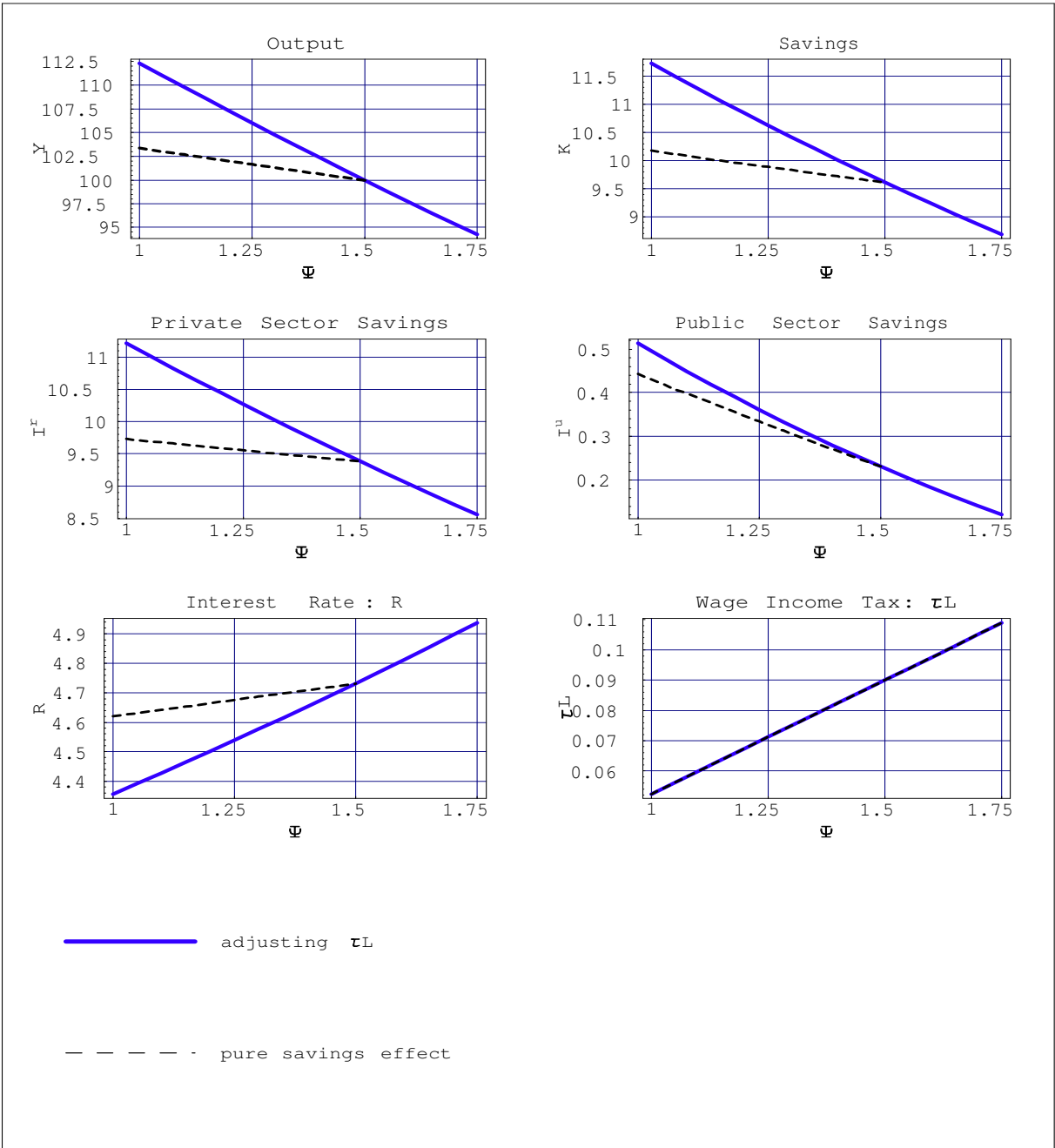
Figure 4: Effect of decreasing public sector pensions Ψ and adjusting labor tax τ_L
