# Interplay of Public and Private Educational Spending: Macroeconomic Implications

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**Abstract**

This paper examines how the composition of education financing influences economic performance and inequality. I develop an overlapping-generations model with heterogeneous agents in which human capital is accumulated through both public and private education spending. The model predicts that shifting the financing mix toward public provision fosters economic growth and reduces income inequality. These predictions are tested using cross-country dynamic panel data models. The empirical results show that a larger public-private education spending gap, where public spending exceeds private, significantly increases GDP per capita and lowers disposable income inequality. The findings underscore that not only the level but also the structure of education financing plays an important role in shaping macroeconomic and distributional outcomes.

**Keywords:** Human Capital · Income Inequality · GDP per capita · Education
**JEL Classification:** H52 · I21 · I22 · I24 · O40

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# 1 Introduction

In recent years, many countries have seen an increase in income inequality (Alvaredo et al. 2018b) and a decrease in intergenerational mobility (Narayan et al. 2018). According to Hassler et al. (2007), these trends may be linked to problems with the educational system, specifically in terms of the quantity and quality of education. Because education is a key channel for equalizing opportunities, the way it is financed, through public or private means, has significant implications for long-run growth and distribution. This paper focuses on the macroeconomic consequences of how education is funded, and in particular on the balance between public and private educational expenditures. These questions are not merely theoretical: in the Netherlands, for instance, a 2015 reform replaced universal student grants with income-contingent loans, sparking debate over access and inequality (de Gendre & Kabátek 2021), while in Germany, tuition fees were abolished across all federal states by 2014 after a period of reintroductions (Minor 2023). Such policy shifts illustrate the importance of understanding how the public–private mix of education finance affects both growth and distribution.

A central motivation for focusing on the public–private education spending gap is that the composition of education finance shapes access to human capital in ways that total expenditure does not capture. When education systems rely heavily on private spending, households face higher out-of-pocket costs, which can discourage investment among students from low-income backgrounds, particularly where credit markets are imperfect (Chetty et al. 2014). By contrast, a higher public share in education spending lowers financial barriers, broadens access, and supports a more equitable accumulation of skills. OECD evidence shows that systems with stronger public cost-sharing exhibit higher intergenerational mobility, smaller skill gaps, and better learning outcomes among disadvantaged groups (OECD 2018a).

The financing structure also interacts with long-run growth dynamics. In systems where education is largely privatized, only wealthier families can invest optimally in human capital, potentially slowing aggregate growth when a significant share of the population remains credit-constrained. Public financing helps relax these constraints and encourages broader participation in skill formation. At the same time, financial composition affects incentives: private provision may enhance quality through competitive pressures, whereas public provision ensures minimum standards and limits socio-economic segregation (Hanushek & Woessmann 2011). These considerations underline why the balance between public and private spending, rather than either component alone, is central to understanding the evolution of growth and inequality.

In economies with high levels of inequality and a strong reliance on private spending for education, financial barriers may prevent many individuals from investing adequately in human capital.[1] This underinvestment reduces the accumulation of aggregate human capital and may slow economic growth. At the same time, unequal educational opportunities can reinforce skill polarization, widening the income gap between skilled and unskilled workers and perpetuating poverty traps. The central hypothesis of this research is that economies that prioritize public over private spend-

[1] A review on the effects of credit constraints on human capital, social mobility, and income inequality is presented by Lochner & Monge-Naranjo (2011).

ing on education will experience stronger and more inclusive economic growth, along with reductions in income inequality.

Human capital investments, including their sources of funding, are a crucial means of promoting growth and equality.[2] These investments can be made through both private and public institutions, depending on availability, affordability, and institutional design. The preference for public or private education varies by country and has been studied extensively. For example, Glomm & Ravikumar (2003) and Dotti (2019) show that public education can reduce inequality under certain conditions. De la Croix & Doepke (2009) argue that, in unequal societies, wealthier households may opt for private education, indirectly affecting the quality of public schooling. Interestingly, when human capital is initially more equally distributed, a system based largely on private education can sometimes generate higher economic growth (De la Croix & Doepke 2004). These contributions show the complex interplay between funding regimes and economic outcomes.

Glomm & Ravikumar (1992) provides important insights into how public and private education regimes affect both growth and inequality. In systems dominated by private spending, income per capita can be higher when inequality is initially low, whereas under public regimes, inequality declines more rapidly. However, much of the existing literature examines either public or private education in isolation. A key gap is the lack of research on the interaction between public and private education spending. This leads to the central questions of this paper: given that education is almost always funded through a combination of public and private sources, what is the optimal balance? How does shifting the mix toward public spending affect GDP per capita and inequality? And from a policy perspective, is it desirable to spend more on public and less on private education? Answering these questions can provide valuable guidance for designing education finance systems that support both growth and equity.

To address these questions, this paper combines a simple theoretical framework with an empirical analysis. The theoretical contribution is an overlapping-generations (OLG) model in which growth is driven by human capital, accumulated through both publicly financed and parentally financed education. This paper differs from earlier contributions such as De la Croix (2001) by focusing not on credit frictions but on the explicit policy tradeoff between public and private financing. The novelty of the framework is in highlighting how this financing mix affects growth, inequality, and welfare. The model predicts that a greater reliance on public spending promotes growth and reduces inequality, but that welfare gains peak at an intermediate level of public provision. This welfare dimension allows us to link normative questions directly to the theory.

This theoretical analysis is complemented by an empirical application using cross-country panel data. The empirical strategy examines whether the composition of education spending, public versus private, is systematically associated with growth and inequality outcomes. Dynamic panel data methods are employed to mitigate concerns about endogeneity and persistence, while limitations of data availability on private spending are carefully discussed. The results from the empirical analysis broadly

[2]For an updated review on returns to human capital investments see Heckman et al. (2018), Flabbi & Gatti (2018), and Rossi (2020). Concerning economic growth, check Ogbeifun & Shobande (2021).

support the theoretical predictions. Countries with higher levels of public spending relative to private spending tend to achieve higher GDP growth and lower inequality, though the effects are not unlimited and appear to flatten beyond a certain threshold. The implication is that a predominantly public role in financing education is growth- and equity-enhancing, but policy design must also take into account efficiency concerns and the complementary role of private contributions.

By analyzing both theoretical mechanisms and empirical evidence, this paper contributes to the literature on education, growth, and inequality and offers new insights for the design of education financing policies. It emphasizes that the composition of education spending matters, not just the total level. The remainder of the paper is organized as follows. Section 2 presents the theoretical model and its analysis. Section 3 provides the empirical application. Section 4 discusses results, policy, and future research. Lastly, Section 5 concludes.

## 2 Theoretical Model

The novelty of the model lies in examining the interplay between public and private investment in education, rather than comparing fully public and fully private systems. The analysis focuses on a realistic policy trade-off: how the relative balance between these two sources of finance shapes economic growth and income inequality. In practice, households rely on both public and private inputs for human capital formation: public provision of core schooling complemented by parental spending on health, tutoring, extracurricular activities, or educational technology.

The theoretical framework follows the structure of the OLG model in De la Croix (2001) but shifts the emphasis to a different policy dimension, namely the composition of education financing. Unlike earlier work that concentrates on credit frictions, the model abstracts from borrowing constraints and instead highlights how the public–private financing mix and its welfare implications influence human capital accumulation. Human capital is built jointly through publicly funded inputs and parentally financed investments, with intergenerational transmission reinforcing these effects, thereby generating sustained growth and shaping the distribution of income.

### 2.1 Environment

Consider an overlapping-generations economy in which individuals live for three periods and die at the end of the third. For simplicity, each individual has one parent and one child, so there is no population growth. The population size is normalized to one. Individuals share identical preferences and abilities; differences across households arise only from their level of human capital, and thus their income. In the first period of life, agents neither work nor consume; they only acquire human capital for adulthood. In the second period, agents inelastically supply one unit of labor, earn wages, consume, and save for retirement. In the third period, they retire and consume from their savings. At $t = 0$, the initial generation is endowed with human capital $h_{j0}$. To focus on the interplay between public and private financing of education, the model abstracts from credit markets.

### 2.1.1 Household Optimization

Agents born in period $t-1$ (generation $t$) have preferences defined over three components: household consumption in adulthood $c_t$, consumption in retirement $d_{t+1}$, and investment in their child's education $e_t$. Their lifetime utility is given by

$$\max_{c_t, d_{t+1}, e_t} \quad u(c_t, d_{t+1}, e_t) = \ln(c_t) + \beta \ln(d_{t+1}) + \gamma \ln(e_t), \tag{1}$$

where $\beta$ is the discount factor for retirement consumption and $\gamma$ captures the weight households place on children's education. Adults face two budget constraints.[3] In adulthood, income is earned from inelastically supplying $h_t$ units of efficient labor at wage $w_t$, net of an income tax $\tau_t$. This income is allocated to consumption, savings, and investment in children's education:

$$(1-\tau_t)\, w_t\, h_t = c_t + s_t + e_t. \tag{2}$$

In retirement, agents consume out of their savings with gross interest factor $R_{t+1} = 1 + r_{t+1}$:

$$R_{t+1} s_t = d_{t+1}. \tag{3}$$

In the model, human capital is accumulated during the first life stage, when agents make no independent choices about time use or consumption. Instead, their stock of human capital depends on parental inputs and public resources. The production function for human capital is

$$h_t = \Psi\, g_{t-1}^{\lambda}\, e_{t-1}^{\theta}\, h_{t-1}^{1-\lambda-\theta}, \tag{4}$$

where $0 < \lambda + \theta < 1$ and $\Psi > 0$ is a productivity parameter. Current human capital depends on public spending $g_{t-1}$, private educational investment $e_{t-1}$, and inherited parental human capital $h_{t-1}$. This formulation captures the intergenerational externality of parental human capital, generating endogenous growth. The initial adult generation is endowed with $h_{i0} > 0$, distributed according to a log-normal distribution $\Gamma_0(\cdot)$ with mean $\mu_0$ and variance $\sigma_0^2$. In each period, average human capital is

$$\bar{h}_t \equiv \int h_t \, d\Gamma_t(h_t), \tag{5}$$

which, under population normalization, also equals the aggregate supply of efficient labor. Importantly, public ($g_t$) and private ($e_t$) educational investments are not simply alternative procurement channels for identical services. Rather, they represent qualitatively distinct inputs, public school provision versus private tutoring, extracurricular activities, or health investments, that complement each other in building human capital. Formally, the Cobb–Douglas specification in equation (4) implies that public and private inputs are strict complements in human-capital formation: the marginal product of each input is increasing in the level of the other, and human capital collapses if either input is zero. Thus, $g_t$ and $e_t$ are not substitutes for a single educational service but represent distinct inputs whose joint presence is required for effective skill

[3] The first-order conditions of the household problem are presented in the Appendix A.1.

accumulation.

