Macroeconomic Effects of Public Education Expenditure

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Abstract
This article studies the growth and welfare effects of public education spending in the USA for the post-war period. We calibrate a standard dynamic general equilibrium model, where human capital is the engine of long-run endogenous growth. Our results suggest that while increases in public education spending raise growth, these increases are not necessarily welfare promoting. Welfare gains however can be realized if increases in public education spending are accompanied by changes in the government tax-spending mix. (JEL codes: H52, E62)

1 Introduction
In almost all countries, primary and secondary education are publicly provided. The government uses tax revenues to finance public schools, libraries, etc., at a zero or very low price. Also, in many countries, the government finances or co-finances higher education. Behind such public education policies there are two important issues: the role of human capital as an engine of economic growth, and the existence of externalities, or spillovers, from economy-wide human capital.

The path-breaking work of Romer (1986) and Lucas (1988), stressing the roles of knowledge and human capital accumulation, has led to an enormous body of theoretical and empirical literature attempting to better understand the determinants of endogenous (long-term) growth. The same literature has also emphasized the potential role of human capital externalities, which means that the return on the human capital of private agents is increasing in the average human capital in the economy (Lucas 1988; Azariadis and Drazen 1990; Tamura 1991). The importance of externalities in this context is emphasized by Lucas (2002) who states that
“if ideas are the engine of growth and if an excess of social over private returns is an essential feature of the production of ideas, then we want to go out of our way to introduce external effects into growth theory, not to try to do without them” and “the existence of important external effects of investment in human capital—in knowledge—has long been viewed as an evident and important aspect of reality”. On the other hand, there are economists who believe that general human capital externalities are not likely to be large (Heckman and Klenow 1997; Judd 2000).

Although the magnitude of human capital externalities remains an open issue, especially at the aggregate level, it is the belief in these externalities that typically justifies public education policies. As said above, the latter are an economic and political reality in almost all countries. As a result, there is a growing theoretical literature on the effects of public education policies on growth and welfare (Glomm and Ravikumar 1992; Zhang 1996; Bearer, Glomm and Ravikumar 2000; Blankenau and Simpson 2004; Su 2004; Blankenau 2005). Nevertheless, we are not aware of any estimation or calibration research that explores the empirical links between public education, growth and welfare. An exception is Angelopoulos, Malley and Philippopoulos (2007). Here, we synthesize and present the highlights of our work.

In our work, we calibrate, solve and conduct policy analysis by using a fairly standard dynamic stochastic general equilibrium model which is in the spirit of the observations stated above. Namely, the model’s engine of long-term growth is human capital accumulation. We also allow for positive externalities generated by the stock of average economy-wide human capital, as well as public education expenditure. Both the human capital externality and public education expenditure enter as inputs in private human capital accumulation. In other words, they can both enhance the productivity of households’ private education choices. The way we model human capital externalities is as in Azariadis and Drazen (1990) and Tamura (1991), while the way we model public education expenditure remains inconclusive.

2 Despite the obvious need, from a policy perspective, to understand the quantitative links between externalities, human capital accumulation and growth, there has been surprisingly little empirical work at the aggregate level. Indeed, we are only aware of one study which attempts to directly estimate human capital externalities in a growth context (Gong, Greiner and Semmler 2004), while Mamuneas et al. (2001) and Heckman and Klenow (1997) examine the link between externalities and the level of aggregate output. There has however been much more work at the sub-aggregate level [see e.g. Ciccone and Peri (2006) and the review paper by Davies (2003) for references]. In general, it seems that in both the macro and micro literatures, the empirical size of externalities remains inconclusive.

3 Note that a stochastic environment is employed, since we wish to examine the implications of uncertainty on the welfare effects of alternative policies.

We use this model to provide a quantitative assessment of the effects on growth and welfare from changes in public education expenditure as a share of output. We do so under various fiscal (tax and spending) policies. We first study the case in which the government finances changes in the share of public education expenditure through changes in a distorting income tax. This allows us to realistically assess the costs of public education expenditure. But we also study the cases in which the same changes in public education expenditure are financed by changes in lump-sum taxes/transfers, as well as the case in which all types of government expenditure, i.e. not only public education, change by the same proportion.

In our policy experiments, our base of departure will be the US economy in the sense that, before we do our policy experiments, we calibrate our model economy to resemble the main features observed in the post-war US economy. Our calibration profits significantly from having access to a dataset which includes consistent measures for human and physical capital (Jorgenson and Fraumeni 1989). In contrast to the relevant empirical studies referred to above, these data allow us to correctly distinguish between inputs to, and output from, the human capital production function.

Focusing on the implications for long run growth and expected lifetime utility, and using the solution to the second-order approximation of the model, our main findings are as follows.

First, there is evidence of positive externalities from the average stock of human capital in the economy. There is also evidence that public education expenditure augments private human capital accumulation. Without these features, we cannot obtain a data-consistent long-run equilibrium.

Second, the growth and welfare effects of public education expenditure are not monotonic. Specifically, the pattern between public education expenditure and long-run growth, as well as the pattern between public education expenditure and lifetime utility, are inverted-U curves (Laffer curves) with the peak of the curves giving the growth-maximizing and the welfare-maximizing public education expenditure as share of output. Given that higher public education spending crowds-out private consumption, the welfare maximizing share is much smaller than the growth maximizing one. Actually, we find that the welfare maximizing public education expenditure share is around the data average, which is 5.3 percent of GDP.

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4 Evidence of an inverted U-shaped relationship between public education spending and growth is also reported in the empirical literature. For instance, Blankenau, Simpson and Tomljanovich (2007) find that growth is positively related to public education services once the negative effects of increased taxes are taken into account.
Third, welfare gains are obtainable if increases in public education spending are accompanied by changes in the government tax-spending mix. In particular, welfare gains can be made if the composition of public spending is altered in favour of education spending relative to the other components of total government spending. For instance, if the public education share rises to, say, 6 percent of GDP, there are welfare gains that amount to 1.9 percent of private consumption from reallocating public funds in favour of spending on public education, instead of increasing all types of government expenditure together and thus unavoidably raising distorting taxes.

Fourth, increases in uncertainty (namely, the volatility of the innovations to the processes driving public education spending and total factor productivity) reduce expected lifetime utility, as well as the welfare gains associated with using lump-sum versus distorting taxes to finance public education expenditure.

