INCOME TAXATION, TUITION SUBSIDIES, AND CHOICE OF OCCUPATION: IMPLICATIONS FOR PRODUCTION EFFICIENCY

GEIR HAAKON BJERTNÆS

CESIFO WORKING PAPER NO. 1627
CATEGORY 1: PUBLIC FINANCE
DECEMBER 2005

CESifo *Working Paper No. 1627*

INCOME TAXATION, TUITION SUBSIDIES, AND CHOICE OF OCCUPATION: IMPLICATIONS FOR PRODUCTION EFFICIENCY

Abstract

The desirability for production efficiency is re-examined in this study, where agents choose occupation based on lifetime income net of tuition costs. Efficient revenue raising implies that the government should trade off efficiency in production for efficiency in intertemporal consumption, as capital income is taxed in optimum. The subsequent wage difference between high- and low-skilled occupations is increased compared to a production efficient outcome, which is in contrast to previous results in the literature.

JEL Code: H21, H24.

Keywords: optimal income taxation, subsidies for tuition, skill formation, production efficiency.

Geir Haakon Bjertnæs
Statistics Norway
Research Department
Postboks 8131 Dep
0033 Oslo
Norway
geir.h.bjertnas@ssb.no

Statistics Norway, Research Department, 1. May 2005.
Thanks to an anonymous referee, Finn Roar Aune, Taran Fæhn, and other colleagues at Statistics Norway for useful comments.

1. INTRODUCTION

The last few years, the empirical basis for some of the assumptions behind the production efficiency theorem of Diamond and Mirrlees (1971) has been questioned. The theorem states that the economy should be on its production frontier at the optimum when the government can tax all factors at different rates. The deduction of this result was, however, based on the following questionable assumptions: The first is that labor skill types are assumed to be perfect substitutes in production. The factor price equalization theorem (the Heckscher-Ohlin theorem) supports this assumption. However, Katz and Autor (1999) find that the wage differences between occupations to a large extent are driven by local demand and supply factors. The second is that skill-specific tax rates are feasible and that the government can observe individual-specific features. However, obtaining this information might be costly. In fact, most tax systems rely on more aggregate variables like e.g. income. One particular question raised is whether it can be optimal to design the tax system to compress the *pre-tax* wage gap between high and low-skilled occupations at the expense of efficiency in production. New insight was gained when these two questionable assumptions where relaxed. Naito (1999) shows that the Diamond and Mirrlees (1971) production efficiency theorem brakes down when labor skill types are imperfect substitutes in production, skill-specific taxation is excluded, and a fixed allocation of individuals in each occupation responds to incentives by varying hours of work. In this setting, indirect taxation aimed at compressing the wage rates can increase welfare even in the presence of a non-linear income tax. The intuition is that the wage compression generates skill-specific redistribution of income, which represents a more efficient way to redistribute income, while the subsequent inefficiency in production generates a marginal cost when distortions are small. However, Naito’s assumption of given skills can be put under question. Saez (2004) restores the production efficiency theorem when he lets individuals choose occupation freely based on after-tax income. A policy that increases the low-skilled wage rate relative to the high-skilled would only result in more individuals choosing the low-skilled occupation. Hence, such policy does not redistribute income more efficiently than a non-linear income tax.

In this analysis, I take into account that agents tend to choose occupation based on costs and benefits over a lifetime, and not just after-tax income. Within such a setting the government needs to determine a set of policy parameters likely to influence the choice of occupation, and hence, the optimal design of the tax system. Tuition subsidies affect the amount of tuition costs paid by individuals, labor income taxation affect the wage premium of choosing a high-skilled occupation, and capital income taxation affect the return on financial saving, which differ across occupations. The choice of occupation is closely linked to the choice of education, and these policy parameters are found to be crucial in the literature on optimal taxation and choice of education (see e.g. Bovenberg and Jacobs (2005), Nilsen and Sørensen (1997), and Nerlove et al. (1993)). Unfortunately, this literature does not consider implications for the pre-tax wage compression, as skill types are prefect substitutes in production within these studies.

This paper presents a new general equilibrium model on optimal taxation and choice of occupation that incorporates these policy instruments[1]. I specifically explore taxation of labor income, capital income, and tuition costs, all being policy-relevant instruments used in most countries. The allocation of individuals between occupations is determined in equilibrium by a non-arbitrage condition where (expected) present value lifetime income net of taxes and tuition costs is equal between occupations. The occupation-specific wage rates are adjusted endogenously to this condition. The main finding is that a production-efficient allocation of skill types is undesirable on pure efficiency grounds. In fact, efficient revenue raising to finance government consumption implies that the high-skilled wage rate should be increased relative to a production-efficient outcome of wage rates. These conclusions are opposite to those in Saez (2004) and Naito (1999) respectively.

[1] This model is based on the model used in Bjertnæs (2001).

The intuition for this result is found by considering how taxation affects the costs and gains of occupational choices. The gain of choosing a high-skilled occupation consists of a higher wage income, while the cost consists of higher tuition payments. A uniform tuition subsidy rate equal to a (proportional) tax rate on labor income implies no distortion in choice of occupation, as both costs and gains are reduced by the same factor. However, a lower tuition subsidy rate generates a more modest need for revenue to finance these subsidies. As the tuition subsidy rate is set lower than the labor income tax rate to reduce the tax financing cost, the incentive to choose the high-skilled occupations is reduced. A tax on capital income contributes to reverse this distortion, as choosing high-skilled occupations implies less financial saving. However, the distortion in choice of occupation should not be completely neutralized, as the government is forced to trade off the distortion in choice of occupation against a distortion in intertemporal consumption created by the tax on capital income. Consequently, efficient revenue raising implies a lower (higher) supply of high (low) skilled labor compared to the production efficient allocation, which also imply a higher (lower) wage rate for high (low) skilled labor.