### 2.1.2 Firms

Production is carried out by competitive private firms using physical capital $K_t$ and human capital $H_t$. The production function is

$$Y_t = K_t^{\alpha} H_t^{1-\alpha}, \tag{6}$$

with $0 < \alpha < 1$ and full depreciation of capital each period. The capital–efficient-labor ratio $k_t = K_t/H_t$, output per unit of efficient labor is $y_t = k_t^{\alpha}$. Competitive factor markets imply that factors are paid their marginal products:

$$w_t = (1-\alpha)k_t^{\alpha}, \qquad R_t = \alpha k_t^{\alpha-1}. \tag{7}$$

### 2.1.3 Government

An infinitely lived government provides public inputs into human capital. Per-capita public educational spending $g_t$ is financed by a proportional income tax $\tau_t$ levied on adult labor income:

$$g_t = \tau_t w_t \bar{h}_t. \tag{8}$$

Each young individual receives the same $g_t$. This term can be interpreted broadly to include schooling as well as other public services that contribute to human capital formation, such as healthcare or training programs.

## 2.2 Equilibrium and Dynamics

An equilibrium consists of sequences $\{h_t\}, \{c_t\}, \{d_t\}, \{e_t\}, \{s_t\}, \{w_t, R_t\}, \{g_t\}$ and distributions $\{\Gamma_t\}$ such that: (i) households optimize given prices; (ii) firms satisfy (7); (iii) the government budget constraint $g_t = \tau_t w_t \bar{h}_t$ holds; (iv) labor and capital markets clear.

Using the household first-order conditions (Appendix A.1), market clearing implies

$$K_{t+1} = \frac{\beta}{1+\beta+\gamma}(1-\tau_t) w_t \bar{h}_t. \tag{9}$$

Substituting optimal private education into the human capital accumulation function (4) yields

$$h_{t+1} = \Psi\, \tau_t^{\lambda} \left( \frac{\gamma(1-\tau_t)}{1+\gamma+\beta} \right)^{\theta} w_t^{\lambda+\theta}\, \bar{h}_t^{\lambda}\, h_t^{1-\lambda}. \tag{10}$$

Expression (10) captures the central mechanism: higher taxes increase public human capital investment ($g_t$) but reduce disposable income, which lowers private educational investment ($e_t$) and savings ($s_t$). The net effect depends on the relative elasticities $\lambda$ and $\theta$. This framework mirrors the empirical strategy in Section 3, which directly studies how the public–private mix of education finance affects income inequality and GDP per capita. The following section introduces a welfare analysis to evaluate these trade-offs more fully.

## 2.3 Numerical Simulation

The numerical simulation serves to illustrate and quantify the model's mechanisms in a realistic environment, without aiming to deliver precise quantitative predictions. The analytical results establish how the public–private mix in education finance affects growth and inequality, but they do not indicate the magnitude or persistence of these effects, nor how sensitive they are to key parameters. Calibration anchors the model in observed OECD patterns so that the simulated dynamics reflect plausible economic environments rather than hypothetical parameter choices. The exercise, therefore, clarifies which predictions are quantitatively robust, such as the strength of the growth response, the speed of inequality reduction, and the trade-offs introduced by taxation, and helps identify which relationships are likely to matter in the empirical analysis that follows.

The structural parameters of the model are calibrated to match empirical counterparts, with targets summarized in table 1. Given the model's focus on the composition of education finance and its effects on household consumption and savings, the chosen empirical moments include public and private education expenditures, net household saving rates, household education spending as a percentage of GDP, and the income Gini coefficient. These targets are based on averages for OECD countries in 2017. The calibrated parameters are $\gamma = 0.03$, $\theta = 0.25$, $\lambda = 0.25$, $\Psi = 0.63$. On the household side, $\beta = 0.95$ follows the standard of the literature. On the firm side, the capital share parameter $\alpha$ is set to 0.3 (King & Rebelo 1999). The labor income tax $\tau$ is set to 0.157, in line with OECD averages (OECD 2018b).

Table 1
Calibration Targets

| | Model | Data |
|---|---|---|
| Public Expenditure (% of GDP) | 4.71 | 4.02 |
| Private Expenditure (% of GDP) | 0.73 | 0.81 |
| Saving Rates (% of GDP) | 9.63 | 5.80 |
| Education-Household Spending (% of GDP) | 5.44 | 2.41 |
| Income Gini Coefficient | 5.00 | 5.40 |

For simplicity, the initial adult generation is split into two groups with high and low human capital endowments, $h_{H_0}$ and $h_{L_0}$. This stylized division highlights differences in outcomes linked to initial inequality. For example, households with higher endowments may treat education as a luxury good and spend proportionally more. As discussed earlier, public and private educational expenditures are not perfect substitutes: public spending represents broad-based provision, while private spending often reflects complementary investments such as tutoring or technology.

Figure A.3.1 summarizes the central findings. Panel (a) shows that higher public education spending raises GDP growth, while Panel (b) illustrates the resulting decline in inequality. Both variables converge as the economy approaches its steady state. These results mirror the analytical mechanism of the model: public investment increases the human capital of low-income households, narrowing the distribution of skills and raising aggregate productivity.

A second implication concerns the composition of education finance. As shown

in Figure A.3.2, GDP per capita rises with the ratio of public to private spending, though with diminishing marginal returns. Taxation, therefore, generates the familiar trade-off: moderate tax rates finance productive public investment, while excessive rates reduce disposable income, private investment, and savings. The numerical results reinforce the model's main conclusion: shifting the financing mix toward public education supports higher long-run growth and lower inequality, subject to standard tax-efficiency considerations.

### 2.3.1 Policy Mix

A key implication of the theoretical model is that the composition of education finance, i.e., the public-private mix, affects the distribution of human capital and, as a consequence, both growth and inequality. To illustrate this mechanism numerically, I consider a simple policy experiment that shifts education finance toward public spending without altering the tax system. The purpose is not to generate precise quantitative predictions, but to show the qualitative response of the calibrated economy. In this policy experiment, education spending is marginally changed by 1%. Public education spending increases slightly faster than in the baseline, while private education spending grows somewhat more slowly. This generates a moderate rebalancing of education finance toward public provision, raising the public share of total education expenditure by roughly 14 percent (Table 2).

The results show that this composition shock produces a modest but clear redistributional effect. Income inequality declines by about 0.7 percent on average. The reduction reflects the mechanism emphasized in the theoretical model: greater public investment eases the effective cost of human capital accumulation for initially disadvantaged households, narrowing the distribution of skills. At the same time, the efficiency effects are negligible. Average GDP per capita increases by approximately 0.08 percent relative to the baseline. This small positive response indicates that shifting the financing mix toward public spending does not generate noticeable efficiency losses in the calibrated economy; if anything, it marginally raises aggregate output by enhancing the human capital of low-income households.

Table 2
Numerical Illustration: Baseline vs. Policy Mix

| | Baseline | Policy Mix | % Change |
|---|---|---|---|
| Public Education Expenditure (% GDP) | 4.71 | 5.36 | +13.8 |
| Private Education Expenditure (% GDP) | 0.74 | 0.73 | −1.2 |
| Total Education Expenditure (% GDP) | 5.45 | 6.09 | +11.7 |
| Saving Rate (% GDP) | 9.64 | 9.71 | +0.7 |
| GDP per Capita (normalized) | 1.000 | 1.001 | +0.08 |
| Inequality (Gini Coefficient, normalized) | 1.000 | 0.993 | −0.72 |

## 2.4 Robustness Checks and Parameter Variations

To evaluate the robustness of the numerical results, alternative values for the key education–productivity parameters $(\lambda, \theta, \gamma)$ are explored. These parameters govern the effectiveness of public and private educational investments in the human capital production function. Across a broad range of values, the qualitative results remain unchanged: higher public spending raises growth and reduces inequality, while economies relying more heavily on private spending exhibit weaker long-run income performance and greater inequality. Although parameter changes affect the short-run magnitude of these responses, the economy converges back to the baseline path in the long run. The full set of sensitivity figures and numerical outputs is reported in Appendix C.

### 2.4.1 Alternative Human Capital Specifications

To ensure that the main results are not specific to the baseline formulation of human capital, I also explore alternative specifications in which public spending interacts with initial human capital or with private education investment. These extensions capture two empirically relevant concerns: public resources may not benefit all individuals equally, and the effectiveness of public spending may depend on how it combines with private expenditures. Testing these possibilities allows the model to accommodate cases where public inputs disproportionately help either high- or low-human-capital households, or where public and private spending act as complements or substitutes. Across all cases, the qualitative findings remain unchanged: directing public resources toward individuals with lower initial human capital raises growth and reduces inequality, and the efficiency–equity trade-off associated with taxation remains robust. The full set of details and figures is provided in Appendix D.

### 2.4.2 Tax System Variations

To verify that the main results are not an artifact of assuming a proportional income tax, I also consider progressive income and capital taxation. These extensions keep the average tax rate unchanged but redistribute the tax burden toward higher-income households, allowing the model to reflect more realistic tax systems. In both cases, the additional revenue is used to finance public education. The results show that progressive taxation reduces inequality without lowering growth: higher-income households contribute more to public investment, which raises the human capital of lower-income households and strengthens aggregate productivity over time. In some cases, GDP per capita increases slightly, as the gains from expanded public education outweigh the potential disincentive effects of higher marginal tax rates. Full numerical results and figures are presented in Appendix E.

The model delivers three broad predictions and clarifies the mechanisms behind them. First, increasing the public share of education financing raises long-run GDP per capita by relaxing investment constraints for low-human-capital households, enabling them to acquire more skills and raising the aggregate stock of human capital. This effect is strongest when public inputs are productive and when private inputs exhibit diminishing returns. Second, a heavier reliance on private spending amplifies

inequality: because private investment is financed out of disposable income, high-income households invest more and transmit higher human capital to their children, widening the skill distribution. Public spending, by contrast, lowers the effective marginal cost of education for disadvantaged households, compressing the human capital distribution and reducing the income Gini coefficient. Third, these conclusions are robust across alternative human capital formulations, parameter variations, and tax structures, all of which preserve the core mechanism that public financing broadens access to skill accumulation.

Together, these mechanisms imply that what matters for aggregate outcomes is not simply the level of education spending, but the relative contribution of public and private inputs. In the model, this public–private mix is an endogenous outcome of household income, tax policy, and the marginal productivity of each type of investment. When public spending lowers the effective cost of education for low-human-capital households, it crowds in their investment and compresses the skill distribution; when private spending dominates, investment responds more strongly to income and the distribution widens.

This leads to two empirical predictions. Countries in which public inputs represent a larger share of total education investment should exhibit (i) higher average human capital and GDP per capita, and (ii) lower income inequality, particularly in the lower tail where credit constraints and low initial human capital bind most tightly. These theoretical implications motivate the empirical analysis in Section 3, which examines whether cross-country differences in the composition of education finance, not just its level, are systematically related to differences in growth and inequality.

## 3 Empirical Analysis

The analysis aims to examine the relationship between public and private expenditure on education and two outcomes: income inequality and GDP per capita. The main strategy for each model is to control for the key factors commonly found in the literature on the topic. However, due to the complexity of these types of analyses, the results can be contradictory. To address these challenges, the system GMM proposed by Arellano & Bover (1995) Blundell & Bond (1998) will be used, as it is a more efficient estimator in the presence of heteroskedasticity. This method combines equations in differences and levels and specifies instruments using lagged differences for level series and lagged levels for differenced series.[4]

The accuracy of the system GMM estimation depends on the validity of its instruments, so it is important to include tests to validate them. The Hansen test is one such test, which checks for correlation between the instruments and residuals. Another issue that arises with small dynamic panel data sets is the number of instruments used. A common suggestion is to keep the number of instruments under the number of countries in the panel. Using more instruments can lead to the overfitting of endogenous variables and decrease the reliability of the overidentifying restrictions test. Additionally, the AR(2) test for serial correlation in the error term will be used to control for a second-order correlation between the error and the first-differenced

[4]For a complete overview of dynamic models, see Kiviet (2020) and Bond (2002).

equation.