The rest of the article is organized as follows. Section 2 summarizes the theoretical model. Section 3 explains briefly how we work. Section 4 discusses the data and calibration. Section 5 contains the results and Section 6 concludes.

2 Theoretical setup

This section briefly presents the model developed and solved in Angelopoulos, Malley and Philippopoulos (2007). Our theoretical setup is a dynamic stochastic general equilibrium model of the sort used in real business cycle studies combined with the popular human capital framework of Lucas (1990). Thus, the engine of endogenous growth is human capital accumulation. To conduct our policy experiments, in comparison to the Lucas framework, we add externalities generated by the average stock of human capital in the society, as well as government expenditure on public education. There are also shocks to total factor productivity and public education expenditure. We thus operate in a stochastic environment, which allows us to explicitly analyse the effects of uncertainty on welfare.

To remain focused on publicly provided education (e.g. public schools and libraries), we abstract from other public education policies (e.g. public subsidies to private education or education vouchers)\(^5\) and private

\(^5\) We thus do not study the allocation of public funds between alternative uses, e.g. between basic public education and subsidies to private college education, which is the focus in Zhang (1996), Su (2004) and Blankenau (2005). Bearse, Glomm and Ravikumar (2000) also study education vouchers.
education expenditure. We also assume away other common types of government spending (government investment in infrastructure and utility-enhancing public consumption) and use a relatively simple public finance structure with a single income tax and a lump-sum instrument only.6

2.1 Households

There is a large number of identical households indexed by the superscript $h$ and identical firms indexed by the superscript $f$, where $h, f = 1, 2, \ldots, N_t$. The population size, $N_t$, evolves at a constant rate $n \geq 1$, so that $N_{t+1} = nN_t$, where $N_0$ is given. Each household’s preferences are given by the following time-separable utility function:

$$E_0 \sum_{i=0}^{\infty} \beta^i U(C_{ih}^t)$$

where $E_0$ is the conditional expectations operator; $C_{ih}^t$ is consumption of household $h$ at time $t$; and $0 < \beta < 1$ is the subjective rate of time preference. The instantaneous utility function is increasing, concave and satisfies the Inada conditions. We use the CRRA form for utility:

$$U_t = \frac{(C_{ih}^t)^{1-\sigma}}{1-\sigma}$$

where, $1/\sigma (\sigma > 1)$ is the intertemporal elasticity of substitution between consumption in adjacent periods.

Each household saves in the form of investment, $I_{ih}^t$, and receives interest income, $r_tF_{ih}^t$, where $r_t$ is the return to private capital and $K_{ih}^t$ is the beginning-of-period private capital stock. Each household also has one unit of effort time in each period $t$, which it allocates to work, $u_{ih}^t$ and education, $e_{ih}^t$, so that $u_{ih}^t + e_{ih}^t = 1$. A household with a stock of human capital, $H_{ih}^t$ receives labour income, $w_tu_{ih}^tH_{ih}^t$, where $w_t$ is the wage per unit of human capital and $u_{ih}^tH_{ih}^t$ is effective labour. Finally, each household receives dividends paid by firms, $\Pi_{ih}^t$. Accordingly, the budget constraint of each household is

$$C_{ih}^t + I_{ih}^t = (1 - \tau_t)[r_tF_{ih}^t + w_tu_{ih}^tH_{ih}^t + \Pi_{ih}^t] + G_{ih}^o$$

where $0 < \tau_t < 1$ is the distortionary income tax rate and $G_{ih}^o$ is an average (per household) lump-sum tax/subsidy (the role played by $G_{ih}^o$ will be explained below in subsections 2.3 and 2.5).

6 See Angelopoulos, Malley and Philippopoulos (2008) for an extended public finance structure, which includes multiple tax and spending instruments.
Each household’s physical and human evolve according to the following relations

\[ K_{t+1}^h = (1 - \delta^p) K_t^h + I_t^h \]  

and

\[ H_{t+1}^h = \left(1 - \delta^h\right) H_t^h + \left( e_t^h H_t^h \right)^{\theta_1} (\overline{H}_t)^{1-\theta_1} \bar{B}_t \]  

where, \( 0 < \delta^p, \delta^h \leq 1 \) are constant depreciation rates on private physical and human capital respectively. The second expression on the r.h.s. of (5), consisting of three multiplicative terms, can be interpreted as the quantity of “new” human capital created at time period \( t \). This expression is comprised of the following arguments: (i) \( e_t^h H_t^h \) is \( h \)'s effective human capital; (ii) \( \overline{H}_t \) is the average (per household) human capital stock in the economy; (iii) \( \bar{B}_t \equiv B(g_t^e)^{\theta_1} \) represents human capital productivity, where \( B > 0 \) is a constant scale parameter and \( g_t^e \) is average (per household) public education expenditure expressed in efficiency units (see below) and (iv) the parameters \( 0 < \theta_1 \leq 1, \ 0 \leq (1 - \theta_1) < 1, \ 0 \leq \theta_2 \leq 1 \) capture the productivity of household’s human capital, the aggregate human capital externality and public education spending, respectively.\(^7\)

The assumption that individual human capital accumulation is an increasing function of the per capita level of economy-wide human capital encapsulates the idea that the existing know-how of the economy provides an external positive effect. Equivalently it can be thought of as a learning-by-doing effect as discussed in Romer (1986). Examples of other papers which use the per capita level of aggregate human capital in either the goods or human capital production functions include Lucas (1988), Azariadis and Drazen (1990), Tamura (1991) and Glomm and Ravikumar (1992).

The assumption that individual human capital accumulation depends on the per household public education share, \( g_t^e \), in Equation (5) is consistent with the goal of public education policy, as well as with theoretical work (Glomm and Ravikumar 1992; Blankenau and Simpson 2004; Su 2004; Blankenau 2005).\(^8\) Finally, note that, the parameter restrictions

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\(^7\) Following Lucas (1988), we assume that human capital is basically the only input in human capital accumulation (Barro and Sala-i-Martin 2004).

\(^8\) Blankenau (2005, pp. 493–4) also has a good discussion of the effects of public education on students’ achievement. As he points out, assuming a positive effect is not uncontroversial, this is why public expenditures “are included with a parameter \( \theta_2 \) to gauge their relative importance in producing human capital”.