This result is important because of its implications for the design of the tax system, and the subsequent argument against wage compression. The paper also shows that the production-efficient allocation of skills requires a specific design of the income tax system. This is important because such conditions for production efficiency have not been considered in the literature on optimal taxation. For example, a pure non-linear labor income tax system is said to be production efficient. However, skill formation is likely to be affected when individuals choose occupation based on lifetime income. Hence, further study is needed within this field of research.

Section 2 states the general assumptions. Section 3 elaborates on the market solution, while efficient taxation is analyzed in section 4 and 5. Section 6 concludes and suggests some extensions for further research.

2. GENERAL ASSUMPTIONS

Consider a small, open economy taking the interest rate in the rest of the world as given. The economy produces one tradable good, which is either invested or consumed. The price is set to unity. Labor is internationally immobile. Individuals live for two periods. At the beginning of the first period, individuals choose a high-skill or a low-skill occupation. Individuals supply given amounts of their type of skill in the labor market in the second period of life. These types of skill are imperfect substitutes in production.

The following notation is followed throughout the paper.

$n_{timeperiod}^{occupation}$

Superscript denotes type of occupation (low-skill = 1, high-skill = 2) for variable n (= number of individuals). Subscript indicates time period. Superscript will be ignored for variables not characterized by skill type. Subscripts will be skipped for variables that are not characterized by either age or time of involvement in the market.

The supply of labor effort is normalized so that individuals in occupation *i* supply one unit of their skill type in the second period. The education required for each occupation involves resources. z^i denotes the amount of resources needed per student in occupation *i*. The high-skilled occupation is assumed to require more resources per student than the low-skilled occupation, i.e. $z^2 > z^1$.

The production function is given by

$$Y = n^{1\alpha} n^{2\,1-\alpha}, \tag{1}$$

where n^i is the occupation specific supply of labor used in production. The number of individuals is fixed, and set to unity, and divided between the two types of occupations.

$$n^1 + n^2 = 1 \tag{2}$$

3. THE MARKET SOLUTION

In the market solution there is free competition in all markets. Individuals can lend and borrow freely at the given interest rate, r . Tax and subsidy changes are introduced in the beginning of the first period in the model. The public sector collects taxes to finance public consumption, G, and tuition subsidies. When tax on capital income is introduced, individuals are taxed with the same rate on foreign and domestic-source income. A non-arbitrage condition for investments implies that the pre-tax return on domestic investment equals the interest rate abroad. The wage rates between occupations are determined by a non-arbitrage condition for choice of education

3.1 INDIVIDUALS

Individuals are endowed with the same initial abilities, and maximize an identical Cobb-Douglas utility function[2] w.r.t. first and second period consumption, constrained by the present value of consumption being equal to their present value of lifetime income.

$$\max \quad c_1^{\gamma} c_2^{(1-\gamma)} \tag{3}$$

w.r.t c_1, c_2, constrained by their budget constraint

$$c_1 + \left(\frac{1}{1+r(1-\tau_r)}\right)c_2 = W^i(1-\tau)\left(\frac{1}{1+r(1-\tau_r)}\right) - (1-s)z^i .$$

Where τ_r is the capital income tax rate, τ is the labor income tax rate, s is the tuition subsidy rate, and W^i is the occupation specific wage rate. The relative price between first and second period consumption is determined by capital income taxation and the given interest rate. A zero tax rate on capital income implies that the rate of substitution between first and second period consumption equals the rate of transformation. Hence, the distortion in intertemporal consumption is completely removed. Present value lifetime income consists of the discounted second period wage income, minus tuition costs.

Individuals are assumed to choose occupation to maximize their expected lifetime income. In a market solution where the population is divided between both occupations, the expected wage rates have to adjust so that expected lifetime income net of taxes and tuition costs is equal in both occupations. Rational expectations are assumed, hence

$$W^1(1-\tau)(\frac{1}{1+r(1-\tau_r)})-(1-s)z^1 = W^2(1-\tau)(\frac{1}{1+r(1-\tau_r)})-(1-s)z^2 \,. \tag{4}$$

Since tuition cost is higher in the high-skilled occupation, it follows that the high-skilled wage rate exceeds the low-skilled wage rate. This represents the return on the extra tuition costs in the high-skilled occupation. Forgone earning is not included as a cost of education, as individuals are assumed to earn all wage income in their second period of life. However, including first period wage income to take account of forgone earnings would not change the functioning of this economy, as the non-arbitrage condition for education imply that the extra wage income earned by a high-skilled equals the extra tuition costs. Hence, results are not likely to be affected by this simplification.

The indirect utility function is given by

$$\gamma^{\gamma}(1-\gamma)^{(1-\gamma)}(1+r(1-\tau_r))^{(1-\gamma)}\left[W^i(1-\tau)(\frac{1}{1+r(1-\tau_r)})-(1-s)z^i\right], \tag{5}$$

and first period consumption is given by

$$c_1 = \gamma\left[W^i(1-\tau)(\frac{1}{1+r(1-\tau_r)})-(1-s)z^i\right].$$

[2] The Cobb-Douglas functional form is chosen for both utility and production to simplify the calculations.

3.2 PRODUCERS

Firms maximize present value of profits, taking factor prices as given.