## 3.1 Empirical Framework

### 3.1.1 Income Inequality

The first dependent variable is income inequality, and it is measured by the Gini coefficient of disposable income. The baseline specification for the dynamic panel data analysis of income inequality is presented by:

$$\log \mathrm{GINI}_{it} = \beta\, \mathrm{PP}_{it} + \alpha_1 \log \mathrm{GINI}_{i,t-1} + \alpha_2 \log \mathrm{GDP}_{it} + \alpha_3 X_{it}^{gini} + \gamma_i + \epsilon_{it}, \qquad (11)$$

where the subscripts $i$ and $t$ denote a particular country and time, respectively. The variable $GINI_{it}$ represents the logarithm of the disposable income inequality measured by the Gini coefficient, the one period lagged value, $GINI_{i,t-1}$, is included, the main independent variable $PP_{it}$ is the difference of public minus private tertiary education spending, $logGDP_{it}$ is the logarithm of the GDP per capita and $X_{it}^{gini}$ includes control variables such as government consumption, employment in agriculture, adolescent fertility, employment, years of compulsory education, and governance. Also, $\gamma_i$ is a country-specific control, and $\epsilon_{it}$ accounts for a random error term.

The control variables are included in $X_{it}^{gini}$ for brevity and were obtained from the vast literature on the effects of income inequality on economic growth. Some of this literature includes, for example Anderson et al. (2017), which explores the effects of government spending on income inequality in low and middle-income countries and suggests a positive correlation between total government consumption and income inequality. Employment in agriculture is considered a relevant channel of income inequality due to sector dualism; the shift from agriculture to the non-agricultural sector generates between-sector inequality, thus contributing to inequality (Alderson & Nielsen 2002). Adolescent fertility affects the human capital accumulation of young individuals and their future incorporation into the labor market, thus generating higher levels of inequality (Kearney & Levine 2012).

The relationship between institutional quality and a more equal distribution of income suggests that lower-income families are not given the protection from institutions to overcome certain adverse situations, but the high-income families wield strong political influence (Chong & Gradstein 2007). The deterioration of the employment conditions for unskilled workers affects a higher degree of the low-income share of the population, thus, increasing inequalities (Glyn 1995). Government consumption takes care of the purchase of goods and services that include the compensation of public employees. This makes government consumption a factor that might influence the distribution of income, as it affects public spending (De Mello & Tiongson 2006).

### 3.1.2 GDP per capita

The second part of the analysis includes GDP per capita. The results are estimated similarly to those for the income inequality, with the difference that $X_{it}^{gdp}$ is a specific set of controls better suited for this dynamic panel analysis. The baseline specification

follows:

$$\log \text{GDP}_{it} = \Psi \, \text{PP}_{it} + \theta_1 \log \text{GDP}_{i,t-1} + \theta_2 \log \text{GINI}_{it} + \theta_3 X_{it}^{gdp} + \gamma_i + \upsilon_{it} \qquad (12)$$

where $logGDP_{it}$ is the logarithm of the GDP per capita as a dependent variable, followed by the one-period lagged value $logGDP_{i,t-1}$. The main independent variables are $PP_{it}$, the income inequality measure $GINI_{it}$, and $X_{it}^{gdp}$ are similar to those for 11. However, $X_{it}^{gdp}$ includes control variables for a GDP growth analysis, such as tertiary enrollment in education, governance, foreign direct investment (FDI), gross fixed capital formation (GFCF), trade, inflation, employment in agriculture, employment rate, and government expenditure on education.

Tertiary enrollment is used as a measure of human capital. Higher education enhances the skills of individuals to use in the labor market, abilities, helps in the adoption of new technologies, and increases innovation in a country. It is an important condition to achieve sustainable growth (Benhabib & Spiegel 1994). Governance and GDP growth are highly and positively correlated as governance sets conditions for political stability and promotes higher GDP growth (Islam & McGillivray 2020). FDI has been identified as an important source of financing for some countries and as a factor driving economic growth (Li & Liu 2005). Other important engines of economic growth relevant in the literature are gross fixed capital formation (Meyer & Sanusi 2019), agriculture (Tiffin & Irz 2006), and employment rate Eriksson (1997). Similarly, controlling for Trade openness is necessary for the growth literature as shown by Dollar & Kraay (2003), indicating its important role on growth in the very long run, and even bigger over shorter horizons. Changes in growth rates due to inflation, over long periods, are suggested by Barro et al. (1996) to have dramatic effects on standards of living.

An additional issue presented in these two specifications is that there are variables included in the analysis that might be endogenous. For this reason and to exploit the versatility of the system GMM, these potentially endogenous variables are dealt with by instruments. In this case, besides income inequality, the GDP per capita and the main independent variable addressing education sources of investment are instrumented and validated by different tests.

## 3.2 Data and Descriptive Evidence

This analysis uses a balanced panel dataset with 37 countries spanning 12 years from 2008 to 2019.[5] Income inequality is measured using the Gini coefficient and sourced from the World Bank Database, together with the GDP per capita. As data on aggregate private educational spending is difficult to obtain, the study relies on the OECD Education Statistics database to provide sufficient data on private and public expenditures on tertiary education. The independent variable of interest, $PP_{it}$ in equations (11) and (12) or "Public-Private Educ. Ex." in the analysis, represents the difference between private and public spending on tertiary education. A negative value indicates that private spending is higher than public spending, while a positive value indicates

[5]The list of countries is detailed in table B.0.1 in the Appendix.

the opposite. This variable provides insights into the prevalence of a particular source of education in a given country.[6] The summary statistics and sources and definitions of the remaining variables used in the analysis are provided in Tables B.0.2 and B.0.3 in the Appendix.

Another important aspect to consider in a cross-country analysis is the inherent differences of each country and how they change over time. A descriptive view for this is provided in Figure B.0.15 for GDP per capita and Figure B.0.16 for income inequality. The left panel of these figures shows how these variables vary per country, and the right panel shows the variability per time. The average value, either per country or time, displays how heterogeneous the values are. The disposable income inequality variable in Figure B.0.15 shows a great level of heterogeneity between countries but a very similar mean value for all the years of the analysis. Similar results are found in Figure B.0.16 for GDP per capita. These insights are useful for the development of the regression results.

## 3.3 Empirical Results

This subsection presents the results obtained from equations (11) and (12). The econometric models are estimated using a system GMM dynamic panel data, and due to the heterogeneity found in the descriptive results of the figure B.0.15 and B.0.16, it is only the use of country fixed effects in both analyses. The system GMM estimation results are obtained by including only 1 to 2 lag periods in all the regressions. To validate the regression results, some tests are also reported. The Hansen test examines the validity of the instruments, where the null hypothesis is that the instruments are uncorrelated with the residuals, and the AR(2) test checks whether the error term is serially correlated, where its null hypothesis is that the error terms in the first-differenced regression show no second-order serial correlation. The results include two separate dependent variables, income inequality and GDP per capita.

### 3.3.1 Income Inequality

Table 3 reports the baseline dynamic specification in column (1), estimated following equation (11). The dependent variable is the log of the disposable income Gini. Consistent with the persistence typically observed in inequality dynamics, the coefficient on the lagged dependent variable is large and highly significant (0.92). The public–private education expenditure differential is negative and statistically significant, indicating that a widening gap, reflecting higher public relative to private education investment, is associated with lower income inequality. A one-unit increase in the public–private differential is associated with a 6.4 percent reduction in the disposable income Gini.

All regressions treat the disposable income Gini, GDP per capita, and the public–private expenditure differential as endogenous. Their lags serve as internal instruments, while all remaining controls enter as external instruments. The full list of instruments is provided in Section B of the Appendix. The specification passes

[6] A clear visual intuition can be obtained in Figure B.0.14 in the Appendix.

Table 3
Dynamic Regression: Income Inequality

| | Log Disposable Income Gini | |
|---|---|---|
| | (1) | (2) |
| L.Log D. Income Gini | 0.921*** | |
| | (0.056) | |
| L2.Log D. Income Gini | | 0.703*** |
| | | (0.131) |
| Public–Private Gap | −0.064*** | −0.131*** |
| | (0.021) | (0.039) |
| Observations | 226 | 202 |
| Hansen p-value | 0.291 | 0.171 |
| AR(2) p-value | 0.887 | 0.064 |
| No. Instruments | 20 | 22 |
| No. Countries | 23 | 25 |

Note: The table reports the effects of education investment on the Log Disposable Income Gini. Standard errors are Windmeijer-corrected and robust to heteroscedasticity. Constant, country effects, and control variables are included but not reported for brevity. Significance levels are: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

standard diagnostic tests: the Hansen test does not reject instrument validity, and the AR(2) test fails to detect second-order serial correlation.

Column (2) presents a specification that replaces the first lag of the Gini with its second lag, allowing for a slower adjustment process. Including a second lag of inequality is an important robustness check because inequality is a slow-moving variable and its persistence can absorb substantial variation in dynamic GMM models. The equalizing effect of public–private education expenditure remains negative and significant under this alternative dynamic structure, demonstrating that our main finding does not depend on the specific lag order and is robust to slower adjustment processes. Countries with relatively higher public education spending experience lower levels of income inequality. The two dynamic specifications demonstrate that the main result, the equalizing effect of higher public relative to private education investment, is robust to alternative assumptions about the persistence of income inequality and the structure of the dynamic model.

Table 4 presents an alternative set of dependent variables—income shares for the top 1%, top 10%, and bottom 50%, to assess whether the baseline findings are robust across different dimensions of the income distribution. These measures, drawn from the World Inequality Database Alvaredo et al. (2018a), provide a complementary view of inequality by focusing directly on distributional shares rather than a summary index. The specification follows the same dynamic structure as the baseline model, with appropriately adjusted controls.

Across all three columns, the lagged dependent variable remains large and highly persistent, as expected for distributional shares. More importantly, the coefficient on the public–private education expenditure gap retains its sign and significance in each specification. For the top 1% and top 10%, a larger public–private expenditure differential is associated with reductions of 2.3% and 3.3% in their income shares, respectively. These results indicate that greater public investment relative to private

Table 4
Dynamic Regression: Income Distribution Shares

| | Shares of Income Distribution | | |
|---|---|---|---|
| | Top 1% | Top 10% | Bottom 50% |
| L.Log Top 1% | 0.920*** | | |
| | (0.043) | | |
| L.Log Top 10% | | 0.968*** | |
| | | (0.032) | |
| L.Log Bottom 50% | | | 0.945*** |
| | | | (0.036) |
| Public-Private Gap | −0.023* | −0.033* | 0.024* |
| | (0.013) | (0.019) | (0.013) |
| Observations | 226 | 217 | 215 |
| Hansen p-value | 0.346 | 0.854 | 0.258 |
| AR(2) p-value | 0.183 | 0.414 | 0.443 |
| No. Instruments | 26 | 24 | 24 |
| No. Countries | 29 | 25 | 24 |

Note: The table reports the effects of education investment on Column (1), the log of the top 1%, (2) the log of the top 10%, and (3) the bottom 50% of the income distribution. Standard errors are Windmeijer-corrected and robust to heteroscedasticity. Constant, country effects, and control variables are included but not reported for brevity. Significance levels are: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

investment tends to compress the upper end of the distribution.