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employed in Equation (5) imply increasing returns to scale (IRS) at the social level.\(^9\)

Households act competitively by taking prices, policy variables and aggregate outcomes as given. Thus, each household \(h\) chooses the paths \(\{C_t^h, u_t^h, e_t^h, f_t^h, K_{t+1}^h, H_{t+1}^h\}_{t=0}^\infty\) to maximize Equation (1) subject to Equations (3)–(5), the time constraint \(u_t^h + e_t^h = 1\), and initial conditions for \(K_0^h\) and \(H_0^h\).

### 2.2 Firms

To produce its homogenous final product, \(Y^f_t\), each firm, \(f\), chooses private physical capital, \(K_f^t\), and effective labour, \(u_f^tH_f^t\). Thus, the production function of each firm is:

\[
Y_f^t = A_t \left( K_f^t \right)^\alpha \left( u_f^tH_f^t \right)^{1-\alpha} \tag{6}
\]

where \(A_t\) represents the level of Hicks neutral technology available to all firms, \(0<\alpha, (1-\alpha)<1\) are the productivity of private capital and labour respectively.

Firms act competitively by taking prices, policy variables and aggregate outcomes as given. Accordingly, subject to Equation (6), each firm \(f\) chooses \(K_f^t\) and \(u_f^tH_f^t\) to maximize a series of static profit functions,

\[
\Pi_f^t = Y_f^t - r_fK_f^t - w_fu_f^tH_f^t. \tag{7}
\]

The full set of optimality conditions for the households and firms are reported in Angelopoulos, Malley and Philippopoulos (2007).

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\(^9\) There are several different assumptions that can be made regarding the returns to individual and aggregate human capital. We have chosen the constant returns to scale (CRS) specification, since it nests some popular models in the related literature. For instance, Lucas’ (1988, 1990) equations for human capital accumulation follow if we set \(\theta_1 = 1\) and \(\theta_2 = 0\), while Tamura’s (1991) equation with externalities follows if we set \(\theta_2 = 0\). Another possibility could be to allow the power-coefficient of per capita aggregate human capital \((1-\theta_1)\) to be free and restrict instead the power-coefficient of public education spending, \(\theta_2\) (as in Blankenau and Simpson (2004), who assume CRS at social level). Recall that some restrictions are unavoidable to obtain a stationary equilibrium human capital evolution equation. In addition to nesting and being directly comparable to some important models in the literature, our model specification has the advantage of giving a unique well-defined solution that is consistent with some key features of the US economy. In contrast, alternative specifications along the lines discussed above yielded either multiple long-run equilibria, local indeterminacy or non-plausible long-run solutions. For details regarding our calibration, see subsection 4.2.
2.3 Government budget constraint

Total expenditures on public education, $G^c_t$, and other lump-sum types of transfers/taxes, $G^o_t$, are financed by total income tax revenue. Thus,

$$G^c_t + G^o_t = \tau_t \sum_{h=1}^{N_t} (r^K_h + w^h_H + \Pi^h)$$

(8)

where only two of the three ($G^c_t, G^o_t, \tau_t$) policy instruments can be exogenously set. Note that we use a balanced budget. Ignoring public debt is not critical here since changes in lump-sum taxes/transfers are equivalent to debt financing (see Baxter and King (1993) for a similar budget constraint).

When we solve the model, we will choose $G^c_t$ to be exogenously set and then allow either $\tau_t$, or $G^o_t$, to be the endogenous, residually determined, policy instrument. In other words, to assess the effects of increases in government expenditure on education, we will explore the importance of the financing decisions by studying the use of either changes in the distorting income tax rate, or changes in lump-sum taxes/transfers. Further details are reported in subsection 2.5 below.

Finally, note that, when we calibrate the model, the inclusion of $G^o_t$ will make the residually determined value of the income tax rate correspond to the rate, which exists in the data. This will allow for a realistic assessment of the trade-offs between increased spending on public goods versus increased distortions due to higher tax rates.

2.4 Decentralized competitive equilibrium

Given the paths of two out of the three policy instruments, say $\{G^c_t, G^o_t\}_{t=0}^\infty$, and initial conditions for the state variables, $(K^h_0, H^f_0)$, a decentralized competitive equilibrium (DCE) is defined to be a sequence of allocations $\{C_t, u_t, e_t, I_t, K_{t+1}, H_{t+1}\}_{t=0}^\infty$, prices $\{r_t, w_t\}_{t=0}^\infty$ and the tax rate $\{\tau_t\}_{t=0}^\infty$ such that (i) households maximize utility; (ii) firms maximize profits; (iii) all markets clear and (iv) the government budget constraint is satisfied in each time period. Note that market clearing values will be denoted without the superscripts $h, f$.

Since human capital is the engine of long-run endogenous growth, we transform variables to make them stationary. We first define per capita quantities for any variable $X$ as $\bar{X}_t \equiv X_t / N_t$, where $X_t \equiv (Y_t, C_t, I_t, K_t, H_t, G^c_t, G^o_t)$. We next express these quantities as shares of per capita human capital, e.g. $x_t \equiv \bar{X}_t / \bar{H}_t$. Finally, the gross human capital growth rate is defined as $\gamma_t \equiv \bar{H}_{t+1} / \bar{H}_t$. 

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Using this notation, we obtain the following per capita stationary DCE:  

\[ y_t = A_t(k_t)^{\sigma}(1 - e_t)^{(1-\sigma)} \]  

(9a)

\[ ny_t k_{t+1} - (1 - \delta^p) k_t + c_t + g^e_t = y_t \]  

(9b)

\[ ny_t = 1 - \delta^h + (e_t)^{\theta_h} B(g^e_t)^{\theta_e} \]  

(9c)

\[ \lambda_t = (c_t)^{-\sigma} \]  

(9d)

\[ \psi_t = \left[ \frac{(e_t)^{\sigma}(1 - \alpha)(1 - \tau_t)y_t}{(1 - e_t)\theta_1(e_t)^{\theta_1-1} B(g^e_t)^{\theta_e}} \right] \]  

(9f)

\[ \psi_t = \beta E_t \{ (y_t c_{t+1})^{-\sigma}(1 - \alpha)(1 - \tau_{t+1})y_{t+1} + \beta(y_{t+1})^{-\sigma} \times \psi_{t+1} \left[ 1 - \delta^h + \theta_1(e_{t+1})^{\theta_1} B(g^e_{t+1})^{\theta_e} \right] \} \]  

(9g)

\[ g^e_t + g^o_t = \tau_t y_t \]  

(9h)

where \( \lambda_t \) and \( \psi_t \) are the transformed shadow prices associated with Equations (3) and (5) respectively in the household’s problem.  

