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## Abstract

To analyze the optimal social insurance package, we set up a two-period life-cycle model with risky human capital investment in which the government has access to labor taxation, education subsidies and capital taxation. Social insurance is provided by redistributive labor taxation. Moreover, both education subsidies and capital taxation are used as catalysts to facilitate social insurance by mitigating distortions from labor taxation. We derive a Ramsey-rule for the optimal combination of these two instruments. Relative to capital taxation, optimal education subsidies increase with their relative effectiveness to boost labor supply and with households' underinvestment into education, but they decrease with their relative net distortions. For the optimal absolute levels, indirect complementarity effects (i.e., influencing the effectiveness of the other instrument) do matter. Generally, a decrease in capital taxes should be accompanied by an increase in education subsidies.


JEL-Code: H21, I20, J20, D80.

Keywords: human capital investment, education subsidies, capital taxation, risk, social insurance.

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*"Idleness and pride tax with a heavier hand than kings and parliaments. If we can get rid of the former, we may easily bear the latter."*

(Benjamin Franklin, Letter on the Stamp Act, July 01, 1765)

# 1 Introduction

In all developed countries, the labor income tax plays an important role as a revenue generator for financing public sector expenditures and as a means of income redistribution. As private insurance markets are incomplete (Sinn, 1996), labor taxation is furthermore crucial in providing social insurance against income risks due to uncertain outcomes in education and (productivity) shocks in labor markets (Eaton and Rosen, 1980). Since globalization has amplified income risks in recent years, the importance of the latter role has significantly increased. Moreover, since the mid 1980s globalization has driven down both corporate and personal capital taxes by intensifying tax competition and increasing the elasticity of real savings (see, e.g., Winner, 2005). Furthermore, there is (anecdotal) evidence at least in Europe that education subsidies have decreased as well (i.e., tuition fees have risen). However, both (real) capital taxation and education subsidies are still additional policies for social insurance.

This paper focuses on the insurance role of labor taxation and on the net efficiency costs unavoidably created in the process of providing insurance. We derive the optimal social insurance package as a combination of labor and capital taxation as well as educational policy. The new focus will be on optimally combining the additional policies in order to foster insurance provision by boosting labor supply (overcoming the "idleness", in Franklin's words). Analogous to catalysts in chemical reactions, capital taxation and education subsidies facilitate provision of social insurance by reducing efficiency costs, but they do not themselves provide insurance. Our findings are highly policy-relevant, since we show that capital taxation and education subsidies are strategic substitutes. In light of ongoing tax competition, this result calls into question the policy development described above and the recent restrictive education policies in particular.

A major part of risk in labor income is associated with educational investment, which can either mitigate or aggravate the exposure to income risk.[1] However, educational investment is a dynamic process and interacts with savings in real capital. Thus, it is naturally necessary to bring both decision margins into the picture. Since they are close substitutes (e.g., Nielsen and Sørensen, 1997), any policy which fosters (hampers) human capital investment will obviously harm (promote) real savings and vice versa. Thus, in addition to providing sufficient social insurance, setting up an education policy and

[1] Empirical evidence that human capital investment cuts both ways with respect to exposure to risk is provided, e.g., by Palacios-Huerta (2003), Belzil and Hansen (2004), and Hartog (2005). The theoretical analysis dates back to Levhari and Weiss (1974).

incorporating the treatment of savings in real capital are some of the most important tasks in the efficient design of a modern welfare state.

The idea of viewing supplementary instruments as catalysts of social insurance via the labor income tax is – especially with respect to real capital taxation – a recent development. In the absence of endogenous human capital investment, both Kocherlakota (2005) and Jacobs and Schindler (2009) have analyzed this topic. The latter focus on linear tax instruments, pointing out that capital taxation mitigates labor tax distortions by intertemporal wealth and substitution effects that increase the opportunity costs of leisure. Following the 'new dynamic public finance' approach (see also Golosov et al., 2006), Kocherlakota shows in a non-linear taxation setting that there is a role for capital taxation, since capital taxes relax the incentive constraints. Incorporating (unobservable) human capital formation, Hamilton (1987) states that positive capital taxation should overcome underinvestment in education due to uninsurable risk and self-insurance, by decreasing the intertemporal opportunity costs of educational investment, if (i) labor supply is exogenous and (ii) either savings are zero or absolute risk aversion is constant. His results are backed by Grochulski and Piskorski (2010), who apply non-linear tax instruments.

Turning to observable educational investment, Anderberg and Andersson (2003) state that education should be overprovided (underprovided) if it is a risk-decreasing (risk-increasing) activity. In doing so, educational policy exploits the insurance effect of human capital and it complements social insurance by income taxation. In their approach, the government directly controls educational investment. Jacobs et al. (2010) make clear that the results from this paper cannot be transferred to a decentralized setting. Individuals already exploit the insurance effect of education by self-insurance. Education subsidies are still used for mitigating labor supply distortions by increasing the effective wage rate, but they do not provide insurance. Furthermore, the optimal level of education subsidies crucially depends on the internalization of a fiscal externality that stems from the interplay of labor taxation and over- or underinvestment in education.

To the best of our knowledge, only da Costa and Maestri (2007) and Anderberg (2009) have analyzed the simultaneous use of education subsidies and capital taxation. They apply a non-linear taxation setting and find a positive intertemporal wedge, indicating a role for capital taxation. However, their results differ as to whether the constrained optimal level of educational investment is socially efficient. Moreover, it is generally difficult or even impossible to implement these optimal wedges through tax instruments.

In contrast to these previous contributions, we derive the optimal capital taxation and optimal education subsidies simultaneously and highlight the interactions between these two catalysts. To that end, we apply a comprehensive two-period life-cycle model in which ex-ante homogenous households invest in education, decide on savings, and choose labor supply. In the second period, income realizes according to a general earnings function that depends on educational investment, labor supply, and an idiosyncratic shock. The exposure to risk can increase or decrease with human capital investment. In any case, second-period consumption is stochastic, and households are heterogenous ex-post. In line with the literature, we assume that insurance markets are missing. Nevertheless, the government can provide social insurance through redistributive income taxation. The policy package consists of a linear income tax accompanied by a lump-sum transfer, a proportional capital tax, and linear education subsidies.

Our analysis leads to a number of new insights. *Firstly*, education subsidies and capital taxes differ both in the ways they boost labor supply and in the distortions they induce. Simple intuition that only capital taxes should be used (because they are more effective in boosting labor supply) is as misleading as the opposite case of saying that only education subsidies would be the method of choice, since they are less distortive. We derive the explicit formula for the optimal education subsidy rate and the optimal capital tax rate, showing the trade-offs between their net complementarity effects on labor supply and their net distortions of educational investment and real savings, respectively. Thereby, (net) complementarity effects measure the increase in labor supply stemming from fostering human capital and discouraging savings in real capital, respectively. Moreover, we identify "indirect complementarity effects", which reflect offsetting interactions between the two catalysts. In particular, the more education subsidies (capital taxation) worsen the efficiency gain of the other instrument, the less they should be employed.

*Secondly*, by extending the model used by Hamilton (1987), we show that there is no longer a role for capital taxation in internalizing the (fiscal) effect of self-insurance by under- or overinvesting in education. Consequently, the additive property (Sandmo, 1975) holds, and solely education subsidies are used to correct for inefficient educational investment, because they are the more efficient instrument to control for education level. The Hamilton-intuition carries over only in the special case in which education subsidies are not available. By incorporating endogenous labor supply and a general earnings function, we point out in this case that the Hamilton-result holds under much weaker conditions and capital taxes are also used to boost labor supply. Furthermore, the optimal capital tax rate can become negative if there is severe overinvestment in education. In this case, discouraging excessive educational investment by a subsidy on capital income overcompensates its negative effects on labor supply.

*Thirdly*, we derive a Ramsey-type rule, which provides the optimal education subsidies relative to the optimal use of capital taxation. It shows that capital taxes and education subsidies are (strategic) substitutes. Thus, decreases in capital taxes (e.g., due to tax competition or globalization) should be accompanied by increases in education subsidies. This result is highly policy-relevant and should be kept in mind when discussing education policy reforms.

*Fourthly*, our analysis adds to the 'new dynamic public finance' literature (e.g., Anderberg, 2009). We show that the main results and the basic intuition in this strand of the literature are still valid under linear tax instruments and informationally much less demanding requirements. The advantage of our setting is that the tax structure can be directly implemented and that the driving forces behind the optimal instruments as well as their interactions can be explicitly characterized.