The problem is

$$\max n^{1^{\alpha}} n^{2^{1-\alpha}} - W^1 n^1 - W^2 n^2 \qquad (6)$$

w.r.t. n^1, n^2

The first order conditions are

$$\alpha \left(\frac{n^1}{n^2} \right)^{-(1-\alpha)} = W^1, \qquad (7)$$

$$(1-\alpha) \left(\frac{n^1}{n^2} \right)^{\alpha} = W^2, \qquad (8)$$

Due to the residence principle of taxation, the pre-tax return on domestic investments equals the foreign interest rate, and hence, is unaffected by taxation. Introduction of real capital into this model would not alter the first order conditions for labor due to this feature. Hence, real capital can be excluded from the production function without affecting any of the results obtained in this study.

3.3 SCHOOLS

The schools will supply the amount of education that the individuals demand, given that the individuals cover tuition costs net of tuition subsidies, $(1-s)z^i$.

3.4 THE FOREIGN BUDGET CONSTRAINT

The second period production is given by the production function, (1). The Euler sentence and the first order conditions from the producer side, (7) and (8), imply that second period production equals the total factor income.

$$Y = W^1 n^1 + W^2 n^2 \qquad (9)$$

This factor income is spent according to the budget constraints in the economy. Adding present value of consumption for all domestic individuals to the present value of government consumption, and applying their budget constraints and the equilibrium conditions in the economy, results in

$$\left[c_1 + z^1 n^1 + z^2 n^2 + G\right](1+r) + c_2 = Y$$

Hence, the foreign budget is balanced when first period consumption plus tuition costs are financed by foreign loans that are repaid with interest in the second period. Allowing international trade in a capital good at the given interest rate is not sufficient to determine factor prices in this economy, as one traded good is insufficient to determine factor prices on two non-traded input factors. Hence, this trade does not exclude general equilibrium effects in the occupation specific wage rates in this economy.

4. TAXATION AND THE ALLOCATION OF INDIVIDUALS

4.1 EFFECTS OF TAXATION

By inserting the first order condition from the producer side into the non-arbitrage condition for education, and substituting n^2 with $1 - n^1$, I get

$$\alpha\left(\frac{n^1}{(1-n^1)}\right)^{-(1-\alpha)}(1-\tau)(\frac{1}{1+r(1-\tau_r)})-(1-\tau)gz^1 = \qquad (10)$$

$$(1-\alpha)\left(\frac{n^1}{(1-n^1)}\right)^{\alpha}(1-\tau)(\frac{1}{1+r(1-\tau_r)})-(1-\tau)gz^2$$

One immediate implication is that there are no distributional effects from taxation in this economy. Any tax change that favors one occupation results in wage adjustments that neutralizes this favorable tax effect. However, these wage rate adjustments is generated by reallocation of individuals between occupations. The effect of each of the policy parameters is as follows:

Tuition subsidies:

Uniform tuition subsidies generate a first round benefit to individuals that choose the high-skilled occupation relative to individuals that choose the low-skilled occupation, because high-skilled pay more tuition costs. However, this benefit is neutralized as more individuals choose the high-skilled occupation. The high-skilled wage rate is reduced, while the low-skilled wage rate is increased. A more detailed discussion of this effect is found in Dur and Teulings (2004), and Heckman et al. (1998).

Labor income taxation:

Proportional taxation of labor income generates a first round loss to individuals in the high-skilled occupation relative to individuals in the low-skilled occupation because high-skilled earn more labor income. However, more individuals are allocated into the low-skilled occupation, and the occupation specific wage rates are adjusted to neutralize this loss.

Capital income taxation:

Capital income taxation generates a first round gain to individuals in the high-skilled occupation relative to individuals in the low-skilled occupation as high-skilled earn more second period income which becomes more valuable because it allows them to save less financially. Hence, more individuals are allocated into the high-skilled occupation, and the wage rates are adjusted to neutralize this gain.

4.2 PRODUCTION EFFICIENCY

The production efficient allocation of individuals between occupations is obtained by maximizing present value of production net of tuition costs

$$\frac{{n^1}^{\alpha}(1-n^1)^{1-\alpha}}{1+r} - z^1 n^1 - z^2(1-n^1) \tag{11}$$

w.r.t. n^1

The first order conditions implies that

$$\frac{\alpha\left(\frac{n^1}{1-n^1}\right)^{-(1-\alpha)}}{1+r} - z^1 = \frac{(1-\alpha)\left(\frac{n^1}{1-n^1}\right)^{\alpha}}{1+r} - z^2 . \tag{12}$$

This condition states that the discounted value of one extra high-skilled individual minus tuition costs for this individual is equal to the discounted value of one extra low-skilled individual minus tuition cost for this individual.

The design of the tax system that generates production efficiency are found by inserting (12) into the non-arbitrage condition for education, where the first order conditions from the producer side are inserted, (10). The combination is

$$\frac{1-\tau}{1+r(1-\tau_r)} = \frac{1-s}{1+r} \quad . \tag{13}$$

5. Optimal taxation

5.1 The first-best

The tax system is constrained to linear instruments, and does not include instruments that rely on variables that are individual-specific and/or non-observable to the government. First, pre-tax wage income differences only rely on choice of occupation in this study. However, such differences are unobservable to the government in real life due to individual-specific variables. To avoid tax rules that rely on such individual-specific and non-observable variables, progressive taxation of labor income is excluded from the study. Second, individuals are only categorized by choice of occupation in this study. Hence, occupation specific tuition subsidies are equivalent to individual-specific lumpsum subsidies in this framework. Such individual-specific instruments are excluded from the study by only including uniform tuition subsidies. Third, uniform lumpsum taxation is excluded due to its unfortunate distributional effects.