For the bottom 50%, the effect is reversed: the same differential increases their income share by 2.4%. This pattern is consistent with the mechanism proposed in the main analysis: public educational spending disproportionately raises the human capital of lower-income groups, who rely primarily on wage income.

Empirical evidence shows that the bottom half of the income distribution derives the vast majority of its income from wages, whereas top income groups rely more heavily on capital, business income, and financial returns Piketty et al. (2018). This structural asymmetry helps explain why educational investment generates stronger distributional effects toward the lower tail. Taken together, these results corroborate the baseline findings: the public–private education expenditure gap reduces inequality not only through a summary measure like the Gini coefficient, but also through a direct reallocation of income shares from the top quantiles to the bottom half of the distribution.

### 3.3.2 GDP per capita

The results of the dynamic output specification in equation (12) and the corresponding robustness checks are presented in Table 5. As with the inequality regressions, GDP per capita, the education spending gap, and the remaining endogenous covariates are instrumented using their own lags within the System GMM framework, while additional variables serve as external instruments. A detailed list of all instruments used across specifications is provided in Section B of the Appendix.

Column (1) reports the baseline specification using the first lag of log GDP per capita. The coefficient on the lagged dependent variable is very close to unity (0.99), reflecting the high persistence typical of macroeconomic output series. The main vari-

Table 5
Dynamic Regression: Log GDP per capita

| | Log GDP per capita | |
|---|---|---|
| | (1) | (2) |
| L.Log GDP p.c. | 0.990*** | |
| | (0.013) | |
| L2.Log GDP p.c. | | 0.972*** |
| | | (0.017) |
| Public-Private Gap | 0.025** | 0.030* |
| | (0.011) | (0.016) |
| Observations | 233 | 221 |
| Hansen p-value | 0.077 | 0.054 |
| AR(2) p-value | 0.155 | 0.043 |
| No. Instruments | 27 | 27 |
| No. Countries | 32 | 32 |

Note: The table reports the effects of education investment on the Log GDP per capita. Standard errors are Windmeijer-corrected and robust to heteroscedasticity. Constant, country effects, and control variables are included but not reported for brevity. Significance levels are: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

able of interest, i.e., the gap between public and private education expenditure, remains positive and statistically significant, with an estimated elasticity of 2.5 percent. This confirms the core finding that a greater relative commitment to public education is associated with higher levels of economic output.

Column (2) extends the dynamic structure by replacing the first lag with the second lag of log GDP per capita. The persistence remains extremely strong (0.97), consistent with slow-moving convergence dynamics. The coefficient on the public–private spending gap remains positive and significant, with an elasticity of roughly 3 percent, slightly larger than in the baseline model. The stability of this estimate across alternative lag structures indicates that the relationship between education expenditure composition and GDP per capita is not driven by short-term fluctuations in output dynamics.

Table 6 assesses whether the main findings for GDP per capita extend to an alternative measure of economic performance: GDP per hour worked, a standard indicator of labor productivity. Given the known strong correlation between GDP per capita and GDP per hour, this provides a meaningful validation of the baseline results. Column (1) reproduces the GDP-per-capita specification for reference. Columns (2) and (3) replace the dependent variable with the log of GDP per hour, first using a specification with one lag and then with two lags to capture slower productivity adjustment. Across both models, the lagged dependent variable remains highly persistent, with coefficients close to unity, consistent with the slow-moving dynamics of productivity.

Crucially, the coefficient on the public-private education expenditure gap remains positive and statistically significant in all specifications. The estimated magnitudes range from 4.0 percent in column (2) to 6.5 percent in column (3), slightly larger than the corresponding effect on GDP per capita (2.5 percent). This suggests that the relative strength of public education investment may influence productivity even more directly than overall economic output. Overall, the GDP-per-hour results reinforce

Table 6
Dynamic Regression: Log GDP per hour

| | GDP pc | GDP ph | GDP ph |
|---|---|---|---|
| L.Log GDP p.c. | 0.990*** | | |
| | (0.013) | | |
| L.Log GDP p.h. | | 0.967*** | |
| | | (0.029) | |
| L2.Log GDP p.h. | | | 0.996*** |
| | | | (0.060) |
| Public-Private Gap | 0.025** | 0.040* | 0.065* |
| | (0.011) | (0.020) | (0.038) |
| Observations | 233 | 246 | 226 |
| Hansen p-value | 0.077 | 0.102 | 0.285 |
| AR(2) p-value | 0.155 | 0.353 | 0.132 |
| No. Instruments | 27 | 26 | 26 |
| No. Countries | 32 | 35 | 35 |

Note: The table reports the effects of education investment on the log of GDP per hour. Standard errors are Windmeijer-corrected and robust to heteroscedasticity. Constant, country effects, and additional controls are included but not reported for brevity. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

the main conclusion: countries allocating relatively more resources to public education tend to experience stronger economic performance, whether measured through income per person or labor productivity.

## 3.4 Additional Empirical Analysis: Robustness

Tables C.0.6 and C.0.7, in the Appendix, present a common set of robustness checks that evaluate whether the baseline results are sensitive to alternative functional forms of the public–private education expenditure measure. Columns (1) and (2) introduce a squared term of the public–private expenditure gap to test for potential nonlinearities. For GDP per capita, the quadratic term is small and statistically insignificant, indicating no detectable curvature in its relationship with economic performance. For inequality, by contrast, the squared term is positive and significant, suggesting diminishing marginal reductions in inequality as the gap becomes very large. In both cases, the linear term retains its expected sign and statistical significance, implying that the direction of the baseline effect is unchanged.

Columns (3) incorporate the total volume of education spending (public + private). This specification tests whether the baseline results are driven by overall expenditure levels rather than the composition of funding. In both tables, total education spending is statistically insignificant, while the main coefficient on the public–private gap remains strongly significant and increases in magnitude. These results confirm that it is not the scale of education investment, but rather its distribution between public and private sources, that drives the observed effects on inequality and GDP.

Columns (4) replace the gap with the ratio of public to private spending as an alternative measure of their relative importance. The ratio is negative and significant for inequality, and positive and significant for GDP per capita, fully consistent with the baseline interpretation. This provides a functional-form validation that the relationship holds regardless of whether the composition of education spending is expressed

as a difference or a ratio.

Tables C.0.8 and C.0.9 present a unified set of robustness checks that examine whether the baseline results hold when accounting for intergenerational mobility and initial country conditions. Columns (1) and (2) of both tables introduce measures of absolute and relative intergenerational mobility. Absolute mobility captures improvements in children's outcomes relative to their parents, while relative mobility reflects the degree of intergenerational persistence and is commonly interpreted as a measure of inequality of opportunity. Across both outcome variables, the mobility measures are statistically insignificant. However, the coefficient on the public–private education expenditure gap remains stable in sign and significance. For inequality, the gap continues to reduce the disposable income Gini; for GDP per capita, the gap remains positive and statistically significant. These findings indicate that the baseline results are not sensitive to differences in intergenerational mobility patterns across countries.

Columns (3) and (4) incorporate interactions with initial conditions, either initial income inequality (market or disposable Gini) or initial GDP levels. These variables test whether countries' long-run starting positions condition the effect of current educational investment patterns. Across all specifications, interaction terms are small and statistically insignificant. In the inequality regressions, the public–private expenditure gap remains negative and significant. In the GDP regressions, the gap remains positive and significant, with the magnitude in Column (3) increasing relative to the baseline. This pattern suggests that once long-run initial conditions are accounted for, the underlying relationship between education spending composition and economic performance becomes clearer rather than weaker.

The robustness checks reported in Tables C.0.4 and C.0.5 assess whether the baseline results for both disposable income inequality and GDP per capita remain stable across three key identification challenges: (i) alternative dynamic structures, (ii) regional and income–group heterogeneity, and (iii) reverse-causality concerns. Column (1) in both robustness tables introduces dynamic extensions to the baseline System GMM specification by using deeper lags of the endogenous variables in the instrument set. This adjustment tests whether the baseline estimates are sensitive to alternative dynamic structures or to the depth of the GMM instrument matrix. Across both outcome variables, the results remain highly stable: the public–private education spending gap retains its expected sign, remains statistically significant, and preserves a magnitude close to the baseline specification. As expected for slow-moving macro-distributional variables, both inequality and GDP per capita exhibit strong persistence, confirming well-established findings in the inequality and economic growth literature.

Column (2) in both tables incorporates region and income–group controls to address the possibility that the baseline relationship is driven by structural differences across country clusters. Despite these additional controls, the coefficient on the public–private spending gap remains statistically significant and of similar magnitude to the main specification. This indicates that the association, higher public relative to private education spending, reducing inequality and increasing GDP per capita, is not merely capturing regional patterns or income-group–specific dynamics.

Column (3) in both tables implements a reverse-causality test by replacing the contemporaneous education spending gap with its lagged value. This specification

evaluates whether past inequality or past GDP per capita might influence the composition of education spending rather than the other way around. In both cases, the lagged education expenditure gap remains statistically significant and retains the expected sign. This finding suggests that historical differences in education financing predict current inequality and economic performance, while there is no evidence that changes in inequality or GDP systematically drive the public–private composition of education spending. Thus, reverse causality does not appear to explain the baseline relationship.

The robustness exercises across functional forms, mobility measures, historical initial conditions, dynamic structures, and reverse-causality tests lead to a remarkably consistent conclusion: the composition of education financing matters. Across all specifications and both outcome variables, a larger public share of education spending is associated with lower disposable income inequality and higher long-run economic performance. The direction, magnitude, and significance of the effect remain stable, suggesting that the relationship is not an artefact of model parametrisation, instrument depth, or omitted structural heterogeneity. This consistency across two distinct macro-distributional outcomes underscores the systematic and economically meaningful role that public education investment plays in shaping both equity and growth.

## 4 Discussion

This study has shown that the composition of education finance, the balance between public and private spending, plays a meaningful role in shaping long-run growth and income inequality. Because the public–private education spending gap is expressed in levels, the coefficients in the baseline regressions can be interpreted as semi-elasticities. The inequality specification indicates that a one-unit increase in the public–private gap (achieved either through higher public spending, lower private spending, or a combination of both weighted toward the public component) is associated with a 6.4 percent decrease in the disposable income Gini. This is a sizeable effect: for a country with a Gini of 0.30, such a shift in education financing corresponds to a reduction of roughly 0.019 Gini points. For GDP per capita, the estimated semi-elasticity of 0.025 implies that a one-unit increase in the public–private gap is associated with a 2.5 percent increase in GDP per capita. This corresponds to a meaningful increase in average income and highlights that the composition of education finance is quantitatively relevant for macroeconomic performance. Interestingly, these empirical magnitudes closely align with the responses generated in the numerical policy-mix simulation of the theoretical model. These effect sizes show that reallocating even modest resources toward public education can generate improvements in both equality and aggregate income that are economically significant and policy-relevant.