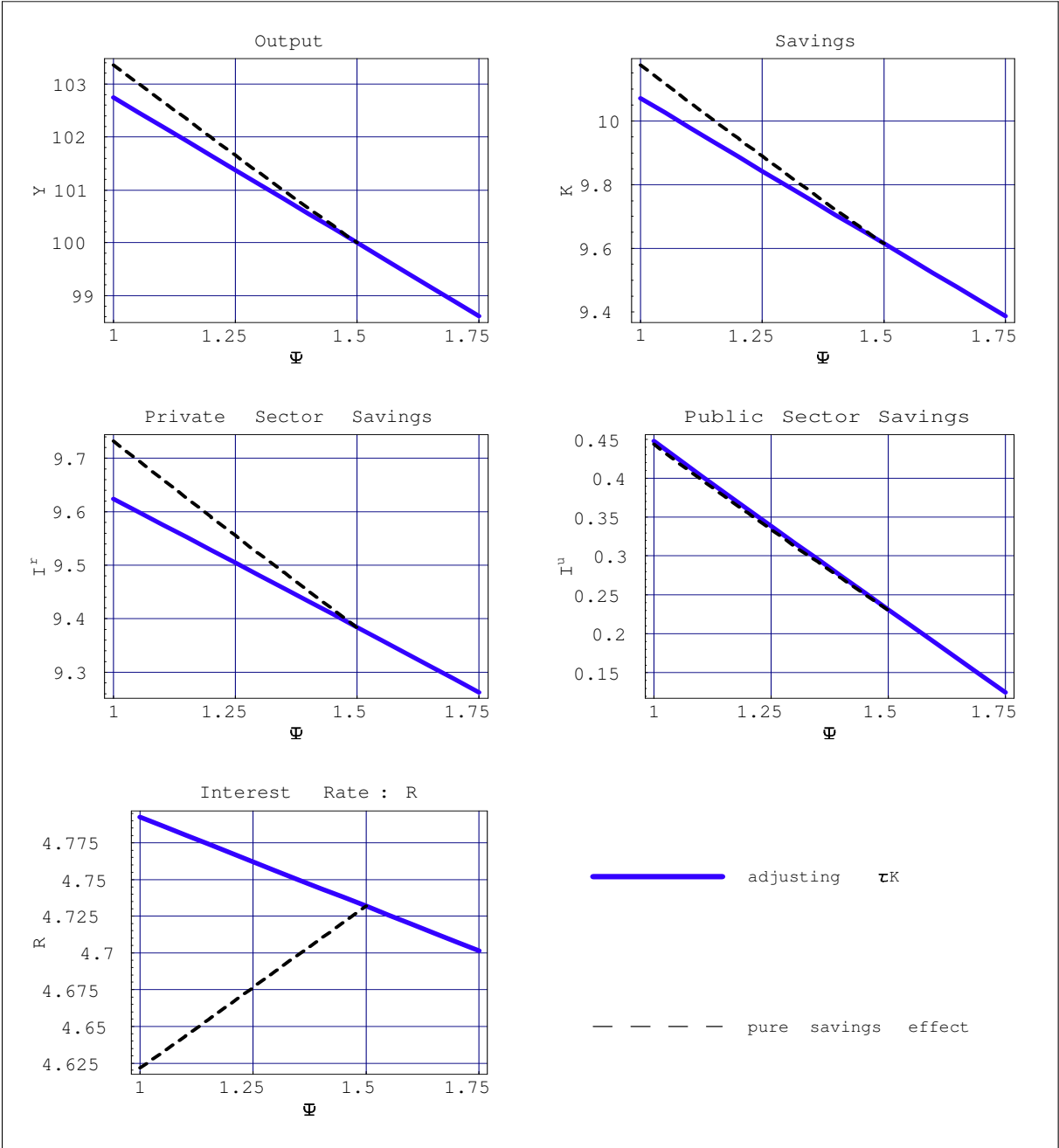
Figure 5: Effect of decreasing public sector pensions Ψ and adjusting capital tax τ_K