Taxation creates two kinds of distortions in this economy. First, intertemporal consumption is distorted by capital income taxation as it reduces the return to financial saving. Second, the allocation of individuals between the two occupations is distorted when the tax parameters deviate from the combination that implies production efficiency, (13). A zero tax rate on capital income eliminates the distortion in intertemporal consumption. By implementing a zero tax rate on capital income into (13), it follows that a tuition subsidy rate equal to the labor income tax rate implies a production-efficient allocation of individuals. The labor income taxation leads to a larger tax payment from a high-skilled individual, as they earn more present value labor income. However, this extra tax burden is exactly offset by the extra tuition subsidies received due to a larger tuition cost. Hence, the government is able to implement the first-best allocation, and rise tax revenue at the same time.

5.2 TAXATION IN A SECOND-BEST SETTING

The exclusion of factors liable to affect the design of the tax/ subsidy system leaves room for interesting extensions. First, non-verifiable learning is not included in this study. The presence of such learning is likely to limit the government's ability to neutralize tax distortions on choice of occupation by employing tuition subsidies. The limited ability to neutralize tax distortions by employing tuition subsidies can be represented by constraining the tuition subsidy rate to be lower than the labor income tax rate (see Jacobs and Bovenberg, 2004). Second, the labor/ leisure choice is not included in this study. The exclusion of this choice is likely to reduce the welfare cost of raising revenue. Hence, a reduction in the tuition subsidy rate, which reduces the need for tax revenue, is likely to generate a welfare gain that is not included in this study. However, constraining the tuition subsidy rate to be lower than the labor income tax rate is a second best approach for analyzing this effect. Such a constraint is included into this framework by setting the share of tuition costs paid by individuals, $1-s$, proportionally to the share of wage income received by individuals, i.e. $1-s=(1-\tau)g$, where $g>1$.

The government chooses income tax rates to maximize the indirect utility function of a high-skilled individual, constrained by a public budget constraint and the specification of the economy. The non-arbitrage condition for education, (10), is included as a constraint implying that all individuals receive the same utility. The indirect utility function is maximized with respect to n^1 in addition to the tax rates due to this constraint.

$$MAX\ \gamma^{\gamma}(1-\gamma)^{(1-\gamma)}(1+r(1-\tau_r))^{(1-\gamma)}\left[(1-\alpha)\left(\frac{n^1}{(1-n^1)}\right)^{\alpha}(1-\tau)(\frac{1}{1+r(1-\tau_r)})-(1-\tau)gz^2\right] \tag{14}$$

w.r.t τ,τ_r,n^1, so that

$$\alpha\left(\frac{n^1}{(1-n^1)}\right)^{-(1-\alpha)}(1-\tau)(\frac{1}{1+r(1-\tau_r)})-(1-\tau)gz^1 =$$

$$(1-\alpha)\left(\frac{n^1}{(1-n^1)}\right)^{\alpha}(1-\tau)(\frac{1}{1+r(1-\tau_r)})-(1-\tau)gz^2$$

and

$$\frac{r\tau_r}{(1+r)}\left[-(1-\tau)gz^1-\gamma\left[\alpha\left(\frac{n^1}{(1-n^1)}\right)^{-(1-\alpha)}(1-\tau)(\frac{1}{1+r(1-\tau_r)})-(1-\tau)gz^1\right]\right]n^1$$

$$+\frac{r\tau_r}{(1+r)}\left[-(1-\tau)gz^2-\gamma\left[(1-\alpha)\left(\frac{n^1}{(1-n^1)}\right)^{\alpha}(1-\tau)(\frac{1}{1+r(1-\tau_r)})-(1-\tau)gz^2\right]\right](1-n^1)$$

$$+\left[\alpha\left(\frac{n^1}{(1-n^1)}\right)^{-(1-\alpha)}\tau(\frac{1}{1+r})-(z^1-(1-\tau)gz^1)\right]n^1$$

$$+\left[(1-\alpha)\left(\frac{n^1}{(1-n^1)}\right)^{\alpha}\tau(\frac{1}{1+r})-(z^2-(1-\tau)gz^2)\right](1-n^1)=G$$

The general equilibrium effects of the occupation-specific wage rates are incorporated into the government maximization problem by replacing the occupation-specific wage rates with their marginal products from the producer side of the economy, (7) and (8). These marginal products are determined by the allocation of individuals between the occupations. The non-arbitrage condition for education, which constitutes the first constraint of the maximization problem, determines the allocation of individuals between occupations for a given set of tax rates. The government budget constraint, which constitutes the second constraint of the maximization problem, states that the present value of tax revenue minus subsidies for tuition equals present value of government consumption (G). The first and second term are (present value) tax revenues from capital income taxation of individuals in occupation 1 and 2, respectively. First-period financial saving of individuals in occupation *i*, is multiplied by the number of individuals in occupation *i*, and by the interest rate, and the capital income tax rate, and then discounted. The third and forth term are tax revenues from labor income minus subsidies for tuition from individuals in each of the occupations.

The incentive to choose the high-skilled occupation is reduced, as the tuition subsidy rate is lowered relative to the labor income tax rate. The incentive is reduced because individuals pay a larger share of the tuition cost, and the tuition cost is higher in the high-skilled occupation. The subsequent reallocation of individuals from the high-skilled occupation, to the low-skilled occupation, restores the non-arbitrage condition for education by increasing the high-skilled wage rate, and lowering the low-skilled wage rate.

This preset distortion in choice of occupation forces the government to consider a tradeoff between the two sources of distortions in the economy. As the tuition subsidy rate is constrained relative to the labor income tax rate, the government is left with capital income taxation as a means to reduce the distortion in choice of occupation. The introduction of capital income taxation generates substitution away from financial saving, as the private returns to financial saving is reduced by a fraction equal to the tax rate. Since individuals in the low-skilled occupation borrow less financially, they harvest a smaller first round gain as a result of capital income taxation, compared to individuals in the high-skilled occupation. To restore the non-arbitrage condition for education, more individuals choose the high-skilled occupation, and the wage rates are adjusted. However, as second-period consumption becomes more expensive relative to first-period consumption, individuals trade off second-period consumption for first-period consumption, hence, intertemporal consumption is distorted.