The remainder of the paper is structured as follows: section 2 introduces the model and sets up the optimal tax problem. Section 3 then derives the optimal social insurance package. As a benchmark case, we discuss first the optimal labor tax rate, if there are no other policies available. Then, we describe the optimal use of education subsidies and capital taxation as catalysts; finally, we analyze the optimal labor tax when both education subsidies and capital taxation are optimally chosen. Section 4 concludes.

# 2 The Model

## 2.1 Technologies and Preferences

We analyze a two-period model in which a continuum of ex-ante identical households decide on their educational investment, consumption, and second-period labor supply. We assume that individuals are endowed with an initial wealth $\omega$ and with one unit of time in each period. We assume further that education $e$ is a pure time investment and that there is no labor-leisure decision in the first period. Educational investment is observable and verifiable. Hence, educational costs (i.e., the forgone earnings) can be deducted against the income tax base and can be additionally taxed or subsidized by educational policy.[2] Aside from investing in education, households can save or borrow in a perfect capital market. Savings are denoted by $a$. The first-period budget constraint (before taxation and education subsidies) reads

$$a = \omega + (1 - e) - c_1, \tag{1}$$

where $c_1$ is consumption in the first period, and where the first-period wage rate as well as the price of consumption has been normalized to one.

In the second period, households supply labor $l$ and consume their savings plus labor income. Gross labor income is represented by a general earnings function dependent on hours worked $l$ and education $e$:

$$\Phi(\theta, l, e), \quad \Phi_e,\ \Phi_l > 0, \quad \Phi_{ee} < 0, \quad \Phi_{ll} \leq 0. \tag{2}$$

$\theta$ is an idiosyncratic shock drawn from a probability distribution $f(\theta)$. Therefore, both

[2] We could also allow for direct resource costs of education without any loss of generality. As long as all inputs are verifiable, this does not change the results (see also Bovenberg and Jacobs, 2003, 2005).

income and the return to education are risky. We assume that for any given value of $\theta$, the marginal return to education $\Phi_e$ is positive and decreasing. Similarly, the marginal return to labor effort $\Phi_l$ is positive and non-increasing. Furthermore, the random variable $\theta$ is assumed to have a positive effect on income: $\Phi_\theta > 0$. In the remainder of the analysis, we focus on the two cases identified in the literature (cf. Levhari and Weiss, 1974): (i) educational investment itself causes and amplifies income risks ($\Phi_{\theta e} > 0$), and (ii) educational investment hedges against income risks ($\Phi_{\theta e} < 0$). The budget constraint in the second period (before taxation) is

$$c_2 = \Phi(\theta, l, e) + (1 + r) \cdot a, \tag{3}$$

where $c_2$ is consumption in the second period and $r$ is the constant real interest rate.

Households derive utility from consumption and disutility from labor. They maximize a von Neumann-Morgenstern expected utility function. Following common practice in the optimal tax literature under risk, we assume the utility function to be additively separable over consumption and labor supply (see, e.g., Cremer and Gahvari, 1995a, 1995b; Golosov et al., 2006; Diamond, 2006):[3]

$$EU = \mathcal{E}[U(c_1, c_2, l)] = \mathcal{E}[u(c_1, c_2)] - v(l), \quad u_1, u_2, -v_l > 0, \quad u_{11}, u_{22}, -v_{ll} \leq 0, \tag{4}$$

where $\mathcal{E}$ denotes the expectation operator (i.e., $\mathcal{E}[X] \equiv \int_\Theta X df(\theta)$, where $\Theta$ is the set of values for $\theta$). The sub-utility function of consumption is increasing and concave, whereas the disutility function of labor supply is increasing and convex. All functions are at least twice differentiable, and we assume the Inada conditions to hold.

Insurance markets to insure (idiosyncratic) income risks are imperfect; for simplicity, we assume that they are missing.[4] Market failure is due to moral hazard, adverse selection, and, as Sinn (1996, p. 261ff) points out, timing and contract problems. Perfect insurance contracts have to be signed before the veil of ignorance has lifted. However, this is hardly possible with respect to human capital risks or innate abilities for example, where parents would have to sign contracts for their children or even for their unborn children. Since a child would have to fulfill these obligations incontestably for all its life, this system would come close to bondage. Thus, Sinn (1996, p. 278) concludes that such insurance *"cannot be provided privately unless the fundamentals of western civil law are called into question."*

Instead, the government can provide social insurance by redistributive taxation. We assume that this takes place through a linear income tax system with a marginal tax

[3]This assumption fulfills the requirements for the Atkinson-Stiglitz theorem to hold. Hence, any non-zero capital tax rate will be due to incomplete insurance markets and providing social insurance.

[4]Note that this assumption simplifies the analysis, but only affects the level of taxation, not the optimal tax structure.

rate $t$ and a lump-sum transfer $T$, which can be seen as a negative income tax or basic income. Furthermore, educational investment is subsidized at a flat rate $s$ and it is fully tax deductible. Last but not least, the return to savings is taxed at a flat rate $\tau$. Interest expenses on borrowing are subsidized at this rate: there is full loss off-set. Taken together, our model is similar to the set-up in Hamilton (1987). However, education can be directly subsidized or taxed in our approach, and we allow for a more general risk (and income) process in which education can either enforce or hedge against income risk.

The timing structure of the model is as follows: First, the government sets the proportional labor tax rate $t$, the subsidy rate $s$, the capital tax rate $\tau$, and the lump-sum transfer $T$. After the policies are announced, households choose educational investment $e$, first-period consumption $c_1$, and labor supply $l$ simultaneously, before risk realizes.[5] Subsequently, (income) risk realizes, incomes are earned, and second-period consumption takes place. Second-period consumption is thus stochastic, while first-period consumption, working time, and education are deterministic.

## 2.2 Households

Due to perfect capital markets, a household faces an intertemporal budget constraint after income tax and education subsidies

$$c_2 = (1-t)\cdot\Phi(e,l,\theta) + R\cdot[\omega + (1-t)(1-(1-s)e) - c_1] + T, \tag{5}$$

where $R = 1 + r\cdot(1-\tau)$ represents the net interest factor. Subject to budget constraint (5), a household maximizes its expected utility function $EU = \mathcal{E}[u(c_1,c_2)] - v(l)$ by choosing optimal intertemporal consumption, educational investment, and second-period labor supply. The maximization problem becomes

$$\max_{c_1,l,e} \mathcal{E}[u(c_1,(1-t)\cdot\Phi(e,l,\theta) + R\cdot[\omega + (1-t)(1-(1-s)e) - c_1] + T)] - v(l), \tag{6}$$

and the appropriate first order conditions are

$$\mathcal{E}[u_1] - R\cdot\mathcal{E}[u_2] = 0, \tag{7}$$

$$\mathcal{E}[u_2\cdot\{(1-t)\Phi_e(e,l,\theta) - R\cdot(1-t)(1-s)\}] = 0. \tag{8}$$

$$\mathcal{E}[u_2\cdot(1-t)\Phi_l(e,l,\theta)] - v_l = 0, \tag{9}$$

Equation (7) implies that for optimal intertemporal allocation of consumption, the expected marginal rate of substitution meets the net interest factor – that is, the standard

[5] It can be shown that a timing sequence in which labor supply is chosen after uncertainty has been resolved does not change any of the results qualitatively (cf. Cremer and Gavhari, 1995a; Anderberg and Andersson, 2003).

Euler equation holds – and we have

$$\frac{\mathcal{E}[u_1]}{\mathcal{E}[u_2]} = R. \tag{10}$$

From the first-order condition for optimal educational investment (8), it follows by Steiner's Rule that the risk-adjusted marginal return to educational investment is equal to the present value of marginal investment costs (after subsidization),

$$(1 - \pi_e) \cdot \mathcal{E}[\Phi_e] = R \cdot (1 - s), \tag{11}$$

where $\pi_e = -\frac{cov(u_2, \Phi_e)}{\mathcal{E}[u_2]\mathcal{E}[\Phi_e]} \in (-1, 1)$ represents the risk premium in educational investment, measuring disutility from increased exposure to risk. $\pi_e$ is positive if education is risk-increasing, i.e., if $\Phi_{\theta e} > 0$. For instance, this holds for sector-specific human capital investment. It is negative if education serves as a hedge and provides insurance against income risks (e.g., general upper-secondary education). This is true if $\Phi_{\theta e} < 0$.