Therefore, the stationary DCE is summarized by the above system of eight Equations in the paths of the following eight variables: \((y_t, y_t, c_t, e_t, k_{t+1}, \lambda_t, \psi_t, \tau_t)\) given the paths of the exogenously set stationary spending flows, \(\{g^e_t, g^o_t\}_{t=0}^{\infty}\) whose motion is defined in the next subsection.

2.5 Processes for policy instruments and technology

To complete the model, we need to specify the processes governing the evolution of fiscal (spending-tax) policy instruments. This first requires that each government spending item, which has already been expressed as share of \(H_t\), be rewritten equivalently as a share of output:  

\[ g^f_t \equiv \frac{g^f_t}{y_t} \]  

(10)

Further details can be found in Angelopoulos, Malley and Philippopoulos (2007).

Note that \( \lambda_t = \Lambda_t / \Pi_t^{\sigma} \) and \( \psi_t = \Psi_t / \Pi_t^{\sigma} \), where \( \Lambda_t \) denotes the shadow price associated with Equation (3) and \( \Psi_t \) denotes the shadow price associated with Equation (5). Also note that \( h \)-superscripts are omitted in a symmetric equilibrium.
where \([j = e, o]\), and \(\widetilde{g}'_t \equiv G'_t / Y_t\).

We assume that public education expenditure as a share of output, \(\widetilde{g}^e_t\), follows an AR(1) process:

\[
\widetilde{g}^e_t = (\widetilde{g}^e_0 - \epsilon^e - \beta^e(\widetilde{g}^e_0)) e^e_t
\]

where \(\widetilde{g}^e_0\) is a constant, \(0 < \rho^e < 1\) is an autoregressive parameter and \(e^e_t\) an iid random shock to public education expenditure with a zero mean and constant standard deviation, \(\sigma^e\). Thus, the innovations \(e^e_t\) represent discretionary education spending changes.

We will call Regime A the benchmark case in which the lump-sum tax/transfer, \(\widetilde{g}^o_t\), is the residual policy instrument, while \(\widetilde{g}^e_t\) evolves as in Equation (11) and \(\tau_t\) is fixed at a constant positive rate (specified below when we calibrate the model). We will call Regime B the more interesting case in which the income tax rate, \(\tau_t\), is the residual policy instrument, while \(\widetilde{g}^e_t\) evolves again as in Equation (11) and \(\widetilde{g}^o_t\) is fixed at a constant share (again specified below when we calibrate the model).

In addition, consistent with political reality (Blankenau and Simpson 2004, p. 588), we will also study the case, called Regime C, in which all types of government spending rise together. Thus, in our setup, increases in \(\widetilde{g}^e_t\) are accompanied by equal increases in \(\widetilde{g}^o_t\). This is like Regime B, in the sense that \(\tau_t\) is residually determined and \(\widetilde{g}^e_t\) follows Equation (11), but now the composition of public expenditure remains constant when government spending as a share of output changes. Formally, in comparison to Regime B, now \(\widetilde{g}^o_t = (g^o_0 / g^e_0) \widetilde{g}^e_t\). The interest is now in the effects of the overall size of the public sector.

Finally, we assume that the stationary stochastic process determining \(A_t\) follows an AR(1) process:

\[
A_t = A_{-1}^{(1-\rho^a)} A_{t-1}^{\rho^a} e^a_t
\]

where \(A > 0\) is a constant, \(0 < \rho^a < 1\) is the autoregressive parameter and \(e^a_t \sim iid(0, \sigma^a_2)\) are the random shocks to productivity.

3 How we work

This section briefly explains how we work. Further technical details are provided in Angelopoulos, Malley and Philippopoulos (2007).

3.1 Solution and welfare

The general equilibrium solution of the model consists of a system of dynamic relations jointly specifying the time-paths of output, consumption, physical capital, human capital growth, the fractions of time
allocated to work and education, and one residually determined policy instrument. To obtain these paths we solve the second-order approximation of our model’s equilibrium conditions Equations (9a–12) around the deterministic steady state. Thus, we work as in Schmitt-Grohé and Uribe (2004). The deterministic steady state is defined to be the case in which stationary variables remain constant (i.e. for any stationary variable $x_t$, $x$ denotes its long-run value) and there are no stochastic shocks.

Note that, in contrast to first-order approximate solutions which impose certainty equivalence, the solution of a second-order system allows us to take account of the uncertainty that agents face when making decisions. In addition, as pointed out by Schmitt-Grohé and Uribe (2004) and Kim and Kim (2003), the second-order approximation to the model’s policy function helps to avoid potential spurious welfare rankings which may arise under certainty equivalence. In other words, we approximate both the equilibrium solution and the associated welfare up to second order (Schmitt-Grohé and Uribe 2007).¹²

Welfare is defined as the conditional expectation of lifetime utility. Thus, we first undertake a second-order approximation of the within-period utility function around the non-stochastic steady state, and then take the discounted “infinite” sum of approximate within-period utility functions to obtain a measure of welfare. We will calculate this welfare for varying shares of public education spending ($g^e$) using the solution(s) of the second-order approximation to the stationary equilibrium. Note that, in comparison to Schmitt-Grohé and Uribe (2007), we work with an endogenous growth model.

We calculate the long-run growth rate and the expected lifetime utility (see subsection 5.1 subsequently for further details) for a wide range of shares of public education spending in GDP. Thus, although we do not solve an explicit optimization problem for the government, this will allow us to find the shares of public education expenditure that yield the maximum long run growth rate and the maximum expected lifetime utility.

3.2 Policy regimes and welfare comparisons

We work as described above for each policy regime, A, B and C, as defined in subsection 2.5. In turn, following Lucas (1990), Cooley and Hansen (1992) and Schmitt-Grohé and Uribe (2007), we compute the welfare gains

¹² See Woodford (2003, Ch. 6) for a review of the literature on the microfoundations of utility-based, welfare analysis. Alternatively, if we work in the traditional linear-quadratic context in which the equilibrium solution is first-order approximate and the utility function is second-order approximate, we need to ensure that the long-run equilibrium, around which we approximate, is efficient in the sense that it coincides with the one chosen by the social planner (Rotemberg and Woodford 1997).
or losses associated with alternative policy regimes by computing the percentage change in private consumption that the individual would require so as to be equally well off between two regimes. This is defined as the $\xi$ measure (see the Appendix in Angelopoulos, Malley and Philippopoulou (2007) for the derivation of $\xi$ in our model).