The aim of this section is to find out whether capital income should be taxed, and whether production efficiency is desirable within this economy. The last question is equivalent to the question of whether general equilibrium effects of occupation-specific wage rates should be exploited to raise revenue. To answer these questions, a number of tradeoffs need to be considered. Capital income taxation generates a direct utility gain that is traded against the effect on the government budget, and the effects of the general equilibrium responses. The direct effect on the government budget is negative, because individuals in both occupations borrow financially. The negative effect on the budget is magnified by a first-period consumption increase. The reallocation of individuals from the low-skilled to the high-skilled occupation contributes to less capital income tax revenue as a high-skilled individual saves less financially, more labor income tax revenue as a high-skilled earns more labor income, and more tuition subsidy payments as a high-skilled receives more tuition subsidies. The subsequent wage decrease for high-skilled individuals generates a direct utility loss. However, less labor income tax revenue is generated, while the negative financial saving is reduced. The subsequent wage increase for low-skilled individuals generates more labor income tax revenue, and more negative financial saving. The labor income tax rate, and hence, the share of tuition costs paid by individuals, are adjusted to balance the government budget. This adjustment has a direct utility effect, however, the allocation of individuals between occupations is unaffected.

The first question, whether capital should be taxed, is answered by employing the envelope theorem on the Lagrangian of the government maximization problem. The capital income tax rate is treated as an exogenous parameter in the maximization problem, and the welfare effect of introducing a marginal tax rate on capital income is given by the derivative of the Lagrangian with respect to the capital income tax rate when this tax rate is zero.

By inserting the non-arbitrage condition for education into $\frac{\partial L}{\partial \tau} = 0$, it follows that

$\lambda = -\gamma^{\gamma}(1-\gamma)^{(1-\gamma)}(1+r)^{1-\gamma}$.

Since λ is the Lagrangian parameter for the government budget constraint, and

$\gamma^{\gamma}(1-\gamma)^{(1-\gamma)}(1+r(1-\tau_r))^{1-\gamma}$ is the marginal utility of present value income, it follows that the marginal cost of public funds equals unity when the capital income tax rate is zero.

The non-arbitrage condition for education and the expression for λ is inserted into $\frac{\partial L}{\partial n^1} = 0$. The resulting equation is

$$\mu = -\gamma^{\gamma}(1-\gamma)^{(1-\gamma)}(1+r)^{1-\gamma} n^1 \left[1 - \frac{(1-g)(z^1 - z^2)(1-n^1)^2}{\alpha(1-\alpha)\left(\frac{n^1}{1-n^1}\right)^{\alpha-1} \frac{(1-\tau)}{1+r}} \right],$$

where μ is the Lagrangian parameter for the non-arbitrage condition for education.

Inserting the non-arbitrage condition for education and these expressions for λ and μ into $\frac{\partial L}{\partial \tau_r}$ results in the following expression:

$$\frac{\partial L}{\partial \tau_r} = -\frac{r\gamma^{\gamma}(1-\gamma)^{(1-\gamma)}(1+r)^{1-\gamma} g(z^1 - z^2)^2 n^1 (1-g)(1-n^1)^2}{\alpha(1-\alpha)\left(\frac{n^1}{1-n^1}\right)^{\alpha-1}}.$$

This expression is positive when $g > 1$ because $(1-g)$ is the only negative factor in the numerator, while the denominator is positive. Hence, imposing a marginal capital income tax rate is welfare enhancing. The intuition is that the welfare cost of introducing a marginal distortion in intertemporal consumption must be smaller than the welfare gain of reducing the infra-marginal distortion in choice of occupation created by a tuition subsidy rate lower than the labor income tax rate.

This result supports the conclusion in Jacobs and Bovenberg (2004) as it holds even in the presence of general equilibrium effects on occupation specific-wage rates.

The second question, whether production efficiency is desirable, is analyzed by investigating whether the first order conditions of the government's maximization problem are violated when production efficiency is assumed. If these conditions are violated it follows that production efficiency is undesirable.

The non-arbitrage condition for education, and the production efficient combinations of the tax and subsidy rates is inserted into $\frac{\partial L}{\partial \tau} = 0$;

$$\lambda = -\gamma^{\gamma}(1-\gamma)^{(1-\gamma)}(1+r(1-\tau_r))^{1-\gamma}\left(\frac{1+r}{1+r-r\tau_r(1-\gamma)}\right)$$

This shows that the marginal cost of public funds is larger than unity in this case, since the expression in the last bracket is larger than unity.

The result of inserting the non-arbitrage condition for education, and the production efficient combinations of the tax and subsidy rates into $\frac{\partial L}{\partial n^1} = 0$ is:

$$\mu = -\gamma^{\gamma}(1-\gamma)^{(1-\gamma)}(1+r(1-\tau_r))^{1-\gamma} n^1 .$$

Inserting the non-arbitrage condition for education, the production efficient combinations of the tax and subsidy rates, and the expressions above for λ and μ into $\frac{\partial L}{\partial \tau_r}$ results in the following expression:

$$\frac{\partial L}{\partial \tau_r} = \frac{r(1-\tau)\gamma^{\gamma}(1-\gamma)^{(1-\gamma)}(1+r(1-\tau_r))^{1-\gamma} g}{1+r(1-\tau_r)}(\gamma-1)\left[(1-\alpha)\left(\frac{n^1}{1-n^1}\right)^{\alpha}\frac{1}{1+r} - z^2\right]\left[1-\frac{1}{1+\frac{r\tau_r\gamma g}{1+r}}\right].$$

This expression is negative when $g > 1$ (which imply that $\tau_r > 0$), since $(\gamma-1)$ is the only negative factor. Hence, it is not welfare enhancing to implement the production efficient allocation. This conclusion is opposite to that in Saez (2004).