As we have assumed educational investment to be observable and tax deductible, the tax system does not directly affect investment in education. However, taxation generally affects investment in education indirectly via the labor supply: a tax-induced decrease in labor supply lowers the return to human capital investment as long as $\Phi_{el} > 0$. This is the case for all earnings functions discussed in the literature (cf. Jacobs and Bovenberg, 2010a). As a result, taxation reduces the incentives for investing in education. Instead, education subsidies boost educational investment, since they reduce the marginal costs.

Missing insurance markets, however, drive a wedge between the expected marginal return to education and the net investment costs, implying

$$\mathcal{E}[\Phi_e] - R \cdot (1 - s) = \pi_e \cdot \mathcal{E}[\Phi_e] = \frac{\pi_e}{1 - \pi_e} \cdot R \cdot (1 - s) \gtrless 0 \quad \text{if} \quad \pi_e \gtrless 0. \tag{12}$$

Facing uninsurable income risk, households use educational investment as a self-insurance device to reduce their exposure to risk. If education is risk-increasing (risk-decreasing), households invest too little (much) in education from a social point of view: the expected marginal return is higher (lower) than the marginal costs. This investment behavior is individually rational, but socially inefficient. The inefficiency will become worse the more risk-averse households are (i.e., the higher the risk premium in absolute terms would be).

Accordingly, the first-order condition for labor supply (9) can be rearranged as

$$(1 - \pi_l)(1 - t)\mathcal{E}[\Phi_l] = \frac{v_l}{\mathcal{E}[u_2]}, \tag{13}$$

where $\pi_l = -\frac{cov(u_2, \Phi_l)}{\mathcal{E}[u_2]\mathcal{E}[\Phi_l]}$ mirrors the risk premium in labor supply. Hence, for optimal labor supply, the risk-adjusted net wage rate equals the marginal rate of substitution between consumption and labor. The presence of risk acts as an additional tax on labor, if labor supply is a risk-increasing activity ($\pi_l > 0$), but it turns into a wage subsidy, in the case that higher labor supply reduces the exposure to income risk ($\pi_l < 0$).

Substituting optimal consumption, educational investment, and labor supply in the expected utility function, the expected indirect utility function becomes

$$V(T,t,s,R) = \mathcal{E}[u(\hat{c}_1,\hat{c}_2)] - v(\hat{l}), \tag{14}$$

where a hat indicates the optimal values.

For later reference, we apply the Envelope theorem (Roy's lemma) to find the derivatives of the indirect utility function as $\frac{\partial V}{\partial T} = \mathcal{E}[u_2]$, $\frac{\partial V}{\partial t} = -\mathcal{E}[u_2 \cdot \{\Phi(e,l,\theta) + R \cdot (1-(1-s)e)\}]$, $\frac{\partial V}{\partial s} = \mathcal{E}[u_2] \cdot R \cdot (1-t) \cdot e$, and $\frac{\partial V}{\partial R} = \mathcal{E}[u_2] \cdot [\omega + (1-t)(1-(1-s)\cdot e) - c_1]$.

## 2.3 Government

We assume a benevolent government with full (and credible) commitment. Thus, a time-inconsistency motive cannot appear. Without loss of generality, we abstract from an exogenous government revenue requirement. The government chooses policy instruments $T$, $t$, $s$, and $R$ to maximize the expected indirect utility $V(T,t,s,R)$ of the households. The informational requirements for employing linear instruments are that only aggregate income, aggregate savings, and aggregate education choices need to be verifiable to the government. Then, taxes can be collected and subsidies can be paid in a withholding fashion at firm level and individual incomes need not be observed.

By the law of large numbers, individual idiosyncratic risks cancel in the aggregate, and we find that the government budget constraint is given by

$$t \cdot [\mathcal{E}[\Phi(e,l,\theta)] + (1+r)\cdot(1-(1-s)\cdot e)] + (1+r-R)\cdot[\omega + (1-t)(1-(1-s)\cdot e) - c_1] - (1+r)\cdot s \cdot e = T \tag{15}$$

All tax revenue is deterministic at the aggregate level and it is used to finance the lump-sum transfer and education subsidies. We abstract from any systematic risk.[6]

Taken together, the optimization problem can be displayed as:

$$\max_{T,t,s,R} V(T,t,s,R) \quad \text{s.t.} \quad (15) \tag{16}$$

[6] In the case of additional systematic (aggregate) income risks, the government's tax revenue would also become risky. This would require an additional insurance device in the form of public consumption to smooth aggregate shocks over private and public consumption (see, e.g., Kaplow, 1994), but it should not affect our main findings on insuring the idiosyncratic part of risk.

Denoting the Lagrange multiplier as $\eta$, the first order conditions are represented by

$$\frac{\partial V}{\partial T} + \eta \cdot \left\{ \Delta_e \cdot \frac{\partial e}{\partial T} + \Delta_l \cdot \frac{\partial l}{\partial T} + \Delta_{c_1} \cdot \frac{\partial c_1}{\partial T} - 1 \right\} = 0, \tag{17}$$

$$\frac{\partial V}{\partial t} + \eta \cdot \left\{ \Delta_e \cdot \frac{\partial e}{\partial t} + \Delta_l \cdot \frac{\partial l}{\partial t} + \Delta_{c_1} \cdot \frac{\partial c_1}{\partial t} + \mathcal{E}[\Phi(.)] + R \cdot (1 - (1-s) \cdot e) \right\} = 0, \tag{18}$$

$$\frac{\partial V}{\partial s} + \eta \cdot \left\{ \Delta_e \cdot \frac{\partial e}{\partial s} + \Delta_l \cdot \frac{\partial l}{\partial s} + \Delta_{c_1} \cdot \frac{\partial c_1}{\partial s} - R \cdot (1-t) \cdot e \right\} = 0, \tag{19}$$

$$\frac{\partial V}{\partial R} + \eta \cdot \left\{ \Delta_e \cdot \frac{\partial e}{\partial R} + \Delta_l \cdot \frac{\partial l}{\partial R} + \Delta_{c_1} \cdot \frac{\partial c_1}{\partial R} - [\omega + (1-t)(1 - (1-s) \cdot e) - c_1] \right\} = 0, \tag{20}$$

where we have defined the (expected) tax wedges as

$$\begin{aligned} \Delta_e &= t \cdot \{\mathcal{E}[\Phi_e] - R \cdot (1-s)\} - R \cdot s - \tau r \\ &= t \cdot \frac{\pi_e}{1-\pi_e} \cdot R \cdot (1-s) - R \cdot s - \tau r, \end{aligned} \tag{21}$$

$$\Delta_l = t \cdot \mathcal{E}[\Phi_l], \tag{22}$$

$$\Delta_{c_1} = -\tau r. \tag{23}$$

The tax wedges indicate the (expected) change in total tax revenue, based on the behavioral responses of households due to a marginal change in one of the tax instruments. Thereby, the second equality in equation (21) stems from applying the households' first-order condition (8) twice.

## 2.4 Decision Margins and Distortions

The task of the government is to provide social insurance – that is, to redistribute between "winners" and "losers". Income risk can be reduced by implementing a wage tax and granting a deterministic lump-sum transfer. However, this comes at the cost of distorting labor supply and creating a fiscal externality. The latter stems from the fact that the marginal return and the marginal costs of educational investment are not equalized, due to self-insurance of households by under- or overinvesting in education. Consequently, a marginal increase in education creates a positive (negative) tax-revenue effect in the case of underinvestment (overinvestment) in education (see Jacobs et al., 2010).

In order to alleviate these efficiency costs, both education subsidies and capital taxation can be applied as 'catalysts' for social insurance via labor taxation. Education subsidies increase human capital investment and, thus, the effective wage rate. As a result, education subsidies alleviate labor tax distortions by increasing labor supply. However, this is paid for by distorting educational investment.

Capital taxation fosters labor supply via two channels: first, it functions as an indirect education subsidy by reducing the opportunity costs of human capital investment. Consequently, it encourages labor supply in the second period, but it distorts educational investment. Second, capital taxation reduces second-period consumption and boosts labor supply by increasing the marginal utility of income, viz., the opportunity costs of second-period leisure.[7] However, the latter effect has the disadvantage of distorting intertemporal consumption choice.