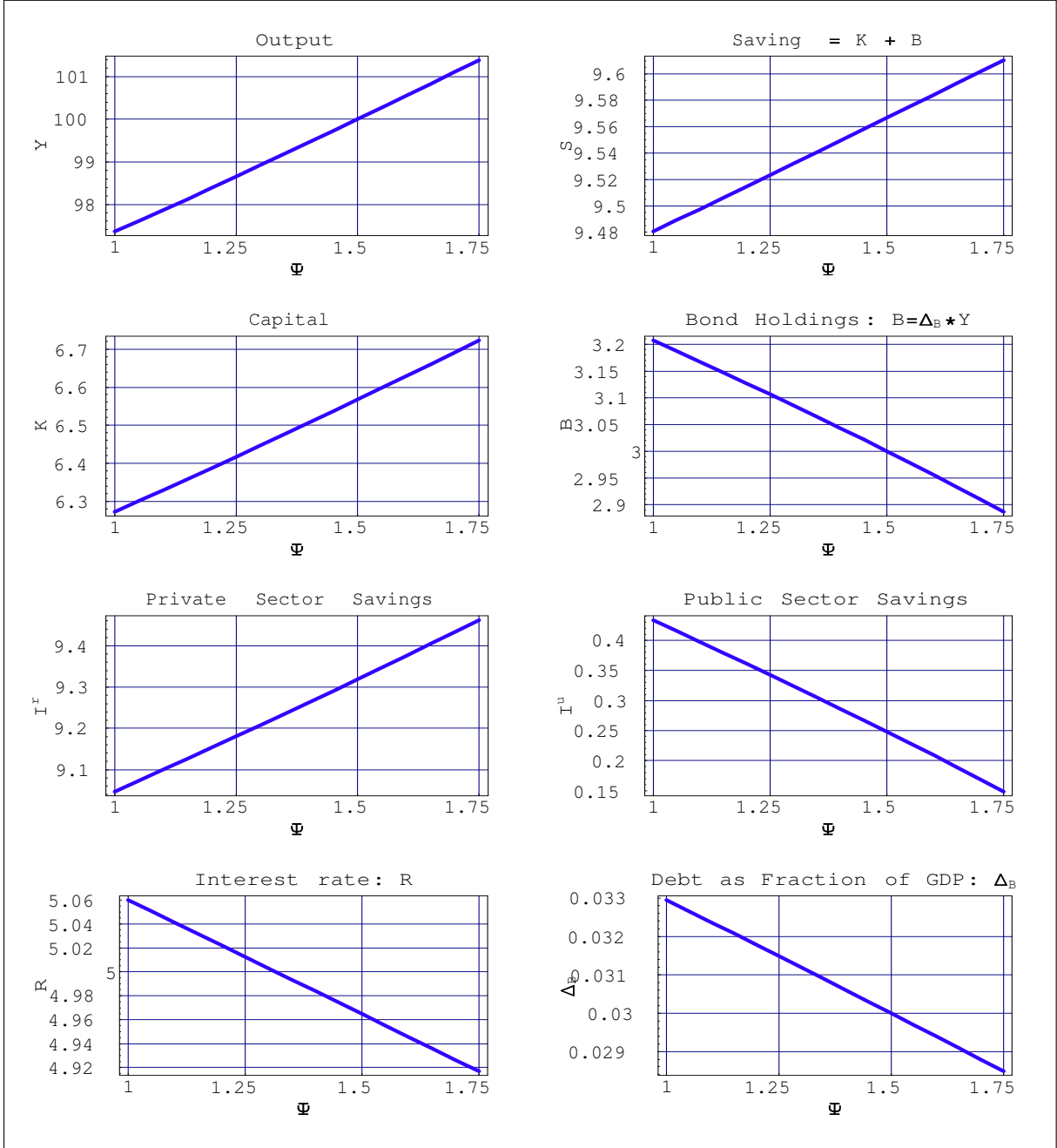
Figure 6: Effect of decreasing public sector pensions Ψ and increasing government debt Δ_B