Note that $1-s = (1-\tau)g$ implies that tax combinations generating production efficiency become a condition on the capital income tax rate:

$$\frac{1}{1+r(1-\tau_r)}=\frac{g}{1+r} \quad .$$

Hence, production efficiency can be implemented by fixing the capital income tax rate. The envelope theorem implies that the welfare is reduced by a marginal increase in that capital income tax rate. The intuition for this result is that the welfare effect from the production side becomes marginal as the allocation of individuals is approaching the production efficient allocation. However, imposing a capital income tax required to obtain the production efficient allocation, generates a welfare cost due to distortion in intertemporal consumption that exceeds the marginal effect from the producer side.

As it is optimal to reduce the allocation of high-skilled individuals relative to the production efficient solution, it follows that the wage difference between high and low-skilled should be increased compared to a production-efficient outcome. This conclusion is opposite to that in Naito (1999). The result is also related to Stiglitz (1982), and Allan (1982), who find that production efficiency may no longer be desirable when labor supply is elastic. The elastic labor supply assumption is used to justify the constraint on the tuition subsidy rate in this study.

6. CONCLUSION AND POSSIBLE EXTENSIONS

This study introduces occupational choices based on lifetime income in a framework where labor skill types are imperfect substitutes in production. Optimal taxation in the case where the tuition subsidy rate is constrained to be lower than the labor income tax rate, induces the government to trade efficiency in production against distortions in intertemporal consumption, as the capital income tax rate is used as a second-best instrument to reduce the distortion in choice of occupation. Hence, the result in Jacobs and Bovenberg (2004) holds in a framework where general equilibrium effects on occupation-specific wage rates are incorporated. The solution implies increased wage differences between high and low-skilled occupations compared to a production-efficient outcome. This conclusion is opposite to that in Saez (2004) and Naito (1999).

The analysis does not cover all aspects of optimal income taxation and subsidies for tuition. The transition period, i.e. the period it takes to adjust the relative supply of high and low-skilled labor, is not considered in this study. However, the optimal solution implies a relative increase in the stock of low-skilled workers compared to the production efficient solution. An increase in the supply of low-skilled labor is likely to occur within a relatively short period of time, as more young unskilled individuals can enter directly into the labor force. Adjustments in the supply of high-skilled labor is likely to occur more gradually, as individuals need to spend time in school to become high-skilled workers. Introducing liquidity constraints is an interesting extension. Another interesting aspect is how the allocation of high and low-skilled labor affects the growth rate. Romer (1990) argues that wage rates for high-skilled labor are lower than their productivity because of positive external effects from employing them in the research sector. Hence, in a second-best solution, where the government has no direct instrument to affect the allocation of high-skilled in the research sector, the education of high-skilled individuals should be subsidized. Further, including ability differences and distributional considerations could reveal interesting tradeoffs between efficiency and equity.

APPENDIX

The Lagrangian of the government maximization problem is

$$L=\gamma^{\gamma}(1-\gamma)^{(1-\gamma)}(1+r(1-\tau_r))^{(1-\gamma)}\left[(1-\alpha)\left(\frac{n^1}{(1-n^1)}\right)^{\alpha}(1-\tau)(\frac{1}{1+r(1-\tau_r)})-(1-\tau)gz^2\right]$$

$$-\mu\left[\alpha\left(\frac{n^1}{(1-n^1)}\right)^{-(1-\alpha)}(1-\tau)(\frac{1}{1+r(1-\tau_r)})-(1-\tau)gz^1-\left((1-\alpha)\left(\frac{n^1}{(1-n^1)}\right)^{\alpha}(1-\tau)(\frac{1}{1+r(1-\tau_r)})-(1-\tau)gz^2\right)\right]$$

$$-\lambda\left[\frac{r\tau_r}{(1+r)}\left[-(1-\tau)gz^1-\gamma\left[\alpha\left(\frac{n^1}{(1-n^1)}\right)^{-(1-\alpha)}(1-\tau)(\frac{1}{1+r(1-\tau_r)})-(1-\tau)gz^1\right]\right]n^1\right.$$

$$+\frac{r\tau_r}{(1+r)}\left[-(1-\tau)gz^2-\gamma\left[(1-\alpha)\left(\frac{n^1}{(1-n^1)}\right)^{\alpha}(1-\tau)(\frac{1}{1+r(1-\tau_r)})-(1-\tau)gz^2\right]\right](1-n^1)$$

$$+\left[\alpha\left(\frac{n^1}{(1-n^1)}\right)^{-(1-\alpha)}\tau(\frac{1}{1+r})-(z^1-(1-\tau)gz^1)\right]n^1$$

$$\left.+\left[(1-\alpha)\left(\frac{n^1}{(1-n^1)}\right)^{\alpha}\tau(\frac{1}{1+r})-(z^2-(1-\tau)gz^2)\right](1-n^1)-G\right],$$

where μ and λ denotes the Lagrange multipliers of the non-arbitrage condition for educational choices and the government budget constraint respectively.

References

Allen, F., 1982: Optimal linear income taxation with general equilibrium effects on wages, *Journal of Public Economics*, **17**, 135-43.