In the following analysis, we examine how these three instruments can be optimally combined in order to balance the net distortions on all margins and to provide the optimal social insurance package. The main question to be answered is how education subsidies and capital taxation can serve as catalysts to facilitate income insurance.

# 3 The Social Insurance Package

## 3.1 Optimal Transfer Income

Following Diamond (1975), we define the expected net social marginal value of income, including the income effects on the tax base, as $b \equiv \frac{\mathcal{E}[u_2]}{\eta} + \Delta_e \cdot \frac{\partial e}{\partial T} + \Delta_l \cdot \frac{\partial l}{\partial T} + \Delta_{c_1} \cdot \frac{\partial c_1}{\partial T}$. Accordingly, rearranging the first-order condition (17) leads to

$$b \equiv \frac{\mathcal{E}[u_2]}{\eta} + \Delta_e \cdot \frac{\partial e}{\partial T} + \Delta_l \cdot \frac{\partial l}{\partial T} + \Delta_{c_1} \cdot \frac{\partial c_1}{\partial T} = 1. \tag{24}$$

Thus, the optimal lump-sum transfer balances the net marginal value of income (from society's perspective) against its marginal revenue costs, which equal unity.

## 3.2 Labor Taxation Without Catalysts

First, we derive as a benchmark case the optimal labor tax rate $t$ without catalysts – namely, the government can use neither education subsidies nor capital taxation. This case arises when neither educational investment nor savings are verifiable by the government. This corresponds to the set of instruments in Eaton and Rosen (1980).

Analogous to Feldstein's distributional characteristic, we define the insurance characteristic

$$\xi \equiv -\frac{cov(u_2, \Phi(.))}{\mathcal{E}[u_2] \cdot \mathcal{E}[\Phi(.)]} > 0 \tag{25}$$

as the negatively normalized covariance between the marginal utility of income and income. The insurance characteristic $\xi$ gives the marginal welfare loss of income risk and measures the government's concern for insurance.

Moreover, we define the expected-utility compensated elasticities with respect to the labor tax rate as $\varepsilon_{et} = \frac{\partial e^c}{\partial t}\frac{1-t}{e}$ and $\varepsilon_{lt} = \frac{\partial l^c}{\partial t}\frac{1-t}{l}$. By applying the Slutsky equations and

[7] See Cremer and Gahvari (1995a) or Jacobs and Schindler (2009) for a detailed analysis of this effect.

equation (24) to eliminate income effects, and by inserting $s = \tau = 0$, the optimal labor tax rate can be derived from equation (18)(see Appendices A and B.1) as

$$\frac{t}{1-t} = \frac{\xi}{\omega_l \cdot (-\varepsilon_{lt}) - \pi_e \cdot \omega_e \cdot \varepsilon_{et}}. \tag{26}$$

Thereby, $\omega_l = \frac{\mathcal{E}[\Phi_l l]}{\mathcal{E}[\Phi]}$ and $\omega_e = \frac{\mathcal{E}[\Phi_e e]}{\mathcal{E}[\Phi]}$ are the expected earnings shares of labor and education in total earnings, respectively.

Equation (26) represents the standard trade-off between the welfare gain of providing insurance and the efficiency costs of doing so. The higher the benefits from social insurance (i.e., the higher $\xi > 0$ is), the higher the optimal tax rate should be, ceteris paribus. However, providing social insurance creates excess burden, in particular from distorting labor supply. We assume – for all the following elasticities as well – that all compensated elasticities maintain their signs under certainty; hence $\varepsilon_{lt} < 0$.[8] All things equal, the larger $(-\varepsilon_{lt}) > 0$ is, the more labor taxation distorts labor supply and the lower the optimal tax rate should be.

Furthermore, the optimal labor tax rate depends on a fiscal externality $(\pi_e \cdot \omega_e \cdot \varepsilon_{et})$, which can be of any sign.[9] Note that the labor tax elasticity of educational investment is negative, $\varepsilon_{et} < 0$, because an increase in labor taxation decreases (compensated) labor supply and therefore the utilization of human capital. In the case of $\pi_e > 0$ ($\pi_e < 0$), where there is under- (over-)investment in education, a marginal decrease in educational investment decreases (increases) tax revenue. Therefore, increasing the labor tax rate causes a negative (positive) fiscal externality, calling for a lower (higher) labor tax rate.

## 3.3 Education Subsidies and Capital Taxation as Catalysts

In the case in which both educational investment and savings in real capital are observable and verifiable, the government can use both instruments as catalysts for social insurance policy. We define the expected-utility compensated elasticities with respect to the subsidy rate as $\varepsilon_{es} = \frac{\partial e^c}{\partial s}\frac{1-s}{e}$, $\varepsilon_{ls} = \frac{\partial l^c}{\partial s}\frac{1-s}{l}$, and $\varepsilon_{c_1 s} = \frac{\partial c_1^c}{\partial s}\frac{1-s}{c_1}$. Furthermore, the corresponding elasticities with respect to the after-tax interest rate $R$ are denoted as $\varepsilon_{eR} = \frac{\partial e^c}{\partial R}\frac{R}{e}$, $\varepsilon_{lR} = \frac{\partial l^c}{\partial R}\frac{R}{l}$, and $\varepsilon_{c_1 R} = \frac{\partial c_1^c}{\partial R}\frac{R}{c_1}$.

The optimal education subsidies follow from combining the first-order conditions (19) and (20) and applying the optimal lump-sum transfer (24) (see Appendix B.2) as

$$\frac{s}{1-s} = \left[\frac{\varepsilon_{ls} - \varepsilon_{as} \cdot \frac{\varepsilon_{lR}}{\varepsilon_{aR}}}{\varepsilon_{es} - \varepsilon_{as} \cdot \frac{\varepsilon_{eR}}{\varepsilon_{aR}}}\right] \frac{\omega_l}{\omega_e} \cdot \frac{\hat{t}}{1-\pi_e} + \frac{\pi_e}{1-\pi_e} \cdot \hat{t}. \tag{27}$$

[8]Though in principle the signs of some of these elasticities are ambiguous due to offsetting insurance effects, this assumption should hold under mild restrictions; see Jacobs and Schindler (2009) for a comprehensive discussion in a related setting as well as Jacobs and Bovenberg (2010b) for signing elasticities in a deterministic model.

[9]See Jacobs et al. (2010) for a detailed discussion of the fiscal externality.

By inserting expression (27) into equation (42), the optimal capital tax rate follows (after some rearrangements) as

$$\frac{\tau r}{R} = \left[ \frac{(-\varepsilon_{lR}) + \varepsilon_{eR} \cdot \frac{\varepsilon_{ls}}{\varepsilon_{es}}}{\varepsilon_{aR} - \varepsilon_{eR} \cdot \frac{\varepsilon_{as}}{\varepsilon_{es}}} \right] \omega_l \cdot \hat{t}. \tag{28}$$

We define $\gamma_e = \frac{R \cdot e}{\mathcal{E}[\Phi]}$ and $\gamma_{c_1} = \frac{R \cdot c_1}{\mathcal{E}[\Phi]}$ as shares of expenditure on education and first-period consumption in total earnings, respectively. Moreover, we define the savings elasticity with respect to education subsidies as $\varepsilon_{as} = -(\gamma_e \cdot \varepsilon_{es} + \gamma_{c_1} \cdot \varepsilon_{c_1 s}) < 0$, which combines the expenditure-share weighted effects of education subsidies on educational investment and on first-period consumption. We assume that education subsidies increase first-period consumption ($\varepsilon_{c_1 s} > 0$). The reasoning is as follows: education subsidies increase total income by encouraging education and increasing the labor supply. The resulting higher labor income increases consumption in both periods from consumption-smoothing. The savings elasticity with respect to the net interest rate is defined as $\varepsilon_{aR} = -(\gamma_e \cdot \varepsilon_{eR} + \gamma_{c_1} \cdot \varepsilon_{c_1 R}) > 0$. It is unambiguously positive, because a higher net interest rate $R$ renders both educational investment and first-period consumption less attractive.

