German Working Papers in Law and Economics

Volume 2006 *Paper* 33

Asset Prices in the Presence of a Tax Authority

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Abstract

This paper examines the equilibrium effect of a shift in the capital income tax rate upon state prices, risk-neutral probabilities, and corresponding security prices in a single-period binomial model economy with an exogenous risk-free rate. The policy design under consideration consists of a simple linear tax code that applies the economic rent as a tax base. It is shown that if tax proceeds are transferred to outsiders, a shift in the tax rate affects state prices, risk-neutral probabilities as well as equilibrium security prices. Thereby, the effect for the equilibrium price of a security is sensitive with respect to the correlation between its own payoff and the payoff of the market portfolio. If in contrast tax proceeds are redistributed within the cohort of market participants, risk-neutral probabilities, and security prices are unaffected by a change in the tax rate, although state prices are sensitive with respect to the tax rate.

1. Introduction

In most economies of the world capital income is exposed to taxation on personal level that simultaneously produces two effects. First, it drives a wedge between two dominant building blocks of any economy: consumers and firms.[1] Second, it allocates funds in the hand of the public sector. Arguably, both effects have the potential to significantly affect economic activities within an economy. For instance, they may influence the cost of capital for firms by altering prices of securities with fixed pre-tax payoffs. Such a *pricing effect* is likely to be expected for most real economies, since empirical evidence indicates that capital markets in general are not perfectly integrated.[2] Thus, capital income taxes are supposed to have a considerable impact upon the level and risk-structure of real investments, which in turn determine economic growth and thus (economic) well-being of subsequent generations of the economy.

Now, while these arguments seem fairly standard in economic theory, there is surprisingly few theoretical work discussing the effect of capital income taxes upon the *level* of equilibrium security prices.[3] In particular, the major strand of literature examining economic effects of capital income taxes, the *public economics literature*, does not seem to examine the pricing effect. In fact, the public economics literature seems mainly concerned with the effect of capital income taxes upon risk-taking behavior of individual agents studying the issue within the small open economy framework where consumers are faced with exogenous world prices. A second strand of literature discussing the effect of capital income taxes is the *asset pricing literature*. In contrast to public economics, this literature is mainly interested in the effect upon the prevailing risk-return structure when discussing the effect of capital income taxes. Thereby, the literature in general examines the issue within the closed economy but does not account for the fact that taxation allocates funds in the hand of the public sector. Moreover, mostly relying on mean-variance preferences these studies are not able to examine the effect for the (absolute) level of security prices.[4]

Having in mind these shortcomings of the existing literature, this paper aims at extending

[1] See *OECD (1994)* for an introduction to capital income tax regimes of many developed countries. *Joumard (2001)* and *Schratzenstaller (2003)* discuss taxation of capital within the European Union.

[2] For instance, econometric analyses of investment decisions find that investor behavior in equity-markets is characterized by a *home bias (e.g. Lewis, 1999)* and even a *local-bias (e.g. Coval and Moskowitz, 1999; Hong, Kubik and Stein, 2005)*.

[3] *Poterba (2002, p. 1161)*, for instance, concludes his survey with the remark that "*[a] final issue that warrants attention is the effect of taxation on the overall level of asset prices.*"

[4] See for instance the static capital asset pricing models in *Brennan (1970)* and *Litzenberger and Ramaswamy (1979, 1980)*, which rely on mean-variance preferences or (multivariate) normal distributed security returns. In these models the predicted market price of risk is a non-trivial function in agents' coefficient of global absolute risk aversion *(e.g. Rubinstein, 1973)*. This, however, makes it impossible to derive analytical results for the effect of taxation upon equilibrium security prices for reasonable preferences (e.g. CRRA preferences). Similar problems occur in the dynamic analysis of *Auerbach and King (1983)*.

the public finance literature for an asset pricing perspective: it examines the equilibrium effect of a shift in the capital income tax rate upon state prices, risk-neutral probabilities, and corresponding security prices. More specifically, we analyze a policy design that consists of a simple linear tax code in a single-period model economy with an exogenous risk-free interest rate but endogenous stock prices. With respect to accumulated tax proceeds two polar approaches are discussed: either the government redistributes them within the cohort of market participants or transfers them to 'outsiders' (i.e. non-market participants). The rationale behind our model set-up is as follows: we are interested in the effect of capital income taxes for an economy with perfectly integrated bond but locally segmented stock markets.[5] Instead of analyzing any particular country's tax regime, we consider a rather stylized tax system that applies the economic rent (defined as the sum of dividends or interests plus capital gains) as the tax base. However, in the single-period set-up analyzed here our tax regime coincides with a flat withholding tax on capital income including dividends, interests, and capital gains as currently discussed by the German government *(e.g. Drost and Rezmer, 2006).*