To obtain quantitative results for all the above, we next calibrate the model to the post-war US economy.

4 Data and Calibration

4.1 Data

To calibrate the model, we require data for the endogenous variables as shares of human capital. Thus, it is important to obtain a measure of human capital that is comparable to monetary valued quantities such as consumption, income, capital and government spending. To obtain this, we use data from Jorgenson and Fraumeni (1989, 1992a, 1992b) on human and physical capital. Generally, empirical studies use measures of school enrolment ratios or years of schooling as general proxies of labour quality or human capital. However, in our setup, these proxies are measures of the input to the production function of human capital (time spent on education) and not of the output of this activity, new human capital. These measures are reported in billions of constant 1982 dollars for 1949–84.

The additional (annual) data required for calibration are obtained from the following sources: (i) Bureau of Economic Analysis (NIPA accounts); (ii) OECD (Economic Outlook database); (iii) US Department of Labor, Bureau of Labor Statistics (BLS) and (iv) ECFIN Effective Average Tax Base (Martinez-Mongay, 2000).

4.2 Calibration

The numeric values for the model’s parameters are reported in Table 1. To calibrate the model, we work as follows. We set the value of $1/\beta$ equal to labour’s share in income (i.e. 0.578) using compensation of employees data from the OECD Economic Outlook. This figure is similar to others used in the literature (King, Plosser and Rebelo 1988; Lansing 1998). Given labour’s share, capital’s share, $\alpha$, is then determined residually.

The discount rate, $1/\beta$ is equal to 1 plus the ex post real interest rate, where the interest rate data is from the OECD Economic Outlook. This implies a value 0.964 for $\beta$. Again, this figure is similar to other US studies, (Lansing 1998; Perli and Sakellaris 1998; King and Rebelo 1999). The population gross growth rate $n$ is set equal to the post war labour force growth rate, 1.016, obtained by using data from Bureau of Labor Statistics.
The depreciation rates for physical, $\delta^p$, and human capital, $\delta^h$, are calculated by Jorgenson and Fraumeni to be, on average, 0.049 and 0.018, respectively. We also use a value for the intertemporal elasticity of consumption ($1/\sigma = 0.5$) that is common in the DSGE literature.

We also require constants for government education and other government spending as shares of output. The education spending ratio is set at the data average using NIPA data to $\tilde{\rho} = 0.053$. We set other government spending, $G^o_t$, in the government budget Equation (8), so that the long-run solution for the tax rate gives 0.21, which corresponds to the effective income tax reported in the ECFIN dataset.\(^{13}\) This gives $\tilde{\rho}^o = 0.157$. It is important to point out that, given the above data averages, all three policy regimes defined in subsection 2.5, imply the same long-run solution.

We next move on to the parameters $\theta_1$, $\theta_2$ and $B$ in the production function of human capital and $A$ in the production function of goods. Note that the expression $(e^h H_t^{\theta_1})^{\theta_1} (H_t)^{1-\theta_1} B(s_t^{\theta_2})$ in Equation (5) is

\(^{13}\) We calculate this as the weighted average of the effective tax rates on (gross) capital income and labour income, where the weights are capital’s and labour’s shares in income.

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essentially the production function for the creation of new human capital, or what Jorgenson and Fraumeni (1992a) call investment in human capital. Model consistent values for the scale parameters $A$ and $B$ are obtained by solving Equations (5) and (6) using data averages and long-run values for the variables $y$, $k$, $e$, $y^{e}$, as well as the calibrated parameters $\alpha$, $\theta_1$, $\theta_2$, $n$ and $\delta^h$.\footnote{For this exercise, we obtain model consistent $y$. In particular, $y$ is obtained from Equation (9b), using NIPA data for $g^e$ and $c$. As a dataset for the share of time individuals spend on education as opposed to working is not available, we obtain a proxy for $e$ to calibrate $B$. This is achieved by assuming that $e$ is the ratio of 16 years spent on average on education over 62 minus 6 years available on average for work or education. For example, Prescott finds that as household human capital productivity increases (for a given growth rate), $e$ increases to implausible values (see Table 6 p. 542).} Given the functions for the calibration of $A$ and $B$, we calibrate $\theta_1$ and $\theta_2$ so that we obtain an economically meaningful and data-consistent long-run solution. This can be obtained by setting a value of $(1-\theta_1) = 0.4$ for the human capital externality. Conditional on this value, the productivity of individual human capital is $\theta_1 = 0.6$, and we then calibrate $\theta_2$ to ensure that the long-run gross growth rate of output per labour input is equal to 1.02. This gives $\theta_2 = 0.245$. Note that a value of the gross growth rate of 1.02 is the USA per labour input growth rate for 1949–84 using GDP data from the NIPA accounts and labour data from Bureau of Labor Statistics. The long run solution implied by this calibration is in Angelopoulos, Malley and Philippopoulos (2007).

Regarding the calibrated values of $\theta_1$ and $\theta_2$, it is important to report the following. For higher externalities, the growth rate becomes too low, irrespective of the size of $\theta_2$. This happens because, with very high externalities, there are free riding problems in the creation of human capital. On the other hand, for low externalities, the implied share of time allocated to education ($e$) in the long run becomes unrealistically large (around 0.5).\footnote{As mentioned above, there are no data on the fraction of time agents allocate to increasing human capital as opposed to working. Although there are data on average years of schooling, they can only provide a lower bound on the actual time allocated to learning, as agents take time off work as well for vocational training, to attend seminars, etc. Looking at data for schooling only, our long run solution is a bit higher than the current situation. However, there is a clear trend in schooling data for more years of schooling.} In contrast, our calibrated values $(1-\theta_1) = 0.4$ and $\theta_2 = 0.245$ guarantee a growth rate consistent with the data average (2 percent) and, at the same time, implies that agents in the long run will spend about a third of their non-leisure time in acquiring human capital and two-thirds at work.\footnote{The problems we point out when $(1-\theta_1)$ is low are also alluded to by Prescott (1998). For example, Prescott finds that as household human capital productivity increases (for a given growth rate), $e$ increases to implausible values (see Table 6 p. 542).}

To accurately gauge the persistence of the public spending shocks, we estimate the AR(1) relation given by Equation (11) using US NIPA data.
where the log deviations are defined relative to a Hodrick–Prescott trend. The estimated value for $\rho^e$ is 0.442 and is significant at less than the 1 percent level of significance. The standard deviation of this process, $\sigma^e$, is 0.019. Using a production function and time period similar to ours, Lansing (1998) provides estimates for TFP. Hence, we use his parameters for the stationary TFP process in Equation (12), e.g. $\rho = 0.933$ and $\sigma_a = 0.01$.