A useful way to interpret the results is through the mechanisms that link education financing to growth and inequality. Private education spending tends to amplify inequality because it is financed directly by households, and therefore depends on parental income. When private spending is high relative to public provision, children from wealthier families can invest more in human capital, while poorer households face financial constraints that limit investment. This widens skill gaps and strength-

ens the intergenerational transmission of inequality. Public education spending, by contrast, reduces inequality by lowering the marginal cost of investing in skills for low-income households, thereby broadening access and compressing the distribution of human capital. At the same time, growth responds positively when a larger share of the population invests adequately in education, because aggregate productivity increases when barriers to skill formation are reduced. However, public spending also displays diminishing returns: as public provision becomes very large, additional taxes needed to finance it impose distortions, and the marginal payoff from new public investment falls. These intuitive mechanisms help explain why the empirical results show that increasing the public–private gap both reduces inequality and raises GDP per capita, but also why the theoretical model predicts welfare peaking at an intermediate level of public provision.

The broader implications of these findings extend beyond the quantitative estimates. Public spending appears to have disproportionately positive effects on both economic performance and distributional outcomes, particularly when it expands opportunities for households with initially low human capital. This underscores the need to design education financing systems that not only raise total investment but also ensure that public resources play a central role in promoting equitable access. The results also point toward several concrete policy priorities. First, countries where private spending constitutes a large share of education finance may benefit from strengthening public subsidies or reducing private cost burdens. Second, tuition policy, particularly at the tertiary level, should balance efficiency with equity by ensuring that access does not depend excessively on family resources or student debt. Third, avoiding extreme privatization in earlier stages of education can help preserve equal opportunities and prevent the widening of long-term inequality.

Future research could extend this work in several directions. On the theoretical side, incorporating explicit credit markets, wealth accumulation, or heterogeneous returns to education would provide a richer account of why private education spending may exacerbate inequality. On the empirical side, more granular microdata on household expenditures, tutoring, and student loans would help uncover the mechanisms behind the aggregate patterns documented here. Finally, linking education financing structures to measures of learning quality or social mobility would allow for a fuller understanding of how public and private systems translate resources into long-term economic outcomes.

## 5 Conclusion

This paper has examined how the composition of education financing, specifically the balance between public and private spending, shapes long-run economic performance and income inequality. Using a simple OLG framework, it is shown theoretically that public and private education investments are complementary, but that greater reliance on public financing promotes both growth and equity by broadening access to human capital. To illustrate the quantitative implications of this mechanism, a numerical policy-mix simulation shows that modest shifts toward greater public financing generate higher GDP per capita and lower inequality, with welfare peaking at an intermediate public share because very high levels of taxation generate diminishing returns.

The empirical analysis, based on System GMM estimates for a multi-country panel, supports the theoretical predictions obtained by the policy simulation. A larger public–private education spending gap is associated with significantly lower disposable income inequality and higher GDP per capita. The effect sizes are economically meaningful: a one-unit increase in the gap corresponds to a 6.4 percent reduction in the Gini and a 2.5 percent increase in GDP per capita. These patterns remain stable across a wide set of robustness checks, including alternative dynamic specifications, mobility controls, initial conditions, and functional forms of education spending.

Overall, the results show that how education is financed matters as much as how much is spent. Public spending appears to play a particularly important role in broadening access to skills and supporting inclusive growth, while private spending remains valuable when it complements rather than substitutes for adequate public provision. From a policy perspective, the findings highlight the importance of safeguarding and strengthening public education systems. Reforms that expand public investment, reduce financial barriers to learning, or rebalance tuition systems toward public cost-sharing can yield both equity and efficiency gains. Ensuring that private resources supplement rather than replace public provision may be especially important in countries seeking to promote mobility, reduce inequality, and sustain long-run growth.

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# Appendix

## A Theoretical Model: Additional Information

### A.1 Maximization Problem of Households

$$\max_{e_t, s_t, d_{t+1}} u(c_t, d_{t+1}, e_t) = \ln(c_t) + \beta \ln(d_{t+1}) + \gamma \ln(e_t)$$

$$\text{s.t.} \qquad \chi_t \equiv (1 - \tau_t)\, w_t\, h_t = c_t + \frac{d_{t+1}}{R_{t+1}} + e_t$$

First-order conditions are obtained:

$$\begin{aligned} \frac{\delta u_t}{\delta c_t}: \quad & \frac{1}{c_t} && = -\Lambda \\ \frac{\delta u_t}{\delta e_t}: \quad & \frac{\gamma}{e_t} && = -\Lambda \\ \frac{\delta u_t}{\delta d_{t+1}}: \quad & \frac{\beta}{d_{t+1}} = && \frac{-\Lambda}{R_{t+1}} \end{aligned}$$

from where the following appears:

$$\frac{1}{c_t} = \frac{\gamma}{e_t} = \frac{R_{t+1}\beta}{d_{t+1}} \tag{A.1.1}$$

Replace (A.1.1) in the budget constraint to obtain the optimal consumption

$$\frac{d_{t+1}}{R_{t+1}} \cdot \frac{\beta}{\beta} = (1 - \tau_t)\, w_t\, h_t - c_t - e_t \tag{A.1.2a}$$

$$c_t\, \beta = (1 - \tau_t)\, w_t\, h_t - c_t - \frac{e_t \gamma}{\gamma} \tag{A.1.2b}$$

$$c_t^* = \frac{1}{1 + \beta + \gamma} \chi_t \tag{A.1.2c}$$

To obtain the optimal level of education investment for a child

$$\frac{1}{c_t} = \frac{\gamma}{e_t} \tag{A.1.3a}$$

$$e_t^* = \frac{\gamma}{1 + \beta + \gamma} \chi_t \tag{A.1.3b}$$

To obtain optimal consumption during retirement

$$\frac{1}{c_t} = \frac{R_{t+1}\beta}{d_{t+1}} \tag{A.1.4a}$$

$$d_{t+1}^* = \frac{R_{t+1}\, \beta}{1 + \beta + \gamma} \chi_t \tag{A.1.4b}$$

Replacing equation (A.1.4b) on the budget constraint of the third period of life:

$$R_{t+1}\, s_t = d_{t+1} \tag{A.1.5a}$$

$$s_t^* = \frac{\beta}{1+\beta+\gamma}\chi_t \tag{A.1.5b}$$

## A.2 Additional Equilibrium Derivations

### Lognormal Distribution Dynamics

If $h_t$ is lognormally distributed, $\ln h_t \sim (\mu_t, \sigma_t^2)$, then from (10) we obtain

$$\mu_{t+1} = \ln\left(\Psi\, \tau_t^{\lambda}\left(\frac{\gamma(1-\tau_t)}{1+\gamma+\beta}\right)^{\theta} w_t^{\lambda+\theta}\right) + \lambda \ln \bar{h}_t + (1-\lambda)\mu_t, \tag{A.2.6}$$

$$\sigma_{t+1}^2 = (1-\lambda)^2\sigma_t^2. \tag{A.2.7}$$

Thus, dispersion in human capital shrinks monotonically, implying asymptotic equality.

### Evolution of Average Human Capital

Using the properties of the lognormal distribution,

$$\ln \bar{h}_{t+1} = \ln \bar{h}_t + \ln\left(\Psi\, \tau_t^{\lambda}\left(\frac{\gamma(1-\tau_t)}{1+\gamma+\beta}\right)^{\theta} w_t^{\lambda+\theta}\right) - \frac{(1-\lambda)\lambda\sigma_t^2}{2}. \tag{A.2.8}$$

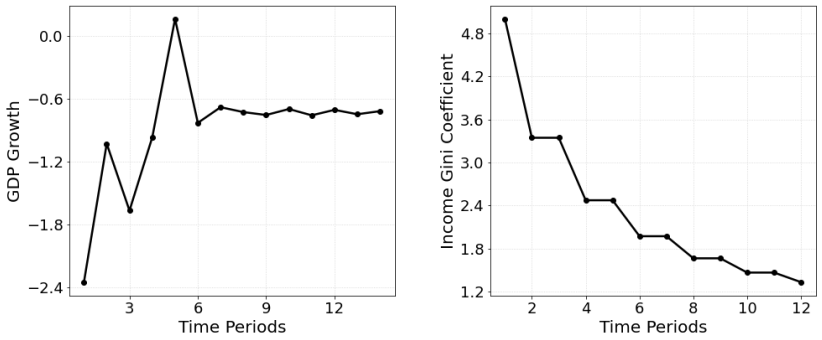
### Dynamics of the Capital–Labor Ratio

Combining the firm's first-order conditions with capital market clearing gives

$$\ln k_{t+1} = \ln\left[\frac{\beta(1-\alpha)^{1-\lambda-\theta}}{\Psi\tau_t^{\lambda}\gamma^{\theta}}\left(\frac{1+\gamma+\beta}{1-\tau_t}\right)^{\theta-1}\right] + (1-\lambda-\theta)\alpha \ln k_t + \frac{(1-\lambda)\lambda\sigma_t^2}{2}. \tag{A.2.9}$$

These expressions are used for numerical simulations in Section 2.3.

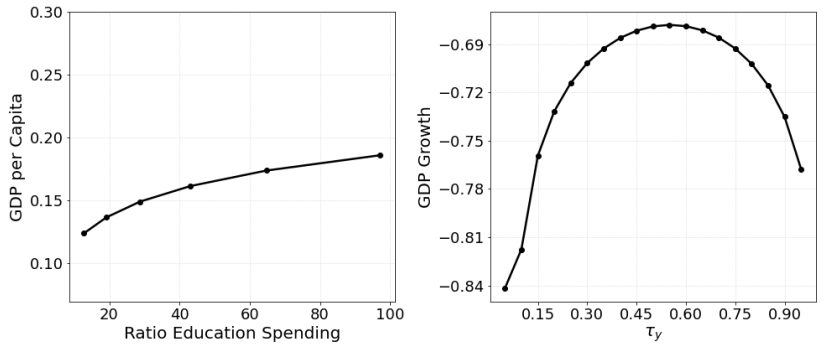
## A.3 Numerical Calibration Figures




(a) GDP Growth (b) Income Inequality

Figure A.3.1: Main Results: GDP Growth and Income Inequality

Note: Model dynamics: the impact of public education spending on GDP growth (Panel a) and income inequality (Panel b). Source: Author's calculations.




(a) GDP per capita (b) Income Tax and Growth Rate

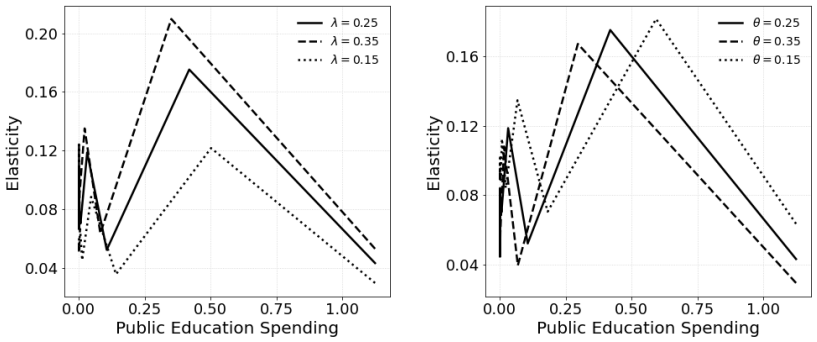
Figure A.3.2: Main Results: GDP per Capita and Tax Rates

Note: Policy trade-offs: the effect of the public–private education spending ratio on GDP per capita (Panel a) and the relationship between taxation and GDP growth (Panel b). Source: Author's calculations.