We restrict ourselves to a binomial model, which allows us to derive analytical results for a broad variety of von Neumann/Morgenstern preferences. Thereby, we adopt an after-tax *state-price pricing approach* and characterize the price of any security as the after-tax payoff weighted sum of all corresponding state prices. With this idea in mind, we disentangle the pricing effect under consideration into an *equilibrium effect* and a *payoff effect*. Specifically, the effect of a particular policy design upon equilibrium state prices is called the equilibrium effect, since it essentially mirrors the effect upon well-being of the representative stand-in household. Thus, the equilibrium effect is not only determined by taxation but also by redistribution of risky tax proceeds. Moreover, recalling that risk-neutral probabilities are normalized state prices, the equilibrium effect may further be disentangled into an effect for the prevailing risk-free after-tax interest rate and an effect for corresponding risk-neutral probabilities. In contrast, the effect upon after-tax payoffs promised by a particular security is called *payoff effect.*[6] The payoff effect of taxation is straightforward: it is determined by the tax code under consideration. Putting the two effects together gives us the pricing effect. Applying a kind of *reversed adjusted present value approach*, we find that the pricing effect of a particular security is determined by the variability of the security's before-tax payoffs, the effect for the risk-neutral probability measure and the level of the riskfree before-tax interest rate.

In an application, our model then predicts that if tax proceeds are transfered to outsiders, i.e. market participants receive no redistribution (*no-redistribution regime*), a shift in the tax rate affects state prices, risk-neutral probabilities as well as equilibrium prices of risky secu-

[5] Here, we in particular have EMU-countries in mind, where the European Central Bank seems to control the interest rate for Euro-investments.

[6] Throughout, before-tax payoffs of securities are exogenous primitives to our analysis.

rities. Thereby, the effect for the equilibrium price of a security is sensitive with respect to the correlation between its own payoff and the payoff of the market portfolio. Specifically, the price sensitivity of a security is positive, if this correlation is positive (and vice versa). In this case, our model predicts a negative tax rate sensitivity for the expected ex-ante equity premium, i.e. an increasing tax rate implies an decreasing expected equity premium and vice versa, since the market portfolio is positively correlated to itself.[7] However, if in contrast tax proceeds are redistributed within the cohort of market participants (*full-redistribution regime*), risk-neutral probabilities and security prices are unaffected by a change in the tax rate, although state prices are sensitive with respect to the tax rate.

The rest of the paper is organized as follows. Section 2 reviews related literature. Section 3 presents the general framework in the absence of taxation. The tax system is introduced and analyzed in section 4. Applications are examined in section 5. Finally, section 6 concludes.

2. Related Literature

Analyzing the effects of taxation has a long history in economic literature. One strand of literature is concerned with the effects of taxation upon the risk allocation process. Most of these papers are concerned with the portfolio choice problem of an individual consumer facing exogenous pre-tax security returns (e.g.*Domar and Musgrave, 1944*, *Mossin, 1968*, *Stiglitz, 1969*, *Sandmo, 1989* and *Hilgers and Schindler, 2004*). Since there is no equilibrium effect of taxation prevailing in these kind of models, they refer (implicitly) to a model of a small open economy. Our tendency towards a different model set-up is rationalized by the home bias. And in fact, our analysis of a *semi-closed model economy* predicts effects not observed in the small open economy set-up. Specifically, while *Sandmo (1989)* finds that there is no substitution effect from assets with low risk to assets with high risk in a small open economy, we find that in our no-redistribution regime the effect of taxation depends upon the correlation of the security's before-tax payoff with the market portfolio. Thus, in a world with inelastic supply of assets we expect for our no-redistribution regime (i) an increasing demand for risky assets and (ii) a substitution effect towards securities that are highly correlated with the market portfolio.

There are also papers analyzing the effects of taxation in equilibrium models of closed economies. *Mintz (1982)*, for instance, analyzes a corporate tax code that basically may be viewed as a personal tax code taxing excess returns. The author shows that neglecting general equilibrium effects (i.e. effects upon agents' marginal rate of intertemporal substitution and therefore upon the risk-free rate and the market price of risk), the tax code under consideration

[7] In a recent paper *McGrattan and Prescot (2005)* examine the effect of taxation for the equity premium in a deterministic growth model.

is neutral, meaning that investment decisions of firms are unaffected by the tax code.[8] *Gordon (1985)* also analyzes a tax code comprising property, corporate, and personal taxes. The author shows that if (i) there is no tax revenue from risk-free investments and (ii) transfer payments leave any agents' wealth position unaffected, then the tax code is *neutral* in the sense that investment decisions are unaffected by taxation. Again, the neutral tax code seems to be a tax code on excess returns. *Konrad (1991)* drives the analysis one step further: directly analyzing a personal tax on excess returns the author shows that such a tax rate is neutral even in a heterogeneous consumer economy allowing for endogenous production and arbitrary, budget-balancing transfer payments. These papers analyze conditions which ensure that taxation does not affect equilibrium outcomes. Essentially, all three papers arrive at a kind of *excess return tax*. Finally, the analysis of *Bulow and Summers (1984)* points out that the equilibrium effect of taxation significantly depends upon whether taxation cuts in gains and risk symmetrically or not.