To sum up, this model economy for the post-war USA is consistent with externalities in private human accumulation and productive public education expenditure. Note that the output effect of the human capital externality in our economy is lower than in Lucas (1988). Lucas supports the same value but, since his externality is modeled as a direct argument in the goods production function, its effect on output produced is much higher. The associated value of the productivity of public education expenditure, $\theta_2 = 0.245$, is also within the range assumed in the related literature (Blankenau 2005, p. 501). We finally point out that the possible benefits from human capital and public education can be broader. In other words, we can think of human capital not only as the skills embodied in a worker, but also as ideas, knowledge and social behaviour, so that there are external effects in addition to know-how and learning-by-doing. Also, public education can reduce criminal activity, increase social cohesion, improve incentives, protect property rights, as well as produce innovation.\(^{17}\)

5 Results for growth and welfare

Using the second-order approximation of the model around its deterministic long-run, and the calibrated parameter values reported in Table 1, we now examine the implications of changes in public education spending. In Angelopoulos et al. (2007), we also evaluate the ability of this model to replicate the main features observed in the post-war US economy.

We first examine, in subsection 5.1, the effects on the long-run growth rate and expected lifetime utility from varying public education spending shares. This is captured by changes in $g^e$ in Equation (11) and can be interpreted as permanent changes in public education expenditure as share of output.

This is carried out under all three Regimes, A, B and C, where the point of departure is the US economy as summarized in Table 1. Recall that

\(^{17}\) See Gradstein and Justman (2000) for a model in which public education contributes to growth not only by building human capital but also by instilling social norms that improve social cohesion.
Regime A is the benchmark case where the government relies on changes in lump-sum taxes/transfers to finance changes in public education spending (with the income tax rate remaining at its calibrated value of $\tau = 0.21$). In Regime B, the same spending changes are financed by changes in the income tax rate (with lump-sum taxes/transfers remaining at their calibrated value of $e_{go} = 0.157$). In Regime C, the government is increasing both $\tilde{g}_t^p$ and $\tilde{g}_t^e$ by the same proportion, so that the overall size of the government is increasing and is being financed by changes in the income tax rate.

In subsection 5.2, we examine the effects on expected lifetime utility from varying degrees of uncertainty over public education spending and total factor productivity. This is captured by changes in $\sigma_e$ and $\sigma_a$ in Equations (11) and (12), respectively.\(^\text{18}\)

5.1 Effects of higher public education expenditure

The relationship between government size and economic growth is not expected to be monotonic. On one hand, governments provide growth promoting public goods and services and, on the other, this provision requires taxes and distorts incentives. There is thus a trade-off being reflected in an inverted-U curve (or a Laffer curve) between government size and economic growth (Barro 1990).\(^\text{19}\) A similar pattern is expected to describe the relationship between government size and welfare.

In our setup, it is useful to have a handle on the magnitudes associated with the growth maximizing size of public education spending and whether this is also welfare maximizing. Therefore, as explained in Section 3 above, we first calculate the long-run growth rate associated with a range of shares of public education spending in GDP, and then do the same with welfare. We do so under each policy regime.

**Growth and welfare maximizing values**

Consider the long-run growth rate. This is measured by $\gamma$, which denotes the balanced growth rate, namely, the common constant rate at which all quantities grow in the long run. In Figure 1, subplot (1,1), where (1,1) refers to row and column numbers respectively, we derive the Laffer curve for the long-run growth rate implied by our model under policy Regime A and in subplots (1,2) and (1,3) we derive the Laffer curves under policy Regimes B and C. This is for a range of values of public education spending as a share of output, $\tilde{g}_t^e$.

\(^\text{18}\) Other results (e.g. the behaviour of each endogenous stationary variable and impulse response functions) are reported in Angelopoulos, Malley and Philippopoulos (2007).

\(^\text{19}\) Malley, Philippopoulos and Woitek (2007) review the literature on the relationship between fiscal policy and economic growth.
Consider next welfare denoted as $V$. As explained in Section 3 above, this is defined as the conditional expectation of the discounted sum of lifetime utility. The resulting welfare curves under policy Regimes A, B and C are shown respectively in subplots (2,1), (2,2) and (2,3) in Figure 1. The same figure illustrates the measure $\xi$ (again as explained in Section 3 above). Specifically, subplots (3,1), (3,2) and (3,3) show $\xi$—respectively, the welfare gain/loss from moving from A to B, A to C and B to C—for a range of values of public education spending as a share of output, $g^e$.

The main results are as follows. Subplot (1,1) in Figure 1, which describes the benchmark fictitious case in which changes in public education spending are financed by changes in lump-sum taxes/transfers, does not give a Laffer curve, i.e. the benefits always outweigh the costs at least in the range of parameter values we use. This is not surprising given the assumed non-distorting way of financing growth-enhancing government spending like public education. In policy Regime B, in subplot (1,2), there is a trade-off and hence a Laffer curve. The growth maximizing public education share is around 50 percent of GDP, which implies an overall government size of around 65 percent of GDP, with the associated gross growth rate being 1.043 percent. For policy Regime C, in subplot (1,3), the growth maximizing $g^e$ is around 15 percent of GDP, with the associated gross growth rate being 1.026 percent.

The above Laffer curves imply that, when the criterion is long-run growth, there is scope for higher public education spending relative to the data average. However, maximization of long-run growth does not necessarily coincide with welfare maximization, therefore we next consider expected lifetime utility.