## A.4 Sensitivity Analysis

This appendix reports robustness checks for alternative values of the education parameters $(\lambda, \theta, \gamma)$. These parameters govern the relative effectiveness of public and private educational inputs in human capital formation. Figures A.4.3–A.4.6 show that varying $\lambda$ and $\theta$ alters the elasticities of human capital and capital accumulation. Public inputs become more productive when $\lambda$ is higher (or $\theta$ lower), whereas private inputs gain importance when $\theta$ is higher. In all cases, elasticities decline as overall spending rises, reflecting diminishing returns.

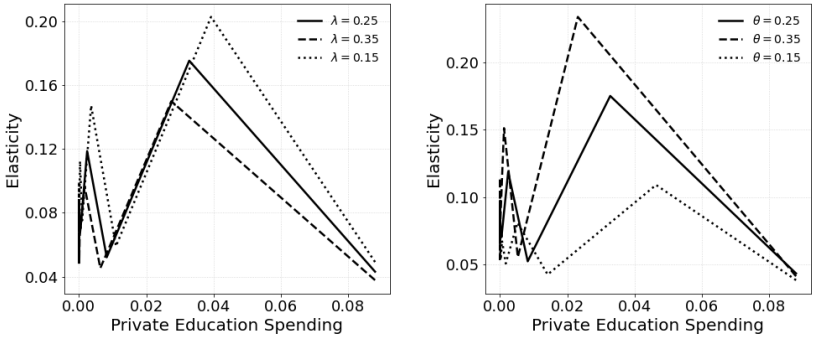
Figures A.4.7 and A.4.8 summarize the macroeconomic implications. Higher values of $\lambda$ increase growth and reduce inequality, while higher $\theta$ produces the opposite pattern. Although these parameters affect short-run dynamics, the economy consistently converges to the baseline path. Overall, the sensitivity analysis confirms that the main qualitative result is robust: a higher public share in education finance has a more equalizing and growth-enhancing effect, whereas heavier reliance on private spending amplifies inequality.




(a) $\lambda$ (b) $\theta$

Figure A.4.3: Elasticity of Human Capital w.r.t. Public Education

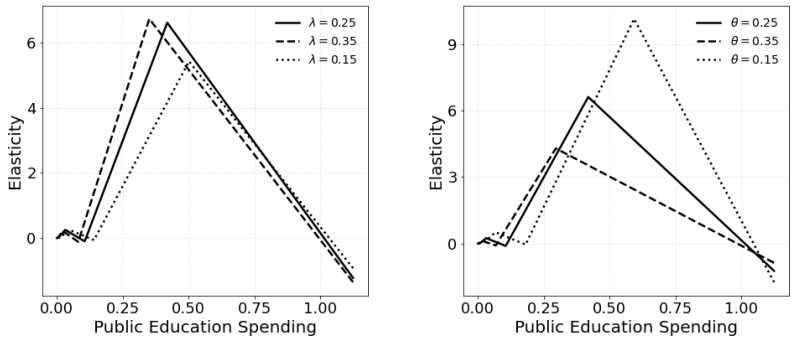
Note: Elasticity of human capital with respect to public education spending. Panel (a) varies $\lambda$, Panel (b) varies $\theta$. Source: Author's calculations.




(a) $\lambda$ (b) $\theta$

Figure A.4.4: Elasticity of Human Capital w.r.t. Private Education

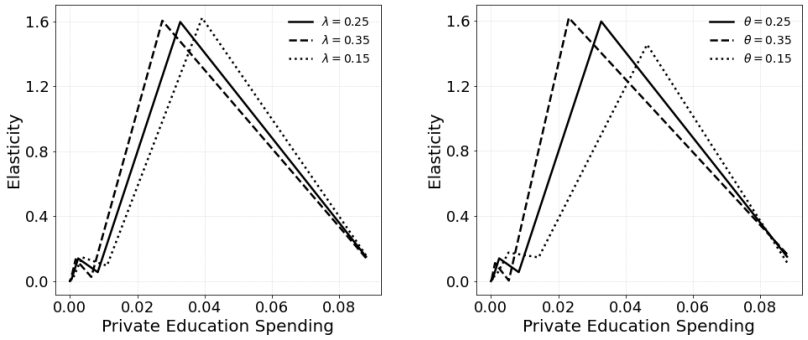
Note: Elasticity of human capital with respect to private education spending. Panel (a) varies $\lambda$, Panel (b) varies $\theta$. Source: Author's calculations.




(a) $\lambda$ (b) $\theta$

Figure A.4.5: Elasticity of Capital w.r.t. Public Education

Note: Elasticity of capital with respect to public education spending. Panel (a) varies $\lambda$, Panel (b) varies $\theta$. Source: Author's calculations.



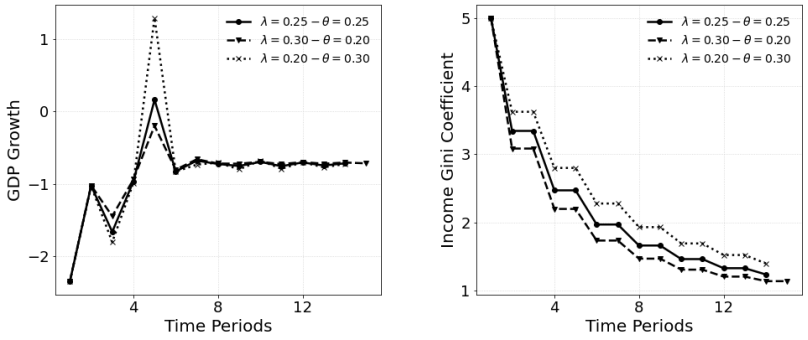

(a) $\lambda$ (b) $\theta$

Figure A.4.6: Elasticity of Capital w.r.t. Private Education

Note: Elasticity of capital with respect to private education spending. Panel (a) varies $\lambda$, Panel (b) varies $\theta$. Source: Author's calculations.

## A.5 Variations of the Human Capital Function

This appendix reports robustness checks based on two alternative specifications of human capital formation. These extensions allow the effectiveness of public spending to vary across individuals or to interact with private spending, addressing the possibility that different forms of education finance are complements or substitutes.




(a) GDP Growth (b) Income Inequality

Figure A.4.7: Main Results with $\lambda$ and $\theta$ Variations

Note: Effects of varying $\lambda$ and $\theta$ on GDP growth (Panel a) and income inequality (Panel b). Source: Author's calculations.

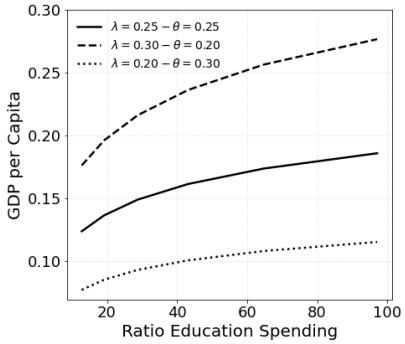



Figure A.4.8: GDP per Capita

Note: Impact of varying $\lambda$ and $\theta$ on GDP per capita. Source: Author's calculations.

## Public Spending and Initial Human Capital

The first variation introduces an interaction between public spending and initial human capital:

$$h_t = \Psi \left( g_{t-1} h_{t-1}^{\zeta} \right)^{\lambda} e_{t-1}^{\theta} h_{t-1}^{1-\lambda-\theta}.$$

Positive values of $\zeta$ imply that public resources are more effective for households with high human capital, while negative values imply they benefit low-human-capital households more. Figures A.5.9 and A.5.10 report the resulting growth and inequality paths.

## Complementarity or Substitutability with Private Spending

The second variation introduces an interaction between public and private inputs:

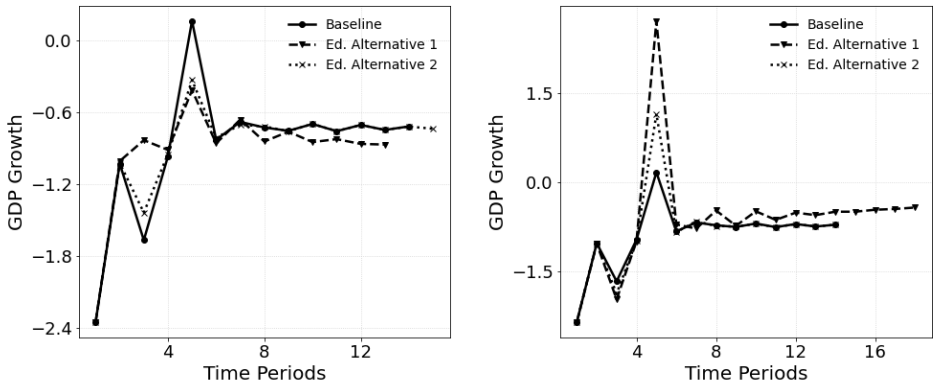
$$h_t = \Psi \left( g_{t-1}^{\lambda} + \zeta e_{t-1} g_{t-1}^{\lambda} \right) e_{t-1}^{\theta} h_{t-1}^{1-\lambda-\theta}.$$

Here $\zeta > 0$ indicates complementarity and $\zeta < 0$ indicates substitutability. Growth–tax trade-offs for this case are shown in Figure A.5.11.

Across both specifications, three patterns emerge:

- Public spending targeted toward lower-human-capital households ($\zeta < 0$) increases growth and reduces inequality relative to the baseline.
- Complementarity with private spending ($\zeta > 0$) tends to dampen growth, while substitutability ($\zeta < 0$) modestly improves outcomes.
- The inverted-U relationship between taxation and growth remains robust across all variations.

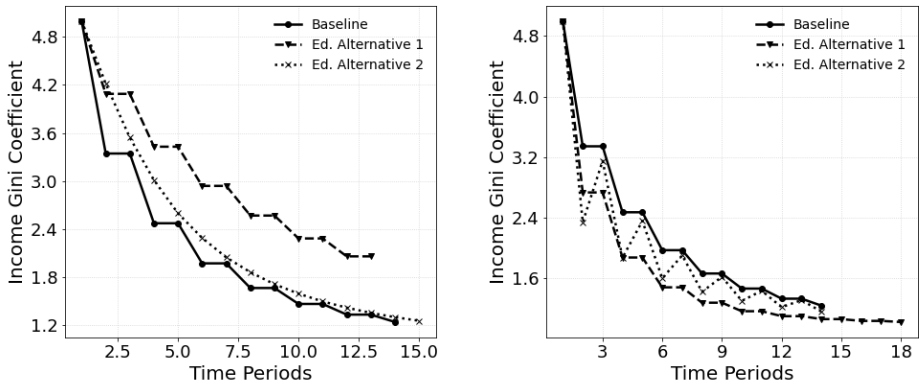
Overall, the macroeconomic consequences of education finance depend on who benefits from public spending and how it interacts with private inputs, but the main qualitative conclusions of the model continue to hold.