The insurance characteristic $\xi$ does not enter into either of the two optimal tax rules, and both expressions hold for the optimal labor tax rate $\hat{t}$ as well as for an arbitrarily given tax rate $t > 0$. Accordingly, two straightforward results apply both to the optimal education subsidies and to the optimal capital taxation. First, neither catalyst directly provides social insurance, since both capital tax payments and education subsidies received do not affect the variance of income; that is, they do not vary across the states of nature. Moreover, all households are homogenous ex ante; consequently, there is no ability bias at work, either (see Maldonado, 2008, and Jacobs and Bovenberg, 2010a, for ability bias in a deterministic world with heterogenous households). Second, neither instrument is used if there is no social insurance. If the labor tax rate were zero, $t = 0$, the only insurance device available would be self-insurance by over- or underinvestment in education, which is optimally chosen by households. This insurance effect would be disturbed by subsidizing education or taxing capital income. Furthermore, in the case where $t = 0$, there would be no fiscal externality to be corrected for.

From equation (27) we find that, *firstly*, optimal education subsidies decrease with distortions caused, which are represented by the denominator in the first term on the right-hand side. The more elastic educational investment is with respect to subsidies ($\varepsilon_{es} > 0$), the higher the excess burden of this instrument will be. However, the availability of capital taxation allows for a mitigating complementarity effect: reducing distortions in educational investment can be traded against distorting real savings, $\frac{\varepsilon_{eR}}{\varepsilon_{aR}} < 0$, and this effect becomes stronger the more the savings tax base responds to education subsidies,

$\varepsilon_{as} < 0$. *Secondly*, education subsidies increase with the marginal efficiency gains from boosting labor supply, as indicated by $\varepsilon_{ls} > 0$ in the numerator of the first term on the right-hand side. Due to the complementarity between labor supply and education, education subsidies foster labor supply and counteract the negative incentive effects of labor taxation (Bovenberg and Jacobs, 2005; Jacobs and Bovenberg, 2010a). *Thirdly*, education subsidies interfere with the complementarity effect of capital taxation on labor supply. Capital taxation also alleviates distortions in labor supply, both by fostering education (Jacobs and Bovenberg, 2010b) and through intertemporal consumption effects (Jacobs and Schindler, 2009), but this efficiency gain has to be traded off against (downward) distortions in savings (see $\frac{\varepsilon_{lR}}{\varepsilon_{aR}} < 0$). Since education subsidies distort real savings downwards as well, they worsen the aforementioned trade-off: applying capital taxes becomes more costly. Hence, education subsidies make the capital tax a less effective instrument to boost labor supply. The stronger this interference ($\varepsilon_{as} \cdot \frac{\varepsilon_{lR}}{\varepsilon_{aR}} > 0$) is, the lower education subsidies should be. They might (ceteris paribus) even turn negative in order to boost the capital-tax effect. In the following discussion, we will call this interference effect the "indirect complementarity effect".

*Fourthly*, we see from equations (27) and (28) that the additive property of internalizing externalities in an optimal-tax setting (Sandmo, 1975) holds, if sufficient instruments are available. In contrast to mitigating labor supply distortions, the externality is corrected by relying on education subsidies only, and in an additive manner. This is represented by $\frac{\pi_e}{1-\pi_e}$, the second summand on the right-hand side of (27). Depending on the sign and the magnitude of the externality, education subsidies can also turn negative. The risk premium $\pi_e$ does not explicitly enter into the formula for the optimal capital tax rate. Accordingly, when education subsidies are optimally chosen, inefficient educational investment does not directly affect capital taxation. The reason is that directly relying on the price of the "commodity" causing the externality is more efficient (see Sandmo, 1975, pp. 92, 95). In our case, this commodity is education and its relevant price is directly linked with education subsidies.

Turning to the optimal capital taxation as given by equation (28), we find that, *firstly*, the capital tax rate decreases with distortions caused in compensated savings, $\varepsilon_{aR} > 0$. The more elastic savings are with respect to the interest rate, the higher the efficiency losses from capital taxation are. However, education subsidies can moderate distortions in savings, traded against distortions in educational investment ($\frac{\varepsilon_{as}}{\varepsilon_{es}} < 0$). This trade-off is more important, the more a higher interest rate decreases educational investment ($\varepsilon_{eR} < 0$). Thus, this complementarity effect works in favor of higher capital taxes. *Secondly*, capital taxation improves efficiency by fostering labor supply via two channels. (i) By reducing second-period consumption, capital taxation increases the marginal utility of income and thus the opportunity costs of leisure. Consequently, capital taxation (ceteris paribus) boosts labor supply in the second period (cf. Jacobs and Schindler, 2009). (ii)

Capital taxation encourages human capital investment. Therefore, it fosters labor supply by increasing the opportunity costs of leisure on this account as well. Consequently, capital taxation mitigates labor supply distortions. This is represented by the first term in the numerator, $(-\varepsilon_{lR}) > 0$. *Thirdly,* there is an "indirect complementarity effect" at work. Education subsidies boost labor supply, but distort educational investment (see the discussion of equation (27) above). This trade-off is more beneficial, the higher $\frac{\varepsilon_{ls}}{\varepsilon_{es}} > 0$ is. The more a higher interest rate decreases educational investment ($\varepsilon_{eR} < 0$), the more the aforementioned trade-off is improved and the lower the capital tax should be ceteris paribus.

Considering the second and the third aspect together, the optimal capital tax can also be negative, contrary to models without endogenous educational investment (Cremer and Gahvari, 1995a,b; Jacobs and Schindler, 2009). Capital taxation will be equal to zero in the special case in which its complementarity effect on labor supply $\varepsilon_{lR}$ exactly cancels out deteriorating the complementarity effect of education subsidies on labor supply, implying $\frac{\varepsilon_{lR}}{\varepsilon_{eR}} = \frac{\varepsilon_{ls}}{\varepsilon_{es}}$. In this case, both instruments are (per "unit" of distortion in educational investment) equally effective in boosting labor supply, and capital taxation becomes redundant, since it additionally distorts intertemporal consumption. Generally, mitigation by capital taxation is less important, the more labor supply distortions are mitigated via education subsidies.

We summarize:

**Proposition 1.** *If both savings and educational investment are verifiable, both capital taxation and education subsidies are used for mitigating labor supply distortions, but they do not provide any direct insurance. Both instruments increase with their complementarity effect on labor and decrease with induced net distortions and with harming the complementarity effect of the other instrument. The additive property for externalities holds and only education subsidies are used to internalize the external effect of missing insurance markets.*

In comparison to models relying only on education subsidies (cf. Jacobs et al., 2010), the availability of capital taxation has significant effects. The intuition can be briefly summarized as follows: first, capital taxation is another way to mitigate distortions in labor supply by indirectly subsidizing educational investment. Second, there is a stand-alone effect of capital taxation on labor supply via intertemporal wealth effects (cf. Jacobs and Schindler, 2009). Therefore, capital taxation has an additional complementarity effect working independently of education.[10] Nevertheless, both education subsidies and capital taxation are used. Education subsidies are less distortive in the sense that they distort only educational investment; however, they affect labor supply only by complementarity

[10] Without showing this explicitly, this intertemporal mechanism is also relevant in extensions of models with centrally decided educational investment (e.g., Anderberg and Andersson, 2003).

between education and labor, and they are costly in the sense that the government has to collect tax revenue to finance subsidies. On the other hand, capital taxes not only distort educational investment, but also intertemporal consumption.

Consequently, extending and generalizing the modeling by Hamilton (1987) preserves the use of capital taxation, but its role fundamentally changes. In particular, capital taxation is no longer required for internalizing the fiscal externality, but only used to alleviate tax distortion in labor supply.

From rearranging and dividing equation (27) by equation (28), we obtain a Ramsey-type rule for the simultaneous use of education subsidies and capital taxation,

$$\frac{\frac{s}{1-s}}{\frac{\tau r}{R}} = \frac{\varepsilon_{aR} - \varepsilon_{lR} \cdot \frac{\varepsilon_{as}}{\varepsilon_{ls}}}{\left(\varepsilon_{es} - \varepsilon_{ls} \cdot \frac{\varepsilon_{eR}}{\varepsilon_{lR}}\right) \cdot \omega_e \cdot (1-\pi_e)} \cdot \frac{\varepsilon_{ls}}{(-\varepsilon_{lR})} + \frac{\varepsilon_{aR} - \varepsilon_{eR} \cdot \frac{\varepsilon_{as}}{\varepsilon_{es}}}{\omega_l \cdot \left[(-\varepsilon_{lR}) + \varepsilon_{eR} \cdot \frac{\varepsilon_{ls}}{\varepsilon_{es}}\right]} \cdot \frac{\pi_e}{1-\pi_e}. \quad (29)$$

The second term on the right-hand side of equation (29) mirrors the effect of the fiscal externality. As implied by the additive property, the relative reliance on education subsidies ceteris paribus increases (decreases) with the magnitude of the fiscal externality $\pi_e$ in the case of underinvestment $\pi_e > 0$ (overinvestment $\pi_e < 0$). Ceteris paribus, the externality is more significant, the higher the net distortions of capital taxation are ($\varepsilon_{aR} - \varepsilon_{eR} \cdot \frac{\varepsilon_{as}}{\varepsilon_{es}} > 0$), i.e., the more costly capital taxation is. These net distortions are positive from the second-order conditions of the governmental optimization problem. The externality matters less, the more relevant labor supply is (viz., the larger the share $\omega_l$ is) and the better capital taxation can alleviate labor supply distortions (i.e., the higher $(-\varepsilon_{lR}) + \varepsilon_{eR} \cdot \frac{\varepsilon_{ls}}{\varepsilon_{es}}$ is).