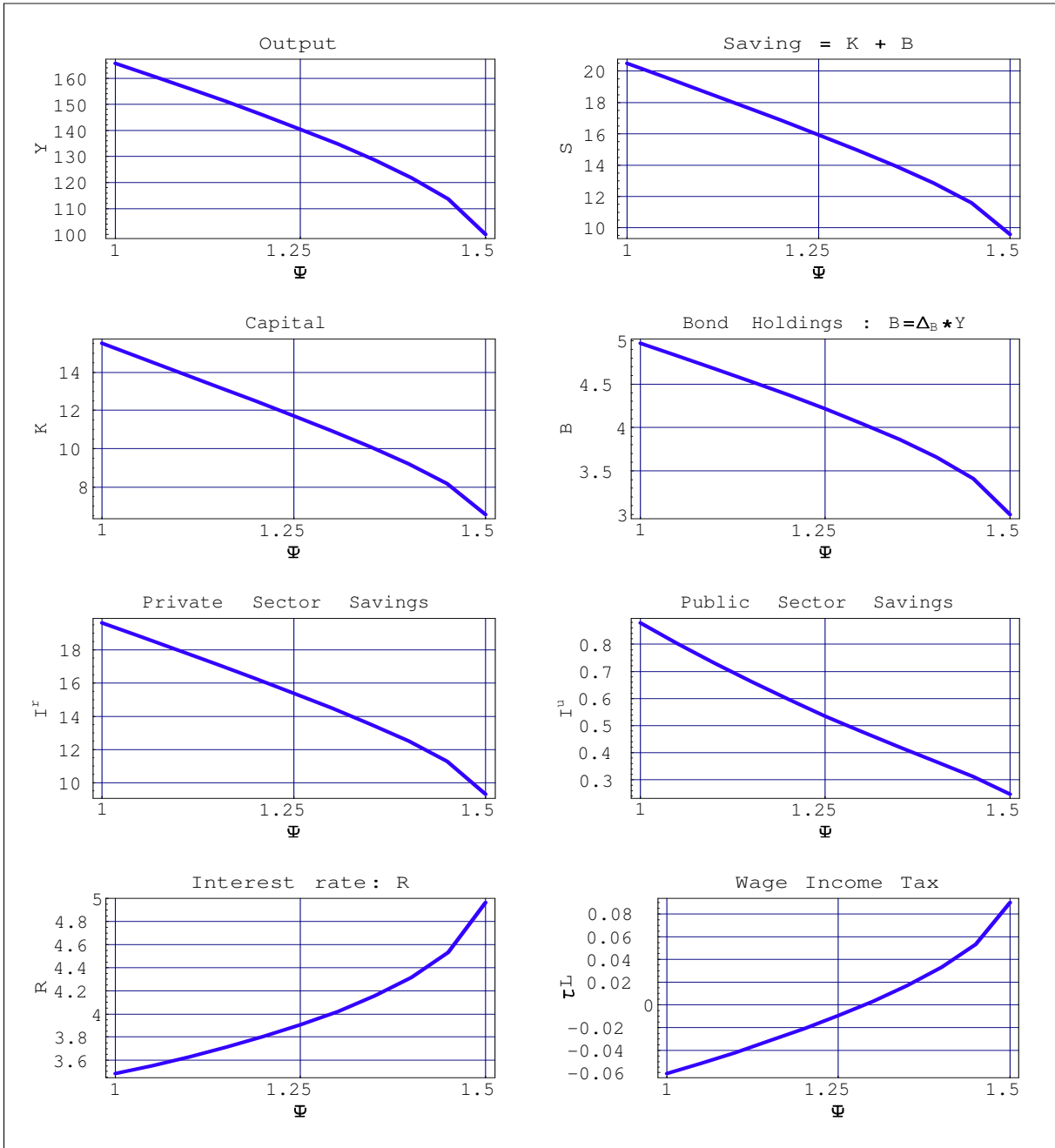
Figure 7: Effect of decreasing public sector pensions Ψ and decreasing labor taxes τ_L