(a) Positive $\zeta$ (b) Negative $\zeta$

Figure A.5.9: GDP Growth under Alternative Human Capital Functions

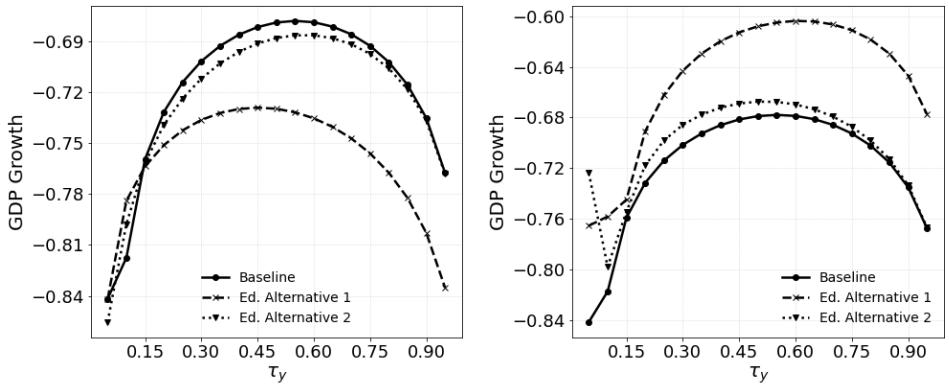
Note: GDP growth trajectories when public education spending benefits high- vs. low-human-capital agents ($\zeta > 0$ or $\zeta < 0$). Source: Author's calculations.




(a) Positive $\zeta$ (b) Negative $\zeta$

Figure A.5.10: Income Inequality under Alternative Human Capital Functions

Note: Income inequality outcomes (Gini coefficient) when public and private education act as complements ($\zeta > 0$) or substitutes ($\zeta < 0$). Source: Author's calculations.




(a) Positive $\zeta$ (b) Negative $\zeta$

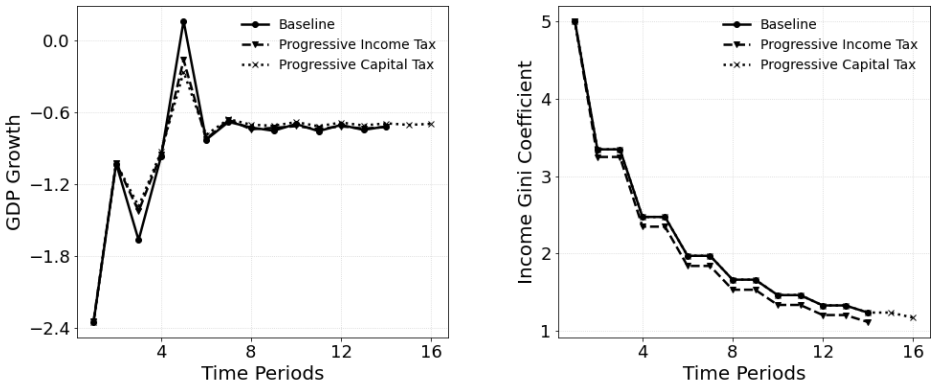
Figure A.5.11: GDP Growth and Tax Rates under Alternative Human Capital Functions

Note: Growth–tax trade-offs under alternative specifications of human capital formation. $\zeta$ indicates whether public resources favor high- or low-human-capital agents, or interact with private spending. Source: Author's calculations.

## A.6 Variations of the Tax System

This appendix reports robustness checks based on progressive income and capital taxation. These experiments maintain the same average tax rate as in the baseline but redistribute the burden across households. Let $(\underline{\tau}, \overline{\tau})$ denote tax rates for low- and high-income households such that their weighted average equals $\tau = 0.157$. Capital taxation is modeled analogously with an average rate of 5 percent.

Figures A.6.12a and A.6.12b show that progressive taxation does not reduce GDP growth. Its main effect is distributional: higher-income households contribute more to public revenues, enabling additional public investment in education. This raises human capital among lower-income households and reduces the income Gini coefficient. As shown in Figure A.6.13, progressive income taxation is associated with higher GDP per capita. The additional public investment offsets potential disincentive effects by strengthening human capital accumulation and aggregate productivity. Across all tax variations, the qualitative results remain robust: progressive taxation reduces inequality while maintaining or improving growth through enhanced public education finance.




(a) GDP Growth (b) Income Inequality

Figure A.6.12: Macroeconomic Effects of Progressive Taxation

Note: Effects of progressive income and capital taxation on GDP growth and income inequality. Source: Author's calculations.

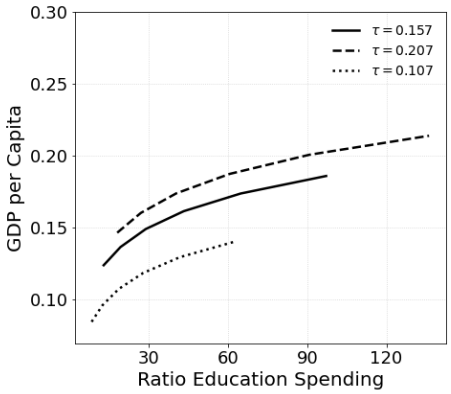



Figure A.6.13: GDP per Capita under Progressive Income Taxation

Note: GDP per capita trajectories under alternative income tax progressivity. Source: Author's calculations.

# B Empirical Analysis: Additional Information

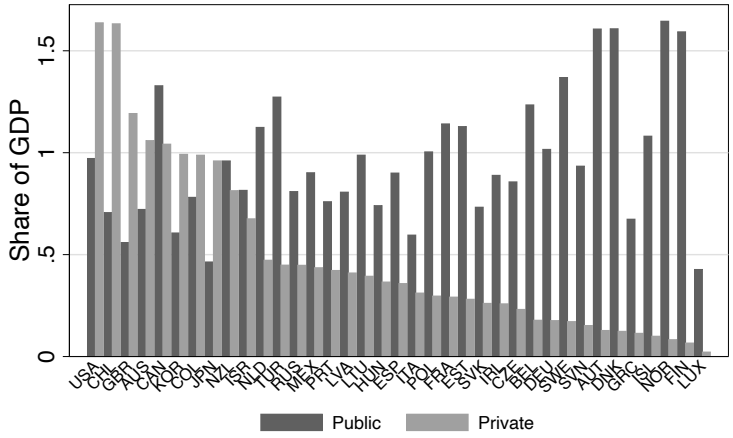



Figure B.0.14: Public and Private Spending on Tertiary Education

Note: The figure shows the shares of public and private investment in tertiary education by country. Source: OECD (2022).

Table B.0.1
List of Countries: Empirical Analysis

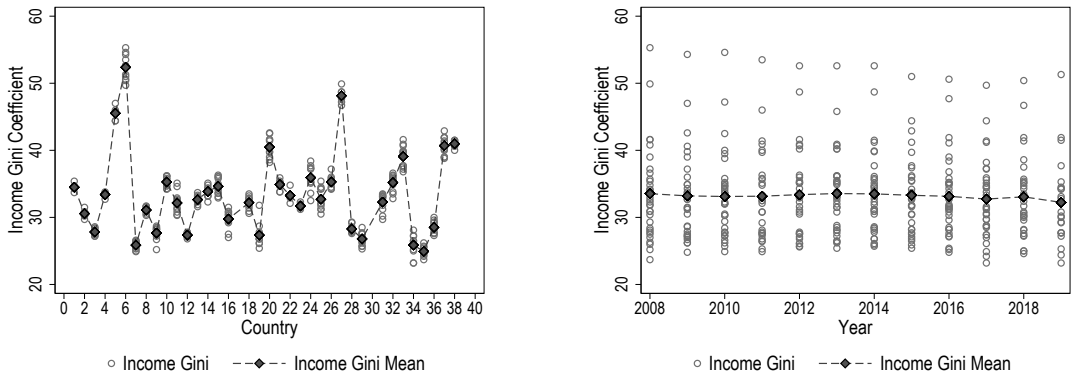
| WB Code | Country | WB Code | Country | WB Code | Country |
|---|---|---|---|---|---|
| AUS | Australia | AUT | Austria | BEL | Belgium |
| CAN | Canada | CHL | Chile | COL | Colombia |
| CZE | Czech Rep. | DNK | Denmark | DEU | Germany |
| ESP | Spain | EST | Estonia | FIN | Finland |
| FRA | France | GBR | Great Britain | GRC | Greece |
| HUN | Hungary | IRE | Ireland | ISL | Iceland |
| ISR | Israel | ITA | Italy | JPN | Japan |
| KOR | Korea. Rep. | LTU | Lithuania | LUX | Luxembourg |
| LVA | Latvia | MEX | Mexico | NDL | Netherlands |
| NOR | Norway | NZL | New Zealand | POL | Poland |
| PRT | Portugal | RUS | Russian Fed. | SVK | Slovakia |
| SVN | Slovenia | SWE | Sweden | TUR | Turkey |
| USA | United States | | | | |

Note: Countries included in the empirical analysis and respective World Bank ISO codes.

Table B.0.2
Summary Statistics (37 countries from 2008-2019)

| Variable | Obs. | Mean | Std.D. | Min. | Max. |
|---|---|---|---|---|---|
| Log GDP p.c. | 444 | 10.21 | 0.68 | 8.52 | 11.61 |
| Log D. Income Gini | 381 | 3.49 | 0.18 | 3.14 | 4.01 |
| Public-Private Gap | 405 | 0.50 | 0.62 | −1.42 | 1.70 |
| Log Tertiary Enrollment | 389 | 4.23 | 0.32 | 2.36 | 5.00 |
| Governance | 444 | 6.17 | 3.84 | −4.72 | 11.20 |
| FDI | 444 | −0.71 | 6.45 | −34.86 | 64.51 |
| Log GFCF | 444 | 3.07 | 0.18 | 2.36 | 3.98 |
| Log Trade | 444 | 4.42 | 0.54 | 3.19 | 5.94 |

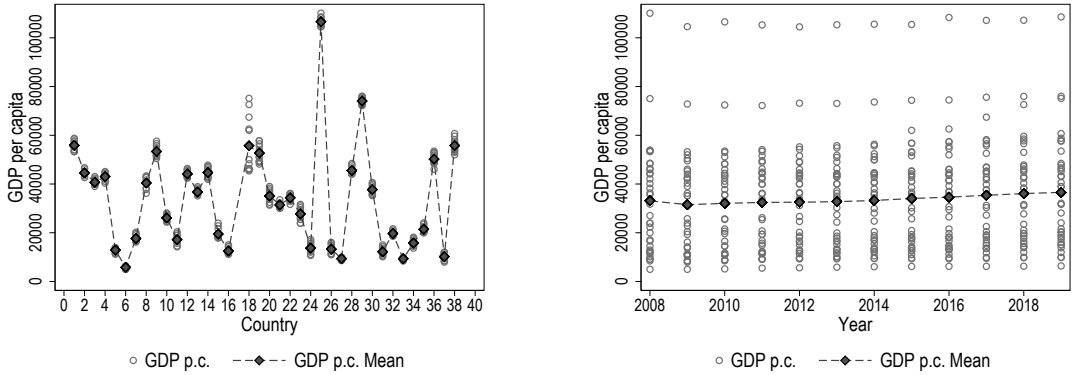
Note: This table reports summary statistics of the variables used in this analysis for 37 countries over the period 2008 - 2019. Further description of the variables in table B.0.3.




(a) Country heterogeneity (b) Time heterogeneity

Figure B.0.15: Income Inequality Heterogeneity

Note: The figure shows the Gini coefficient as a measure of income inequality. Panel (a) shows the heterogeneity of income inequality among the countries included in the main data and panel (b) across time.




(a) Country heterogeneity (b) Time heterogeneity

Figure B.0.16: GDP p.c. Heterogeneity

Note: The figure shows the heterogeneity of the sample for GDP per capita. Panel (a) shows the differences in GDP per capita among the countries included in the main data set and panel (b) across time.