The welfare subplots (2,1), (2,2) and (2,3) suggest that the welfare maximizing $g^e$ share is much less than the growth maximizing one, and practically is around the data average which is 5.3 percent. In particular, under Regime A [subplot (2,1)], the welfare maximizing $g^e$ is around 6 percent, under policy regime B [subplot (2,2)], the welfare maximizing $g^e$ is approximately 4.5 percent, and in regime C the welfare maximizing $g^e$ is found to be about 2.5 percent of GDP. The implied overall welfare maximizing size of the government is 21 percent, 19.5 percent and 10 percent in Regimes A, B and C, respectively.20

The main reason that the welfare Laffer curves peak much earlier than the respective growth Laffer curves is the following. In all three

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20 Robustness analysis of the results with respect to changes in externalities reveals that indeterminacy generally occurs for public education spending to output ratios greater than 0.1, when externalities are zero, i.e. $\theta_1 = 1$. Nonetheless, in the cases where determinacy maintains, we do not find significant quantitative differences in the Laffer curves reported in Figure 1.
Figure 1 Effects of public education spending on steady-state growth and lifetime welfare
Regimes A, B and C, although a higher government size enhances growth by allocating more social resources towards public education, there are also crowding-out effects on private investment and private consumption that work in opposite direction and after a critical value reduce net welfare. This happens simply because, when the government increases its spending, it purchases a part of the private output. In Regimes B and C, there is an additional adverse effect from higher government spending: there is an extra fall in private consumption because the required increase in distorting tax rates reduces post-tax income. Comparing Regimes B and C, the adverse effects due to higher taxation, are worse in C. Therefore, the welfare maximizing $\tilde{g}^e$ is highest in Regime A and lowest in Regime C, with B in between.  

**Welfare comparisons**

Consider welfare comparisons as illustrated in the last row of Figure 1. Subplot (3,1) suggests that for sizes of public education spending above the data average (5.3 percent), regime A welfare dominates Regime B, since in Regime B increases in public spending necessitate higher distorting taxes. For instance, for $\tilde{g}^e = 6$ percent, the percentage gain in private consumption is around 0.7 percent, while for $\tilde{g}^e = 10$ percent, the percentage gain in private consumption is around 3.2 percent. The same subplot implies that for sizes of public education spending below the data average, Regime B welfare dominates Regime A for symmetrically opposite reasons; namely, in Regime B decreases in public spending allow lower distorting taxes. For instance, for $\tilde{g}^e = 4.5$ percent, the percentage gain in private consumption from switching from A to B is around 0.2 percent. Subplots (3,2) and (3,3), respectively imply that Regime A welfare dominates Regime C and Regime B welfare dominates Regime C when public education spending is above the data average, and symmetrically opposite when public education spending is below the data average. The welfare gains are much larger when the comparison is made with respect to Regime C. For instance, for $\tilde{g}^e = 6$ percent, the percentage gain in private consumption from moving from Regime C to A is around 1.9 percent, while the percentage gain in private consumption from moving from Regime C to B is around 1.2 percent. Hence, scenario C, where all types of government spending rise by the same proportion and are financed by higher income taxes, is clearly the worst regime.

Therefore, the policy implication is that if the government aims to raise the share of public education spending above the data average, in terms of

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21 These effects are confirmed by the behaviour of other stationary variables and the study of impulse response functions (Angelopoulos, Malley and Philippopoulos 2007).
lifetime utility, Regime A welfare dominates B, which in turn dominates Regime C. And symmetrically opposite: if the government aims to decrease the share of public education spending below the data average, in terms of lifetime utility, Regime C welfare dominates B, which in turn dominates Regime A.

5.2 Effects of higher uncertainty

This subsection examines the effects of changes in uncertainty, first, on the welfare maximizing share of public education spending and then on the welfare differences between policy regimes for different values of education spending.

Welfare maximizing education spending across regimes

Recall that there are two sources of uncertainty in our model: the shock to government education spending innovations whose standard deviation is $\sigma_e$ in Equation (11), and the shock to TFP innovations whose standard deviation is $\sigma_a$ in Equation (12). We can refer to these two sources of uncertainty generically as $\sigma_u$. For example, when $\sigma_u = 0$, the model is deterministic. When $\sigma_u = 1$, the size of the shocks to productivity and public education spending is equal to $\sigma_a$ and $\sigma_e$, respectively.

In Table 2, we report the change in public education spending share, $\Delta g^e$, that is required to maximize lifetime utility, $V$ when $\sigma_u$ increases and the associated change in $V$ at that point. All changes are calculated relative to the deterministic case.

Table 2 suggests that relative to the deterministic model, increases in uncertainty raise the public education spending share that is required to maximize lifetime utility and that the latter falls. In this set of experiments, Regime A experiences the most welfare losses and the largest increases in public education spending followed by Regimes B and C, respectively.22

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22 A further quantitative assessment, which seeks to explain these differences in welfare across regimes is provided in the next sub-section.
Falling maximum welfare in all three regimes in the face of increased uncertainty is not surprising given that our calibration of utility (i.e. \( \sigma > 1 \)) allows for precautionary saving. The rise in the welfare maximizing education spending shares simply reflects that at higher levels of uncertainty, more resources are available via increased precautionary saving for either public or private investment.

**Welfare differences between regimes**

We next examine the effects of increases in \( \sigma_e \) while keeping \( \sigma_a \) at its data estimate, and *vice versa* for the TFP shock. We present results for \( \tilde{\sigma}^e = 4.5 \) percent, which is the welfare maximizing share under Regime B, and \( \tilde{\sigma}^e = 6 \) percent, which is the welfare maximizing share under Regime A. Recall that 4.5 percent is below the data average, while 6 percent is above the data average.

The results are shown in Figure 2a. Increases in uncertainty of any type do not change the qualitative results obtained above regarding which regime is preferred. In other words, Regime A welfare dominates Regime B for a \( \tilde{\sigma}^e \) share of 6 percent, as \( \xi \) remains positive (and *vice versa* for \( \tilde{\sigma}^e \) at 4.5 percent). Also, Regimes A and B welfare dominate C for a \( \tilde{\sigma}^e \) share of 6 percent as the relevant values of \( \xi \) again remain positive (and *vice versa* for \( \tilde{\sigma}^e \) at 4.5 percent). However, increases in uncertainty have quantitative effects: they affect the magnitude of \( \xi \), i.e. how much one regime is preferred over the other. In general, increases in \( \sigma_e \) or \( \sigma_a \) increase the difference of Regime C from Regimes A and B, while they reduce the difference between A and B. In particular, as \( \sigma_e \) or \( \sigma_a \) rise, the inferiority (resp. superiority) of Regime C gets bigger when \( \tilde{\sigma}^e = 6 \) percent (resp. \( \tilde{\sigma}^e = 4.5 \) percent). On the other hand, as \( \sigma_e \) or \( \sigma_a \) rise, the inferiority (resp. superiority) of B relative to A gets smaller when \( \tilde{\sigma}^e = 6 \) percent (resp. \( \tilde{\sigma}^e = 4.5 \) percent).