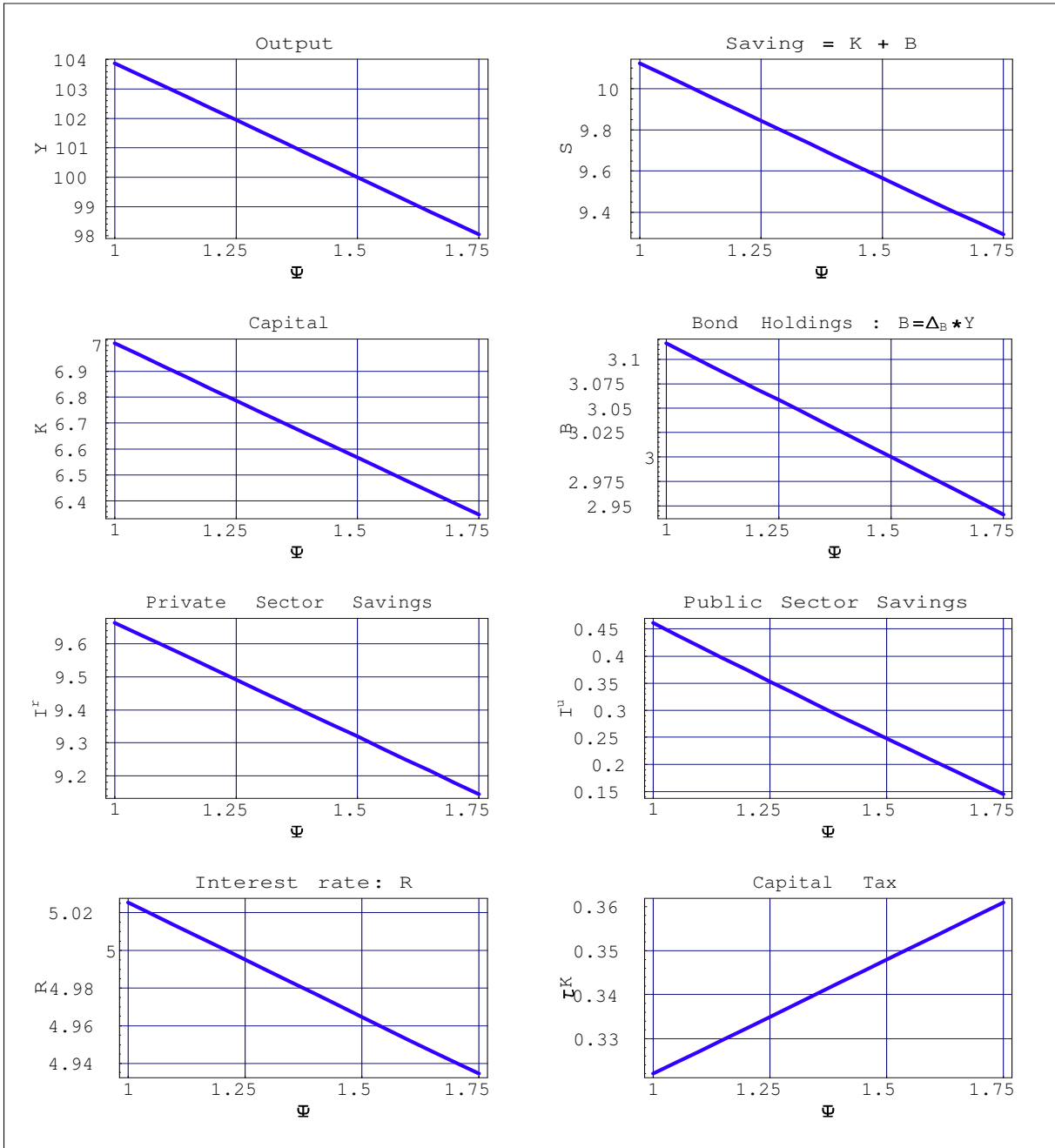
Figure 8: Effect of decreasing public sector pensions Ψ and adjusting capital taxes τ_K