## Additional Instruments in Regression Analysis

**Income Inequality Analysis:** GDP p.h., Log of R&D, Log of market income Gini, Log of Ad. Fertility, governance, gov. consumption, Log of gov. health expenditure per capita, compulsory education, trade, inequality of opportunity of earnings, absolute and relative mobility in education, labor force with intermediate education, initial market and disposable Gini, employment in agriculture, FDI, GFCF, access to electricity, the difference between public and private expenditure on health, total enrollment tertiary education, tax revenue, hospital beds per 1000 people, CO2 emissions, taxes, and inequality of opportunity of earnings.

**GDP per capita Analysis:** Access to electricity, hospital beds per 1000 people, population growth rate, labor force with an intermediate level of education, adolescent fertility, gov. expenditure health, labor productivity, R&D expenditure, the difference between public and private expenditure on health, compulsory years of education, taxes (different) the measure of inequality of opportunity and the income share bottom 50%, fertility rate, labor force, Ad. Fertility.

**Note:** All the additional instruments listed for each dependent variable are included in the main analysis and the robustness checks, but are not necessarily used in every dynamic panel data regression.

Table B.0.3
Definition and Sources of Variables

| Variable | Description and Source |
|---|---|
| Public-Private Gap | Total public minus private expenditure on the highest level of education. Public and private spending measures are a percentage of GDP. Source: OECD (2022). |
| Disposable Income Gini | Gini index measures the extent of the equality of the distribution. Estimates of Gini index of 0 represent perfect equality, while an index of 100 implies perfect inequality. Source: World Bank, Development Research Group. |
| GDP p.c. | GDP per capita (constant 2015 US$). Source: "World development indicators" |
| Tertiary Enrollment | Ratio of total enrollment to the population of the age group that corresponds to the level of education. Source: UNESCO Institute for Statistics. |
| Governance | The sum of control of corruption, government effectiveness, political stability and absence of violence, voice and accountability, regulatory quality, and rule of law. Indicators range from -2.5 to 2.5. Source: The World Governance Indicators. |
| FDI | Annual net foreign direct investment (share of GDP). Source: National Accounts Data, World Bank. |
| GFCF | Annual gross fixed capital formation (share of GDP). Source: National Accounts Data, World Bank. |
| Trade | Annual trade (share of GDP). Source: National Accounts Data, World Bank. |
| Inflation | Annual inflation measured by the consumer price index. Source: International Financial Statistics, International Monetary Fund. |
| Education | General government expenditure on education (share of GDP). Source: UNESCO Institute for Statistics. |
| Top 1% (10%) | Pre-tax national income share held by the top 1% (10%) of the income distribution. Source: World Inequality Database. |
| Bottom 50% | Pre-tax national income share held by the bottom 50% of the income distribution. Source: World Inequality Database. |
| GDP p.h. | GDP per total hours worked of all people engaged in production. This indicator is measured in USD. Source: OECD Data. |
| Absolute Mobility | The measure for absolute mobility is the share of respondents that have attained a higher educational category than their parents, conditional on the parents not having obtained tertiary education. Source Van der Weide et al. (2021). |
| Relative Mobility | The measure for relative mobility is one minus the correlation coefficient from the regression of children's years of education on the education of their parents. Source Van der Weide et al. (2021). |
| Public Ex. Ed. | Includes direct expenditure on educational institutions, educational-related public subsidies given to households and administered by educational institutions. |
| Private Ex. Ed. | Includes all direct expenditure on educational institutions, net of public subsidies, excluding expenditure outside educational institutions such as textbooks purchased by families, private tutoring for students and student living costs. |

Note: Variables included in the empirical analysis with their respective description and sources.

# C Empirical Analysis: Robustness Tests

Table C.0.4
Dynamic Regression: Income Inequality — Technical Robustness

| | Log Disposable Income Gini | | |
|---|---|---|---|
| | (1) | (2) | (3) |
| L.Log D. Income Gini | 0.926*** | 0.875*** | 0.957*** |
| | (0.044) | (0.058) | (0.049) |
| Public-Private Gap | −0.047** | −0.063*** | |
| | (0.020) | (0.022) | |
| L.Public-Private Gap | | | −0.049** |
| | | | (0.018) |
| Observations | 226 | 226 | 223 |
| Hansen p-value | 0.125 | 0.632 | 0.232 |
| AR(2) p-value | 0.855 | 0.734 | 0.726 |
| No. Instruments | 20 | 21 | 20 |
| No. Countries | 23 | 23 | 23 |

Note: This table presents robustness for the log disposable income Gini baseline. Column (1) adds dynamic extensions, (2) includes region–income group controls, and (3) tests reverse causality using lagged public–private education spending. Models use one-step System GMM with collapsed instruments and orthogonal deviations. Standard errors are Windmeijer-corrected and robust to heteroscedasticity. Constant, country fixed effects, and controls are included but omitted for brevity. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table C.0.5
Dynamic Regression: GDP per Capita — Technical Robustness

| | Log GDP per Capita | | |
|---|---|---|---|
| | (1) | (2) | (3) |
| L.Log GDP p.c. | 0.983*** | 0.978*** | 0.978*** |
| | (0.012) | (0.022) | (0.020) |
| Public-Private Gap | 0.027* | 0.039** | |
| | (0.014) | (0.016) | |
| L.Public-Private Gap | | | 0.038*** |
| | | | (0.013) |
| Observations | 233 | 233 | 227 |
| Hansen p-value | 0.317 | 0.160 | 0.131 |
| AR(2) p-value | 0.251 | 0.458 | 0.672 |
| No. Instruments | 27 | 27 | 26 |
| No. Countries | 32 | 32 | 32 |

Note: This table presents robustness for the log GDP per capita baseline. Column (1) adds dynamic extensions, (2) includes region–income group controls, and (3) tests reverse causality using lagged public–private education spending. Models use one-step System GMM with collapsed instruments and orthogonal deviations. Standard errors are Windmeijer-corrected and robust to heteroscedasticity. Constant, country fixed effects, and controls are included but omitted for brevity. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table C.0.6
Dynamic Regression: Income Inequality — Education Robustness

| | Log Disposable Income Gini | | |
|---|---|---|---|
| | (1) | (2) | (3) |
| L.Log D. Income Gini | 0.911*** | 0.835*** | 0.807*** |
| | (0.062) | (0.136) | (0.099) |
| Public-Private Gap Sq. | 0.027** | | |
| | (0.011) | | |
| Public+Private E.E. | | 0.040 | |
| | | (0.046) | |
| Public/Private Gap | | | −0.005** |
| | | | (0.002) |
| Public-Private Gap | −0.079*** | −0.084** | |
| | (0.028) | (0.039) | |
| Observations | 226 | 226 | 263 |
| Hansen p-value | 0.309 | 0.245 | 0.715 |
| AR(2) p-value | 0.894 | 0.791 | 0.367 |
| No. Instruments | 21 | 20 | 21 |
| No. Countries | 23 | 23 | 27 |

Note: This table presents robustness tests of the effect of education variables on the log disposable income Gini. Column (1) includes the squared public–private education gap. 2) includes total public+private education expenditure. (3) tests the ratio of public to private education spending. Standard errors are Windmeijer-corrected and are robust to heteroscedasticity. Country fixed effects and constants included but omitted for brevity. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table C.0.7
Dynamic Regression: GDP per Capita — Education Robustness

| | Log GDP per Capita | | |
|---|---|---|---|
| | (1) | (2) | (3) |
| L.Log GDP p.c. | 0.964*** | 0.940*** | 0.979*** |
| | (0.025) | (0.035) | (0.018) |
| Public-Private Gap Sq. | 0.016 | | |
| | (0.014) | | |
| Public+Private E.E. | | −0.045 | |
| | | (0.044) | |
| Public/Private Gap | | | 0.004** |
| | | | (0.002) |
| Public-Private Gap | 0.064** | 0.057** | |
| | (0.029) | (0.026) | |
| Observations | 233 | 242 | 233 |
| Hansen p-value | 0.097 | 0.260 | 0.179 |
| AR(2) p-value | 0.209 | 0.328 | 0.578 |
| No. Instruments | 25 | 26 | 27 |
| No. Countries | 32 | 32 | 32 |

Note: This table presents robustness tests of the effect of education variables on the log GDP per capita. Column (1) includes the squared public–private education gap. 2) includes total public+private education expenditure. (3) tests the ratio of public to private education spending. Standard errors are Windmeijer-corrected and are robust to heteroscedasticity. Country fixed effects and constants are included but omitted for brevity. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table C.0.8
Dynamic Regression: Income Inequality — Mobility and Interaction Robustness

| | Log Disposable Income Gini | | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| L.Log D. Income Gini | 0.933*** | 0.919*** | 0.975*** | 0.933*** |
| | (0.057) | (0.057) | (0.164) | (0.048) |
| Abs. Mobility | −0.021 | | | |
| | (0.046) | | | |
| Rel. Mobility | | 0.010 | | |
| | | (0.090) | | |
| D.Gini × I.M.Gini | | | −0.006 | |
| | | | (0.043) | |
| GDP p.c. × I.GDP p.c. | | | | 0.000 |
| | | | | (0.000) |
| Public–Private Gap | −0.064** | −0.065*** | −0.047* | −0.055** |
| | (0.025) | (0.023) | (0.026) | (0.022) |
| Observations | 226 | 226 | 226 | 221 |
| Hansen p-value | 0.310 | 0.294 | 0.405 | 0.497 |
| AR(2) p-value | 0.846 | 0.834 | 0.898 | 0.776 |
| No. Instruments | 21 | 21 | 21 | 21 |
| No. Countries | 23 | 23 | 23 | 22 |

Note: This table presents four robustness specifications of the System GMM model for log GDP per capita. This table reports robustness checks using alternative mobility and interaction specifications. Standard errors are Windmeijer-corrected and robust to heteroscedasticity. Country fixed effects, constants, and control variables are included but omitted for brevity. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table C.0.9
Dynamic Regression: GDP per Capita — Mobility and Interaction Robustness

| | Log GDP per Capita | | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| L.Log GDP p.c. | 0.951*** | 1.010*** | 0.934*** | 0.990*** |
| | (0.028) | (0.054) | (0.041) | (0.013) |
| Abs. Mobility | 0.079 | | | |
| | (0.084) | | | |
| Rel. Mobility | | −0.146 | | |
| | | (0.242) | | |
| GDP p.c. x I. GDP p.c. | | | 0.000 | |
| | | | (0.000) | |
| D. Gini x I.M. Gini | | | | 0.001 |
| | | | | (0.007) |
| Public-Private Gap | 0.069* | 0.066** | 0.117*** | 0.025** |
| | (0.037) | (0.026) | (0.041) | (0.011) |
| Observations | 189 | 197 | 242 | 233 |
| Hansen p-value | 0.221 | 0.070 | 0.258 | 0.075 |
| AR(2) p-value | 0.226 | 0.907 | 0.197 | 0.155 |
| No. Instruments | 26 | 25 | 24 | 28 |
| No. Countries | 26 | 26 | 32 | 32 |

Note: This table presents four robustness specifications of the System GMM model for log GDP per capita. This table reports robustness checks using alternative mobility and interaction specifications. Standard errors are Windmeijer-corrected and robust to heteroscedasticity. Country fixed effects, constants, and control variables are included but omitted for brevity. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.