The first term on the right-hand side encompasses two effects: on the one hand, there is the standard distortion effect. The more net distortions capital taxation causes in savings relative to risk-adjusted, income-weighted net distortions in educational investment by education subsidies (i.e., the higher $\frac{\varepsilon_{aR} - \varepsilon_{lR} \cdot \frac{\varepsilon_{as}}{\varepsilon_{ls}}}{\left(\varepsilon_{es} - \varepsilon_{ls} \cdot \frac{\varepsilon_{eR}}{\varepsilon_{lR}}\right) \cdot \omega_e \cdot (1-\pi_e)}$ is), the more expensive capital taxation is in terms of welfare costs. Thus, the more education subsidies will ceteris paribus be used compared to capital taxation. Note that the "indirect complementarity effects" discussed in equations (27) and (28) cancel out, but also that there are now alleviating complementarity effects working via labor supply ($\varepsilon_{lR} \cdot \frac{\varepsilon_{as}}{\varepsilon_{ls}} > 0$ and $\varepsilon_{ls} \cdot \frac{\varepsilon_{eR}}{\varepsilon_{lR}} > 0$, respectively). On the other hand, contrary to a standard Ramsey rule, the instruments differ in their beneficial effects. Thus, education subsidies are also preferable to capital taxation, when former boost labor supply better than the latter does; i.e., when $\frac{\varepsilon_{ls}}{(-\varepsilon_{lR})} > 0$ is higher.

Equation (29) indicates that education subsidies and capital taxes are (strategic) substitutes – that is, if one instrument increases, the other one should optimally decrease. This substitutability establishes a policy-relevant link between educational policy and competition in personal tax rates on real capital. Winner (2005) provides strong evidence that tax competition has been on-going since the mid-1980s by showing a shift from taxing capital to taxing labor. This shift in tax burdens is due not only to corporate tax competition, but also to a decrease in personal capital income taxes, as is observable in all OECD countries. If fiercer 'tax competition' is interpreted as globalization, which ceteris paribus raises the elasticity of savings due to a larger mobility of capital (i.e., as an increase in $\varepsilon_{aR}$), we find from equation (28) that the optimal capital tax decreases, because it now becomes more costly. As can be seen from the Ramsey-type equation (29), education subsidies should be increased relative to capital taxation, at least as long as there is underinvestment, $\pi_e > 0$.

However, the effect on the absolute level of optimal education subsidies implied by equation (27) is ambiguous. On the one hand, education subsidies are less necessary to reduce capital-tax induced distortions in education through decreasing savings ($\varepsilon_{as} \cdot \frac{\varepsilon_{eR}}{\varepsilon_{aR}} > 0$). This ceteris paribus decreases subsidies. On the other hand, it becomes less important that education subsidies hamper the complementarity effect of capital taxation ($\varepsilon_{as} \cdot \frac{\varepsilon_{lR}}{\varepsilon_{aR}} > 0$), since the latter is less effective. This ceteris paribus increases education subsidies. As long as mitigating labor supply distortions carries more weight than mitigating distortions in educational investment, optimal education subsidies increase absolutely as well. Consequently, under these conditions, capital tax competition should be accompanied by increasing direct subsidies on education. We conclude:

**Corollary 1.** *Capital taxation and education subsidies tend to be (strategic) substitutes as long as reducing labor supply distortions is important. Then, a lower capital tax rate due to capital-tax competition should be accompanied by higher (direct) education subsidies.*

## 3.4 Non-observable Educational Investment

Two relevant special cases can be analyzed. For the first, in which capital taxation is not available, we refer to Jacobs et al. (2010). In this section, we analyze the opposite case, in which the government cannot observe educational investment and education subsidies are thus unavailable. This setting allows specification of the results in Hamilton (1987). The optimal capital tax rate in the absence of education subsidies follows from setting $s = 0$ in equation (42) in Appendix B.2 as

$$\frac{\tau r}{R} = -\left(\omega_l \cdot \frac{\varepsilon_{lR}}{\varepsilon_{aR}} + \pi_e \cdot \omega_e \cdot \frac{\varepsilon_{eR}}{\varepsilon_{aR}}\right) \cdot \hat{t}. \tag{30}$$

Again, equation (30) balances the marginal efficiency gains against the marginal excess burden of capital taxation. However, without education subsidies, capital taxation has to correct the fiscal externality as well. Hamilton (1987) assumes multiplicative risk, unambiguously implying underinvestment in education. He argues that capital taxation should be used to correct this inefficient educational investment, and he shows that the optimal capital tax is positive, in the case in which (i) labor supply is inelastic and (ii) either equilibrium savings are zero or there is constant absolute risk aversion. Our approach shows that these very strong assumptions can be relaxed, and it extends the Hamilton-analysis by deriving a closed-form solution for the optimal capital tax.[11]

Equation (30) confirms that capital taxation is increasing with the magnitude of the fiscal externality in the case of underinvestment (i.e., $\pi_e > 0$). In other words, the more education is distorted downwards by uninsurable income risk, the stronger the need for capital taxation in order to encourage education is. Furthermore, the more effective capital taxation is in fostering education ($\varepsilon_{eR} < 0$), the higher its tax rate should be. Contrary to Hamilton (1987), however, the optimal capital tax rate can also turn negative, in the case that educational investment is a risk-reducing activity (i.e., if there is overinvestment and $\pi_e < 0$) and if the fiscal externality effect dominates the complementarity effect in labor supply; this is described in the following paragraph. In this case, interest income should be subsidized to discourage excessive overinvestment into education.

As we allow for endogenous labor supply, there is a second effect at work. Capital taxation boosts labor supply and moderates distortions from social insurance by fostering educational investment and decreasing second-period consumption (see the previous subsection). Accordingly, the optimal capital tax rate also increases with the complementarity between capital taxation and labor supply ($\varepsilon_{lR} < 0$).

All these beneficial effects are traded off against distortions in real savings ($\varepsilon_{aR} > 0$). A higher net interest rate increases the (intertemporal) opportunity costs of human capital investment ($\varepsilon_{eR} < 0$), and it increases the price of first-period consumption ($\varepsilon_{c_1R} < 0$) as well. Consequently, savings are increased by a higher net interest rate. These distortions decrease the optimal capital taxation.

**Proposition 2.** *If education subsidies are not available, capital taxation is used for boosting endogenous labor supply and for internalizing the fiscal effect from under- or overinvestment in education. Depending on the risk properties of education ($\pi_e \gtrless 0$) and the magnitude of the fiscal externality, the optimal capital tax rate can be negative as well.*

Grochulski and Piskorski (2010) show that the unobservability of educational investment makes incentive constraints more severe and that it leads to a larger wedge on real capital investment. The latter is implemented by a higher volatility of marginal capital tax rates. In our linear-taxation model, the optimal capital tax rate tends also to be higher in the absence of education subsidies, but only in case of underinvestment. This is because capital taxation is the only instrument to alleviate labor supply distortions and to internalize the fiscal externality. However, if education is risk-decreasing, capital

[11] Note that the capital tax rate $\tau$ also enters into the elasticities on the right-hand side. As is usual in public finance, it still highlights in detail the trade-offs determining the optimal tax rate.

taxation will be decreased ceteris paribus to fight against the effect of overinvestment in human capital.