	Parameters
Preferences	
	$\sigma = 1.5$
	$\Theta = 0.05$
	$\theta = 0.95$
	$\beta = 0.995^{30}$
Technology	
Consumption Good:	
	$A = 35.26$
	$\alpha_1 = 0.1$
	$\alpha_2 = 0.5$
	$\alpha_1 = 0.4$
Public Good:	
	$Z = 1$
	$\chi_2 = 1$
public capital and labor are substitutes:	$\eta_2 = 0.5$
public capital and labor are complements:	$\eta_2 = -0.25$
	$\delta_{K^G} = 0.8$
Human Capital:	
	$B = 1$
	$\chi_1 = 0.2$
	$\eta_1 = 0.5$
	$\gamma_1 = 0.1$
	$\gamma_2 = 0.5$

Table 1: Preference and Technology Parameters

	Variables	

Policies:

Δ_E	Public education excl. teacher salaries (in % of GDP)	1%
Δ_G	Investment in public good (in % of GDP)	1%
Δ_{T^r}	Transfers to old in private sector (in % of GDP)	6.6%
Δ_B	Debt level	3%
$w_t^u H_t N_t^u$	wages to current civil servants (in % of GDP)	3.5%
$\Psi w_t^u H_t N_{t-1}^u$	pension payments to public sector retirees (in % of GDP)	5%
ξ	public wages as a fraction of private wages	1.28
Ψ	indexation parameter (generosity of public pensions)	1.5

Taxes:

τ_L^{ssu}	social security contribution rate of civil servants	11%
τ_L^{ssr}	social security contribution rate of private sector employees	11%
τ_L^{ssrf}	social security contribution rate of private sector employers	10%
τ_K	capital tax rate (no bonds)	9%
	capital tax rate (with bonds)	0.35%
τ_L^r	labor tax rate private sector, net of social security	9%
τ_L^u	labor tax rate public sector, net of social security	9%

Population:

N_t^u	fraction of civil servants	6%
N^r	fraction of private sector employees	94%
a	fraction of teachers in public sector	42%

Table 2: Government Policy Parameters

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γ_1	Φ			
	1.00	1.25	1.50	1.75
0.05	110.29	105.66	100.00	91.01
0.06	112.04	106.64	100.00	89.37
0.07	113.90	107.68	100.00	87.68
0.08	115.88	108.77	100.00	85.95
0.09	118.00	109.94	100.00	84.17
0.10	120.27	111.17	100.00	82.34
0.11	122.69	112.49	100.00	80.46
0.12	125.30	113.89	100.00	78.53
0.13	128.11	115.38	100.00	76.54
0.14	131.15	116.98	100.00	74.50
0.15	134.43	118.69	100.00	72.40

Table 3: Change in Output with Δ_E adjusting ($\eta_2 = 0.5$)

η_1	Φ			
	1.00	1.25	1.50	1.75
0.00	107.01	103.87	100.00	93.14
0.25	112.68	107.01	100.00	88.35
0.50	120.27	111.17	100.00	82.34
0.75	125.92	114.38	100.00	77.07
1.00	128.59	115.98	100.00	73.63

Table 4: Change in Output with Δ_E adjusting

α_1	Φ			
	1.00	1.25	1.50	1.75
0.05	114.09	107.94	100.00	85.81
0.06	116.88	109.51	100.00	83.15
0.07	119.90	111.20	100.00	80.46
0.08	123.16	112.99	100.00	77.75
0.09	126.70	114.92	100.00	75.02
0.10	130.54	116.98	100.00	72.26
0.11	134.73	119.20	100.00	69.49
0.12	139.33	121.60	100.00	66.70
0.13	144.38	124.20	100.00	63.89
0.14	149.96	127.02	100.00	61.08
0.15	156.15	130.10	100.00	58.26

Table 5: Change in Output with Δ_G adjusting ($\eta_2 = 0.5$)