Bas, Jacobs and Bovenberg, Lans A. 2004: Optimal Capital Income Taxation with Endogenous Humen Capital Formation, mimeo, University of Amsterdam/ Tilburg, www.scholar.nl.

Bjertnæs, G. H., 2001: Optimal Combinations of Income Tax and Subsidies for Education, Discussion Paper 313, Oslo: Statistics Norway.

Bovenberg, Lans A. and Jacobs Bas, 2005: Redistribution and Education Subsidies are Siamese Twins, *Journal of Public Economics*, (Forthcoming)

Diamond, Peter A. and Mirrlees, James A. 1971: Optimal Taxation and Public Production I: Production Efficiency, *American Economic Review* **61**, 8-27.

Dur, R., and Coen N. Teulings, 2004, "Are Education Subsidies an Efficient Redistributive Device? ", In: Jonas Agell et al. (2004), Labor Market Institutions and Public Regulation, MIT Press, pp 123-161.

Heckman, James J., Lochner, L. and Taber, C., 1998: "General Equilibrium Treatment Effects: A Study of Tuition Policy, *American Economic Review*, **88**(2), 381-386.

Katz, Lawrence F. and Autor, David H. 1999: Changes in the Wage Structure and Wage Inequality, in : O. Ashenfelter and D. Card (eds.), 1999, *Handbook of Labor Economics* Vol**. 3A**, Elsevier Science BV, pp 1463-1555.

Naito, Hisahiro, 1999: Re-Examination of Uniform Commodity Taxes under a Non-Linear Income Tax System and its Implications for Production Efficiency, *Journal of Public Economics*, 71, 165-188.

Nielsen, S.B. and Sørensen, P.B. 1997: On the optimality of the Nordic system of dual income taxation, *Journal of Public Economics*, **63**, 311-329.

Nerlove, M., A Razin, E. Sadka and R.K. von Weizsäcker, 1993: Comprehensive income taxation, investment in human and physical capital, and productivity, *Journal of Public Economics* **50**, 397-406.

Romer, P. M., 1990a "Endogenous Technological Change." *Journal of Political Economy* **98**(5) part 2: 71-102.

Saez, Emmanuel, 2004: Direct or Indirect Instruments for Redistribution: Short-Run versus Long-Run, *Journal of Public Economics*, **88**, 503-518.

Stiglitz, J. E., 1982: Self-selection and Pareto efficient taxation, *Journal of Public Economics*, **17**, 213-240.

CESifo Working Paper Series

(for full list see www.cesifo-group.de)

1565 Joerg Breitung and M. Hashem Pesaran, Unit Roots and Cointegration in Panels, October 2005

1566 Steven Brakman, Harry Garretsen and Marc Schramm, Putting New Economic Geography to the Test: Free-ness of Trade and Agglomeration in the EU Regions, October 2005

1567 Robert Haveman, Karen Holden, Barbara Wolfe and Andrei Romanov, Assessing the Maintenance of Savings Sufficiency Over the First Decade of Retirement, October 2005

1568 Hans Fehr and Christian Habermann, Risk Sharing and Efficiency Implications of Progressive Pension Arrangements, October 2005

1569 Jovan Žamac, Pension Design when Fertility Fluctuates: The Role of Capital Mobility and Education Financing, October 2005

1570 Piotr Wdowinski and Aneta Zglinska-Pietrzak, The Warsaw Stock Exchange Index WIG: Modelling and Forecasting, October 2005

1571 J. Ignacio Conde-Ruiz, Vincenzo Galasso and Paola Profeta, Early Retirement and Social Security: A Long Term Perspective, October 2005

1572 Johannes Binswanger, Risk Management of Pension Systems from the Perspective of Loss Aversion, October 2005

1573 Geir B. Asheim, Wolfgang Buchholz, John M. Hartwick, Tapan Mitra and Cees Withagen, Constant Savings Rates and Quasi-Arithmetic Population Growth under Exhaustible Resource Constraints, October 2005

1574 Christian Hagist, Norbert Klusen, Andreas Plate and Bernd Raffelhueschen, Social Health Insurance – the Major Driver of Unsustainable Fiscal Policy?, October 2005

1575 Roland Hodler and Kurt Schmidheiny, How Fiscal Decentralization Flattens Progressive Taxes, October 2005

1576 George W. Evans, Seppo Honkapohja and Noah Williams, Generalized Stochastic Gradient Learning, October 2005

1577 Torben M. Andersen, Social Security and Longevity, October 2005

1578 Kai A. Konrad and Stergios Skaperdas, The Market for Protection and the Origin of the State, October 2005

1579 Jan K. Brueckner and Stuart S. Rosenthal, Gentrification and Neighborhood Housing Cycles: Will America's Future Downtowns be Rich?, October 2005

1580 Elke J. Jahn and Wolfgang Ochel, Contracting Out Temporary Help Services in Germany, November 2005

1581 Astri Muren and Sten Nyberg, Young Liberals and Old Conservatives – Inequality, Mobility and Redistribution, November 2005

1582 Volker Nitsch, State Visits and International Trade, November 2005

1583 Alessandra Casella, Thomas Palfrey and Raymond Riezman, Minorities and Storable Votes, November 2005

1584 Sascha O. Becker, Introducing Time-to-Educate in a Job Search Model, November 2005

1585 Christos Kotsogiannis and Robert Schwager, On the Incentives to Experiment in Federations, November 2005

1586 Søren Bo Nielsen, Pascalis Raimondos-Møller and Guttorm Schjelderup, Centralized vs. De-centralized Multinationals and Taxes, November 2005

1587 Jan-Egbert Sturm and Barry Williams, What Determines Differences in Foreign Bank Efficiency? Australian Evidence, November 2005