## 3.5 Optimal Labor Tax Cum Catalysts

Substituting equations (27) and (28) into equation (36) in the appendix finally leads to the optimal labor tax expression in which both education subsidies and capital taxation are optimally chosen:

$$\xi = \frac{\hat{t}}{1-\hat{t}} \cdot \omega_l \left( (-\varepsilon_{lt}) + \underbrace{\varepsilon_{et} \left[ \frac{\varepsilon_{ls} - \varepsilon_{as} \cdot \frac{\varepsilon_{lR}}{\varepsilon_{aR}}}{\varepsilon_{es} - \varepsilon_{as} \cdot \frac{\varepsilon_{eR}}{\varepsilon_{aR}}} \right]}_{s-effect} - \underbrace{\varepsilon_{at} \left[ \frac{(-\varepsilon_{lR}) + \varepsilon_{eR} \cdot \frac{\varepsilon_{ls}}{\varepsilon_{es}}}{\varepsilon_{aR} - \varepsilon_{eR} \cdot \frac{\varepsilon_{as}}{\varepsilon_{es}}} \right]}_{\tau-effect} \right). \quad (31)$$

The optimal labor tax rate increases with the welfare gain $\xi$ from reducing income risk, but it decreases with the tax elasticity of labor supply ($\varepsilon_{lt}$). The labor supply distortions are, however, more alleviated, the more labor taxation boosts the net complementarity effect of education subsidies by decreasing subsidy-induced distortions in education (i.e., the larger $\varepsilon_{et} < 0$ is in absolute value). This is called the "s-effect" in equation (31). The same holds true for fostering the net complementarity effect of capital taxation by reducing capital-tax-induced distortions in savings (viz., by having a larger $\varepsilon_{at} > 0$). The latter is named the "$\tau$-effect". These complementarity effects ceteris paribus increase the labor tax rate, allowing for a better social insurance.

As demonstrated by Jacobs et al. (2010), the fiscal externality ceases to enter into the optimal labor tax formula. Thus, with optimal education subsidies, inefficient educational investment no longer directly affects the optimal labor taxation. In comparison to Jacobs et al. (2010), the availability of capital taxation increases the likelihood of better social insurance in equation (31) relative to the case without catalysts in (26).

Our analysis provides a complement to the analysis of optimal non-linear taxation in the 'new dynamic public finance' literature (see Golosov et al., 2006; Diamond, 2006). If only real savings are observable, Kocherlakota (2005) and Grochulski and Piskorski (2010) point out that capital should bear a positive wedge for relaxing incentive constraints. In the case of verifiable educational investment, Anderberg (2009) and da Costa and Maestri (2007) show that education should bear a wedge as well, i.e., that both education subsidies and capital taxation are optimally used in order to provide social insurance efficiently.

Our approach confirms their results for the informationally less demanding case of linear tax instruments. The downside of linear taxation is that the tax structure is less flexible; however, the upside is that the government only has to verify aggregate labor income, aggregate savings, and aggregate investment in education. Our analysis sheds light on the driving forces and the main intuition behind optimal positive intertemporal and educational wedges for relaxing incentive constraints (namely, increasing opportunity costs of leisure). In addition, we point out that, under linear tax instruments, the optimal capital tax rate can become negative if it severely interferes with boosting labor supply by education subsidies. To the best of our knowledge, this result is new to the existing literature.

Another advantage of linear instruments is that they are directly implementable. The reason is that successful (i.e., high-ability) agents cannot profit from mimicking unsuccessful (i.e., low-ability) agents. We derive explicit formulas for the optimal education subsidies and the optimal capital tax rate. In contrast, for non-linear taxation in the vein of 'new dynamic public finance', implementing the optimal intertemporal wedges is difficult and needs additional requirements (e.g., special assumptions about the distribution of shocks and record-keeping as in Golosov and Tsyvinski, 2006). Except for very special cases, implementing optimal educational wedges is even impossible (see Anderberg, 2009).

# 4 Conclusions

This paper examined the optimal social insurance package in an intertemporal model. While income risk is insured only by labor taxation, both education subsidies and capital taxation, if available, serve as catalysts for social insurance through mitigating labor supply distortions. Optimal education subsidies increase with their complementarity effect on labor supply via enhancing education, but they decrease with induced net distortions in educational investment. The optimal capital tax also increases with its complementarity effect, which boosts labor supply both by fostering education and by intertemporal wealth effects. It decreases with its distortions in real savings. Both instruments decrease with interfering with the complementarity effect of the other instrument. Since education subsidies and capital taxation differ both in their benefits and in the distortions they cause, both instruments are generally used and their net marginal dead-weight losses are balanced against each other.

Our results show that capital taxation is optimally used under less restrictive assumptions than examined in Hamilton (1987). In the case that educational investment is not observable, capital taxation is used both for mitigating labor supply distortions and for internalizing a fiscal externality, which results from self-insurance of households by over- or underinvesting in education. If educational investment is verifiable, it follows from our analysis that capital taxation is no longer used for internalization of the fiscal externality and that the additive property holds (see Sandmo, 1975). This is because education subsidies are the preferable direct instrument. Nevertheless, capital taxation still plays a role in such a generalized Hamilton-model: it is applied to boost the labor supply. Furthermore, our analysis of linear taxes complements the 'new dynamic public finance' literature. We derive closed-form solutions for optimal tax rates that are directly implementable.

Our results have a clear policy implication: if tax competition decreases personal capital tax rates, education subsidies should increase. In Europe, (personal) capital taxes are indeed decreasing, but education subsidies are decreasing as well. Based on our analysis, this policy should be questioned, if the aim is to foster labor supply and to overcome labor market distortions from providing social insurance.

# A Appendix: Risk-adjusted Slutsky equations

For deriving the risk-adjusted Slutsky equations (see also Cremer and Gahvari, 1995a), we define the expenditure function $X(t, s, R, V)$ as the minimum level of non-labor income $T$ required to attain the expected indirect utility $V$. $X(.)$ can be obtained by setting $X(t, s, R, V) \equiv T$ for the optimal level of indirect utility $V$ as given in equation (14). Consequently, the compensated demand functions are defined as

$$c_i^c(t, s, R, V) \equiv c_i(t, s, R, X(t, s, R, V)), \tag{32}$$

where the superscript $c$ denotes a compensated change. By totally differentiating the compensated demand functions for a given $V$ and using Shephard's lemma, we obtain the following risk-adjusted Slutsky equations with respect to the tax rate $t$:

$$\begin{aligned}
\frac{\partial e}{\partial t} &= \frac{\partial e^c}{\partial t} - ((1-\xi)\mathcal{E}[\Phi] + R \cdot (1-(1-s)e)) \frac{\partial e}{\partial T}, \\
\frac{\partial l}{\partial t} &= \frac{\partial l^c}{\partial t} - ((1-\xi)\mathcal{E}[\Phi] + R \cdot (1-(1-s)e)) \frac{\partial l}{\partial T}, \\
\frac{\partial c_1}{\partial t} &= \frac{\partial c_1^c}{\partial t} - ((1-\xi)\mathcal{E}[\Phi] + R \cdot (1-(1-s)e)) \frac{\partial c_1}{\partial T}.
\end{aligned}$$

The Slutsky equations with respect to changes in the subsidy rate $s$ are

$$\begin{aligned}
\frac{\partial e}{\partial s} &= \frac{\partial e^c}{\partial s} + R(1-t)e\frac{\partial e}{\partial T}, \\
\frac{\partial l}{\partial s} &= \frac{\partial l^c}{\partial s} + R(1-t)e\frac{\partial l}{\partial T}, \\
\frac{\partial a}{\partial s} &= \frac{\partial a^c}{\partial s} + R(1-t)e\frac{\partial a}{\partial T},
\end{aligned}$$

and the equations with respect to variations in the net (after-tax) interest rate $R$ are

$$\frac{\partial e}{\partial R} = \frac{\partial e^c}{\partial R} + (\omega + (1-t)(1-(1-s)\cdot e) - c_1)\,\frac{\partial e}{\partial T},$$
$$\frac{\partial l}{\partial R} = \frac{\partial l^c}{\partial R} + (\omega + (1-t)(1-(1-s)\cdot e) - c_1)\,\frac{\partial l}{\partial T},$$
$$\frac{\partial c_1}{\partial R} = \frac{\partial c_1^c}{\partial R} + (\omega + (1-t)(1-(1-s)\cdot e) - c_1)\,\frac{\partial c_1}{\partial T}.$$