$\eta 2$			Φ	
	1.00	1.25	1.50	1.75
-1.00	103.27	101.74	100.00	96.18
-0.75	104.08	102.27	100.00	94.39
-0.50	105.94	103.42	100.00	91.52
-0.25	109.80	105.69	100.00	87.40
0.00	115.60	108.87	100.00	83.11
0.25	125.16	114.04	100.00	76.23
0.50	130.54	116.98	100.00	72.26

Table 6: Change in Output with Δ_G adjusting

$\gamma 1$			Φ	
	1.00	1.25	1.50	1.75
0.05	-22.64	-12.78	0.00	21.84
0.06	-20.07	-11.31	0.00	19.25
0.07	-17.54	-9.88	0.00	16.77
0.08	-15.06	-8.48	0.00	14.42
0.09	-12.64	-7.12	0.00	12.18
0.10	-10.27	-5.81	0.00	10.08
0.11	-7.98	-4.54	0.00	8.11
0.12	-5.76	-3.33	0.00	6.28
0.13	-3.63	-2.17	0.00	4.59
0.14	-1.59	-1.07	0.00	3.05
0.15	0.36	-0.04	0.00	1.66

Table 7: Absolute Difference: $\Delta_E - \Delta_G$, $(\eta_2 = 0.5)$

$\alpha 1$			Φ	
	1.00	1.25	1.50	1.75
0.05	3.13	1.61	0.00	-1.30
0.06	0.98	0.39	0.00	0.86
0.07	-1.40	-0.95	0.00	3.08
0.08	-4.04	-2.42	0.00	5.35
0.09	-6.98	-4.03	0.00	7.68
0.10	-10.27	-5.81	0.00	10.08
0.11	-13.97	-7.77	0.00	12.54
0.12	-18.15	-9.96	0.00	15.08
0.13	-22.90	-12.40	0.00	17.68
0.14	-28.30	-15.13	0.00	20.36
0.15	-34.51	-18.21	0.00	23.12

Table 8: Absolute Difference: $\Delta_E - \Delta_G$, $(\eta_2 = 0.5)$

γ_1		Φ		
	1.00	1.25	1.50	1.75
0.05	−0.33	−0.30	0.00	1.88
0.06	0.12	−0.05	0.00	1.38
0.07	0.54	0.19	0.00	0.93
0.08	0.93	0.42	0.00	0.51
0.09	1.29	0.62	0.00	0.13
0.10	1.62	0.80	0.00	−0.20
0.11	1.91	0.97	0.00	−0.50
0.12	2.17	1.11	0.00	−0.76
0.13	2.39	1.23	0.00	−0.98
0.14	2.58	1.34	0.00	−1.17
0.15	2.73	1.42	0.00	−1.31

Table 9: Absolute Difference: $\Delta_E - \Delta_G$, $(\eta_2 = -0.25)$

α_1		Φ		
	1.00	1.25	1.50	1.75
0.05	5.01	2.75	0.00	−3.72
0.06	4.14	2.25	0.00	−2.75
0.07	3.38	1.81	0.00	−1.94
0.08	2.71	1.42	0.00	−1.25
0.09	2.12	1.09	0.00	−0.68
0.10	1.62	0.80	0.00	−0.20
0.11	1.19	0.56	0.00	0.18
0.12	0.82	0.36	0.00	0.48
0.13	0.51	0.18	0.00	0.71
0.14	0.25	0.04	0.00	0.88
0.15	0.04	−0.07	0.00	1.01

Table 10: Absolute Difference: $\Delta_E - \Delta_G$, $(\eta_2 = -0.25)$

η_1		Φ		
	1.00	1.25	1.50	1.75
0.00	127.13	115.20	100.00	74.48
0.25	128.60	115.97	100.00	73.52
0.50	130.54	116.98	100.00	72.26
0.75	132.07	117.79	100.00	71.23
1.00	132.87	118.22	100.00	70.64

Table 11: Change in Output with Δ_G adjusting

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