1588 Steven Brakman and Charles van Marrewijk, Transfers, Non-Traded Goods, and Unemployment: An Analysis of the Keynes – Ohlin Debate, November 2005

1589 Kazuo Ogawa, Elmer Sterken and Ichiro Tokutsu, Bank Control and the Number of Bank Relations of Japanese Firms, November 2005

1590 Bruno Parigi and Loriana Pelizzon, Diversification and Ownership Concentration, November 2005

1591 Claude Crampes, Carole Haritchabalet and Bruno Jullien, Advertising, Competition and Entry in Media Industries, November 2005

1592 Johannes Becker and Clemens Fuest, Optimal Tax Policy when Firms are Internationally Mobile, November 2005

1593 Jim Malley, Apostolis Philippopoulos and Ulrich Woitek, Electoral Uncertainty, Fiscal Policy and Macroeconomic Fluctuations, November 2005

1594 Assar Lindbeck, Sustainable Social Spending, November 2005

1595 Hartmut Egger and Udo Kreickemeier, International Fragmentation: Boon or Bane for Domestic Employment?, November 2005

1596 Martin Werding, Survivor Benefits and the Gender Tax Gap in Public Pension Schemes: Observations from Germany, November 2005

1597 Petra Geraats, Transparency of Monetary Policy: Theory and Practice, November 2005

1598 Christian Dustman and Francesca Fabbri, Gender and Ethnicity – Married Immigrants in Britain, November 2005

1599 M. Hashem Pesaran and Martin Weale, Survey Expectations, November 2005

1600 Ansgar Belke, Frank Baumgaertner, Friedrich Schneider and Ralph Setzer, The Different Extent of Privatisation Proceeds in EU Countries: A Preliminary Explanation Using a Public Choice Approach, November 2005

1601 Jan K. Brueckner, Fiscal Federalism and Economic Growth, November 2005

1602 Steven Brakman, Harry Garretsen and Charles van Marrewijk, Cross-Border Mergers and Acquisitions: On Revealed Comparative Advantage and Merger Waves, November 2005

1603 Erkki Koskela and Rune Stenbacka, Product Market Competition, Profit Sharing and Equilibrium Unemployment, November 2005

1604 Lutz Hendricks, How Important is Discount Rate Heterogeneity for Wealth Inequality?, November 2005

1605 Kathleen M. Day and Stanley L. Winer, Policy-induced Internal Migration: An Empirical Investigation of the Canadian Case, November 2005

1606 Paul De Grauwe and Cláudia Costa Storti, Is Monetary Policy in the Eurozone less Effective than in the US?, November 2005

1607 Per Engström and Bertil Holmlund, Worker Absenteeism in Search Equilibrium, November 2005

1608 Daniele Checchi and Cecilia García-Peñalosa, Labour Market Institutions and the Personal Distribution of Income in the OECD, November 2005

1609 Kai A. Konrad and Wolfgang Leininger, The Generalized Stackelberg Equilibrium of the All-Pay Auction with Complete Information, November 2005

1610 Monika Buetler and Federica Teppa, Should you Take a Lump-Sum or Annuitize? Results from Swiss Pension Funds, November 2005

1611 Alexander W. Cappelen, Astri D. Hole, Erik Ø. Sørensen and Bertil Tungodden, The Pluralism of Fairness Ideals: An Experimental Approach, December 2005

1612 Jack Mintz and Alfons J. Weichenrieder, Taxation and the Financial Structure of German Outbound FDI, December 2005

1613 Rosanne Altshuler and Harry Grubert, The Three Parties in the Race to the Bottom: Host Governments, Home Governments and Multinational Companies, December 2005

1614 Chi-Yung (Eric) Ng and John Whalley, Visas and Work Permits: Possible Global Negotiating Initiatives, December 2005

1615 Jon H. Fiva, New Evidence on Fiscal Decentralization and the Size of Government, December 2005

1616 Andzelika Lorentowicz, Dalia Marin and Alexander Raubold, Is Human Capital Losing from Outsourcing? Evidence for Austria and Poland, December 2005

1617 Aleksander Berentsen, Gabriele Camera and Christopher Waller, Money, Credit and Banking, December 2005

1618 Egil Matsen, Tommy Sveen and Ragnar Torvik, Savers, Spenders and Fiscal Policy in a Small Open Economy, December 2005

1619 Laszlo Goerke and Markus Pannenberg, Severance Pay and the Shadow of the Law: Evidence for West Germany, December 2005

1620 Michael Hoel, Concerns for Equity and the Optimal Co-Payments for Publicly Provided Health Care, December 2005

1621 Edward Castronova, On the Research Value of Large Games: Natural Experiments in Norrath and Camelot, December 2005

1622 Annette Alstadsæter, Ann-Sofie Kolm and Birthe Larsen, Tax Effects, Search Unemployment, and the Choice of Educational Type, December 2005

1623 Vesa Kanniainen, Seppo Kari and Jouko Ylä-Liedenpohja, Nordic Dual Income Taxation of Entrepreneurs, December 2005

1624 Lars-Erik Borge and Linn Renée Naper, Efficiency Potential and Efficiency Variation in Norwegian Lower Secondary Schools, December 2005

1625 Sam Bucovetsky and Andreas Haufler, Tax Competition when Firms Choose their Organizational Form: Should Tax Loopholes for Multinationals be Closed?, December 2005

1626 Silke Uebelmesser, To go or not to go: Emigration from Germany, December 2005

1627 Geir Haakon Bjertnæs, Income Taxation, Tuition Subsidies, and Choice of Occupation: Implications for Production Efficiency, December 2005