# B Appendix: Deriving Optimal Tax Rules

## B.1 Optimal Income Taxation

From Roy's lemma, equation (18), and the Slutsky equations (see Appendix A), we find

$$-\left[\mathcal{E}[\Phi(.)](1-\xi) + R\cdot(1-(1-s)\cdot e)\right]\cdot\left\{\frac{\mathcal{E}[u_2]}{\eta} + \Delta_e\cdot\frac{\partial e}{\partial T} + \Delta_l\cdot\frac{\partial l}{\partial T} + \Delta_{c_1}\cdot\frac{\partial c_1}{\partial T}\right\} \tag{33}$$
$$+\mathcal{E}[\Phi(.)] + R\cdot(1-(1-s)\cdot e) + \Delta_e\cdot\frac{\partial e^c}{\partial t} + \Delta_l\cdot\frac{\partial l^c}{\partial t} + \Delta_{c_1}\cdot\frac{\partial c_1^c}{\partial t} = 0,$$

where we define the insurance characteristic

$$\xi = -\frac{cov(u_2, \Phi(.))}{\mathcal{E}[u_2]\cdot\mathcal{E}[\Phi(.)]} > 0. \tag{34}$$

Using $b = 1$ from equation (24) and rearranging (33) results in

$$\xi = -\frac{\Delta_e}{\mathcal{E}[\Phi(.)]}\cdot\frac{\partial e^c}{\partial t} - \frac{\Delta_l}{\mathcal{E}[\Phi(.)]}\cdot\frac{\partial l^c}{\partial t} - \frac{\Delta_{c_1}}{\mathcal{E}[\Phi(.)]}\cdot\frac{\partial c_1^c}{\partial t}. \tag{35}$$

Defining the expected-utility compensated elasticities with respect to the tax rate as $\varepsilon_{et} = \frac{\partial e^c}{\partial t}\frac{1-t}{e}$, $\varepsilon_{lt} = \frac{\partial l^c}{\partial t}\frac{1-t}{l}$, and $\varepsilon_{c_1 t} = \frac{\partial c_1^c}{\partial t}\frac{1-t}{c_1}$, inserting the definitions of the tax wedges (21) to (23), and collecting terms, we end up with

$$\xi = -\frac{t}{1-t}\cdot[\omega_l\cdot\varepsilon_{lt} + \pi_e\cdot\omega_e\cdot\varepsilon_{et}] + \frac{s}{1-s}\cdot\frac{1-\pi_e}{1-t}\cdot\omega_e\cdot\varepsilon_{et} - \frac{\tau r/R}{1-t}\cdot\varepsilon_{at}. \tag{36}$$

Therefore, $\omega_l = \frac{\mathcal{E}[\Phi_l l]}{\mathcal{E}[\Phi]}$ and $\omega_e = \frac{\mathcal{E}[\Phi_e e]}{\mathcal{E}[\Phi]}$ are the expected shares of labor and education in total earnings, respectively. Defining $\gamma_e = \frac{R\cdot e}{\mathcal{E}[\Phi]}$ and $\gamma_{c_1} = \frac{R\cdot c_1}{\mathcal{E}[\Phi]}$ as shares of expenditure on education and first-period consumption in total earnings, respectively, allows us to define $\varepsilon_{at} = -\left(\gamma_e\cdot\varepsilon_{et} + \gamma_{c_1}\cdot\varepsilon_{c_1 t}\right)$ as the compensated elasticity of savings with respect to the labor tax rate $t$. Setting $s = \tau = 0$ leads to equation (26) in the text.

## B.2 Optimal Education Subsidies and Optimal Capital Taxation

Rearranging (19), substituting Roy's lemma, and separating income and substitution effects delivers

$$R\cdot(1-t)\cdot e\cdot\left\{\frac{\mathcal{E}[u_2]}{\eta}+\Delta_e\cdot\frac{\partial e}{\partial T}+\Delta_l\cdot\frac{\partial l}{\partial T}+\Delta_{c_1}\cdot\frac{\partial c_1}{\partial T}-1\right\}+\Delta_e\cdot\frac{\partial e^c}{\partial s}+\Delta_l\cdot\frac{\partial l^c}{\partial s}+\Delta_{c_1}\cdot\frac{\partial c_1^c}{\partial s}=0. \tag{37}$$

Dividing equation (37) by $\mathcal{E}[\Phi(.)]$ and applying equation (24) leads to

$$\frac{\Delta_e}{\mathcal{E}[\Phi(.)]}\cdot\frac{\partial e^c}{\partial s}+\frac{\Delta_l}{\mathcal{E}[\Phi(.)]}\cdot\frac{\partial l^c}{\partial s}+\frac{\Delta_{c_1}}{\mathcal{E}[\Phi(.)]}\cdot\frac{\partial c_1^c}{\partial s}=0. \tag{38}$$

Defining the expected-utility compensated elasticities with respect to the subsidy rate $s$ as $\varepsilon_{es}=\frac{\partial e^c}{\partial s}\frac{1-s}{e}$, $\varepsilon_{ls}=\frac{\partial l^c}{\partial s}\frac{1-s}{l}$, and $\varepsilon_{c_1 s}=\frac{\partial c_1^c}{\partial s}\frac{1-s}{c_1}$, we find (after inserting the tax wedges (21) to (23) and collecting terms)

$$\frac{s}{1-s}\cdot(1-\pi_e)\cdot\omega_e\cdot\varepsilon_{es}=t\cdot(\omega_l\cdot\varepsilon_{ls}+\pi_e\cdot\omega_e\cdot\varepsilon_{es})+\frac{\tau r}{R}\cdot\varepsilon_{as}. \tag{39}$$

The savings elasticity $\varepsilon_{as}=-\left(\gamma_e\cdot\varepsilon_{es}+\gamma_{c_1}\cdot\varepsilon_{c_1 s}\right)<0$ combines the expenditure-share weighted effects of education subsidies on educational investment and on first-period consumption. Using the same techniques for optimal capital taxation, the first-order condition (20) can be reformulated as

$$\begin{aligned}&[\omega+(1-t)(1-(1-s)\cdot e)-c_1]\cdot\left\{1-\left(\frac{\mathcal{E}[u_2]}{\eta}+\Delta_e\cdot\frac{\partial e}{\partial T}+\Delta_l\cdot\frac{\partial l}{\partial T}+\Delta_{c_1}\cdot\frac{\partial c_1}{\partial T}\right)\right\}\\ =\;&\Delta_e\cdot\frac{\partial e^c}{\partial R}+\Delta_l\cdot\frac{\partial l^c}{\partial R}+\Delta_{c_1}\cdot\frac{\partial c_1^c}{\partial R}.\end{aligned} \tag{40}$$

Dividing both sides by $\mathcal{E}[\Phi(.)]$ and utilizing the optimal lump-sum transfer (24), we find

$$\frac{\Delta_e}{\mathcal{E}[\Phi(.)]}\cdot\frac{\partial e^c}{\partial R}+\frac{\Delta_l}{\mathcal{E}[\Phi(.)]}\cdot\frac{\partial l^c}{\partial R}+\frac{\Delta_{c_1}}{\mathcal{E}[\Phi(.)]}\cdot\frac{\partial c_1^c}{\partial R}=0. \tag{41}$$

By defining the corresponding elasticities with respect to a change in the after-tax interest rate $R$ as $\varepsilon_{eR}=\frac{\partial e^c}{\partial R}\frac{R}{e}$, $\varepsilon_{lR}=\frac{\partial l^c}{\partial R}\frac{R}{l}$, and $\varepsilon_{c_1 R}=\frac{\partial c_1^c}{\partial R}\frac{R}{c_1}$, as well as taking the tax wedges (21) to (23) into account, we end up with

$$\frac{\tau r}{R}\cdot\varepsilon_{aR}=-t\cdot(\omega_l\cdot\varepsilon_{lR}+\pi_e\cdot\omega_e\cdot\varepsilon_{eR})+\frac{s}{1-s}\cdot(1-\pi_e)\cdot\omega_e\cdot\varepsilon_{eR}. \tag{42}$$

The savings elasticity is again defined as $\varepsilon_{aR}=-\left(\gamma_e\cdot\varepsilon_{eR}+\gamma_{c_1}\cdot\varepsilon_{c_1 R}\right)>0$. It is unambiguously positive, because a higher net interest rate $R$ renders both educational investment and first-period consumption less attractive. Inserting equation (42) for $\frac{\tau r}{R}$

into equation (39) and collecting terms, we arrive at equation (27) in the text.

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