In order to understand these results, we also present Figure 2b, which shows the effects of higher \( \sigma_e \) and \( \sigma_a \) on the unconditional means, volatilities and correlation of \( \hat{\gamma}_t \) and \( \hat{\gamma}_t \). These statistics are reported for a \( \tilde{\sigma}^e \) share of 6 percent only, since they are practically the same for the 4.5 percent share. The welfare calculations shown in Angelopoulos, Malley and Philippopoulos (2007) indicate that what matters for welfare, in addition to the steady-state values of \( c_t \) and \( \gamma_t \), is the sum of \( \hat{\gamma}_t \) and \( \hat{\gamma}_t \), which enter positively, the sum of squared \( \hat{\gamma}_t \) and \( \hat{\gamma}_t \), which enter negatively, and their cross-products, which enter negatively. In other words, welfare increases when \( \hat{\gamma}_t \) and \( \hat{\gamma}_t \) increase on average, less volatile and less correlated.

The rest of this subsection interprets these results. We start with the effects of higher \( \sigma_e \) focusing on the case in which \( \tilde{\sigma}^e = 6 \) percent. In all regimes, a higher \( \sigma_e \) increases the average value of \( \hat{\gamma}_t \), decreases the
Figure 2 (a) Uncertainty and welfare across regimes and (b) Composition of welfare and uncertainty
Figure 2 Continued
average value of $\hat{\gamma}_t$, increases volatility, and decreases the correlation between $\hat{\gamma}_t$ and $\hat{c}_t$. The average value of $\hat{\gamma}_t$ decreases because the return to human capital becomes more uncertain, given the increase in the volatility of government spending shocks, so that households put less effort in education and thus less human capital is produced. As the return to physical capital follows the return to human capital, since the two forms of capital are complements in the goods production function, investment is also reduced and consumption is increased. Hence, the increase in the mean of $\hat{c}_t$. Bigger shocks produce bigger reactions so that, naturally, the volatility of $\hat{c}_t$ and $\hat{\gamma}_t$ increase. Finally, the correlation between $\hat{c}_t$ and $\hat{\gamma}_t$ decreases, as they move in opposite directions after a government spending shock.

The increase in $\hat{c}_t$ and the fall in the correlation of $\hat{c}_t$ and $\hat{\gamma}_t$ tend to increase welfare but the other effects, outlined above, act to reduce it. Actually, the negative effects dominate in all regimes, so that welfare falls when uncertainty rises in all regimes, as expected under risk aversion. These effects are more pronounced in Regime C. The reason is that in this regime, shocks to public education spending are propagated and amplified through the economy, as—in this regime—such shocks have a relatively big effect on the tax rate. Hence, Regime C becomes even worse in terms of welfare. This propagation of the public education spending shocks via the tax rate also takes place in Regime B relative to A. However, this works in favour of Regime B. In the latter, relative to A, there are more gains by the increase in the average value of $\hat{c}_t$ and the fall in the correlation between $\hat{c}_t$ and $\hat{\gamma}_t$, so that Regime A gets less attractive.

Overall, the net effect of the above implies that as $\sigma_a$ increases, Regime C gets even worse and the superiority of A over B gets smaller. The latter means that the welfare gains associated with using lump-sum versus distorting taxes to finance public education expenditure decrease.

We continue with the effects of higher $\sigma_a$, focusing again on the case in which $\sigma_a = 6$ percent. With the exception of the mean of $\hat{\gamma}_t$, the effects in Regime C are less pronounced than in the previous case. The reason is that, in all regimes, this shock does not affect the tax rate, so that the above amplification mechanism does not work. A second feature is that the average $\hat{\gamma}_t$ increases as $\sigma_a$ increases. The volatility of total factor productivity shocks hurts wage income and hence makes future labour income more uncertain. In order to smooth labour income, optimizing agents react by putting more effort in human capital, hence increasing their own productivity and making future earnings less dependent on total factor productivity. This results in an increase in human capital—hence the increase in $\hat{\gamma}_t$. However, the increase in $\hat{\gamma}_t$ is smaller in Regime C than in A and B. This happens because—for given $\sigma_a$—there is higher volatility in the tax rate under Regime C driven by shocks to public education
(recall that $\sigma_e$ remains at its data average during this experiment), so that the future returns on human capital are more volatile and so education effort is discouraged. A third feature is that the mean of $\tilde{c}_t$ falls. This occurs since, given the complementarities between physical and human capital, investment in the former rises in all regimes and therefore the mean of $\tilde{c}_t$ falls. A fourth feature is that, as TFP shocks affect growth and consumption in the same direction, the correlation between $\tilde{c}_t$ and $\tilde{y}_t$ increases as $\sigma_a$ rises.

Overall, the net effect is as that of $\sigma_e$ above; namely, as $\sigma_a$ increases, Regime C gets even worse and the superiority of A over B gets smaller. As above, this implies that there are smaller welfare gains associated with lump-sum versus distorting taxes.

6 Conclusions and Extensions

In this article, we have examined the importance of public education spending, under human capital externalities, for aggregate outcomes. We generally found that the pattern between public education expenditure and long-run growth, as well as the pattern between public education expenditure and lifetime utility, are inverted-U curves (Laffer curves) with the peak of the curves giving the growth-maximizing and the welfare-maximizing public education expenditure as share of output. Since public education spending crowds-out private consumption, the welfare maximizing public education share is found to be around the data average and is thus much smaller than the growth maximizing one. At current levels of spending, increases in public education spending can enhance welfare only if they are accompanied by changes in the government tax-spending mix. For instance, welfare gains can be made if the composition of public spending is altered in favour of education spending relative to the other components of total government spending, without increases in distorting taxes.

In our companion paper for the UK, Angelopoulos, Malley and Philippopoulos (2008), we have allowed for a more detailed tax-spending mix. Instead of employing a single distorting income tax, we distinguish among taxes on capital income, labour income and private consumption. Also, instead of putting all other types of government spending—except public education—into the same basket, we distinguish among expenditure on public education (that augments private human capital), public infrastructure (that provides production externalities to private firms) and public consumption (that provides direct utility to households). We then reassess the growth and welfare implications when there are changes in the tax policy mix [e.g. we reduce income (capital or labour) taxes and increase
consumption taxes]. Our key results do not appear to be affected by a more detailed public finance structure.

References