Our analysis is not concerned with *neutrality results* per se, but with equilibrium effects of a particular tax regime: an economic income tax. In this regime excess returns as well as the risk-free rate are subject to taxation. However, our analysis shows that if (i) the risk-free interest rate before taxes is exogenously fixed and (ii) tax proceeds are redistributed within the cohort of market participants, which treat redistribution as a perfect substitute for capital income, then even an economic income tax is neutral with respect to equilibrium outcomes.

3. The Model Without Taxes

Consider the following single-period prototype model of an economy inhabited by m consumers that group into two classes: $n \leq m$ rational acting *insiders*, which (are allowed to) participate in the domestic capital market and $m-n$ *outsiders*. At the outset of the period ($t=0$), each insider owns a portfolio of securities offering exogenous time-1 payoffs. At the same time, a frictionless (domestic) capital market opens, where insiders may trade their securities free of transaction costs. Thereby, agents are supposed to trade securities in order to maximize their (expected) utility over (monetary) time-1 income and security payoffs are the only source of time-1 income for market participants. Following the mainstream approach of economics of always-clearing markets, an *equilibrium* for the economy is an $n+1$-tuple of n after-trade portfolios (one for each insider) and a vector of security prices such that (i) for each insider the time-1 payoff of its after-trade portfolio maximizes its utility subject to the corresponding budget constraints (characterized by its initial portfolio) and (ii) the capital market clears.

[8] Allowing for non-state contingent transfer payments and shared public goods, *Mintz (1982, Lemma 1)* provides – rather strict – conditions ensuring that there are no general equilibrium effects for a particular firm.

Thus, equilibrium prices of the economy are essentially determined by aggregate demand and aggregate supply of all individuals. However, to keep the problem tractable we assume that there exists a single *virtual household* such that if this household is endowed with aggregate resources of all market participants, then equilibrium security prices are characterized by the household's optimization problem *(e.g. Duffie, 1996, chapter 1)*. In general, this *pricing household*, which is characterized by its preferences, is a function in the level and the structure of initial resource distribution within the economy. We shall assume, however, that the pricing household is independent of the level and structure of initial resources within the cohort of market participants, i.e. we presume that there exists a representative *stand-in household* throughout mirroring economic behavior of insiders (not only in equilibrium). This assumption is in effect satisfied if our model economy allows for *aggregation of preferences*.[9]

The following assumptions 1 to 4 specify our model in the absence of a tax authority.

Assumption 1 *Time-0 is certain, whereas in time-1 one of two states $\{r,b\}$ realizes. The (statistical) probability that state $s(\in \{r,b\})$ occurs is denoted $\phi_s \in (0,1)$.*

Assumption 2 *There are K securities traded in a frictionless domestic capital market, which are all in a net supply of one. In $t=1$ these securities offer exogenously given state-dependent payoffs $z_k = (z_{kr}, z_{kb})$, which consist of dividends and capital components. Furthermore, there are at least two securities offering linear independent time-1 payoffs. For the payoff of the market portfolio $M_s = \sum_k z_{ks}$ we assume $0 < M_r < M_b$. Accordingly, we call r the recession state and b the boom state.*

Assumption 3 *There is a stand-in household with preferences over (monetary) time-1 income X that may be represented by $U(X) = \sum_{s\in\{r,b\}} \phi_s \times u(X_s)$, where u is twice-differentiable with $u' > 0$ and $u'' < 0$.*

Let p_k denote the equilibrium price of security k, which is characterized by the optimization problem of the stand-in household $\max_X U(X)$ subject to the following constraints: (i) $0 \leq \sum_{k=1}^{K} p_k$ and (ii) $X_s = M_s$ for $s \in \{r;b\}$. Standard arguments then imply the following representation of p_k:

$$\frac{p_k}{\pi_0} = \sum_{s\in\{r;b\}} \phi_s \times \frac{u'(M_s)}{\mathbf{E}[u'(M)]} \times z_{ks}, \tag{1}$$

where π_0 is a *normalization parameter* and $\mathbf{E}$ denotes the expectation operator with respect to the probability measure ϕ. Moreover, let π_s denote the equilibrium state-s state price, that

[9] If an economy allows for aggregation of preferences, equilibrium security prices are independent of the distribution of initial wealth (here represented by initial portfolios) within the economy. For a dynamic economy *Rubinstein (1974)* reports sufficient conditions for aggregation of preferences. *Brennan and Kraus (1978)* prove them to be necessary.

is the equilibrium price of a *state-s contingent claim* promising a payoff χ_s offering one unit of account in time-1 if (and only if) state s occurs. Then it is easy to see, that π_0 may be characterized as the sum of the two state prices, i.e. $\pi_0 = \pi_r + \pi_b$.[10]

Next, we shall assume the existence of an risk-free bond promising an exogenous risk-free interest rate. Essentially, the bond may be interpreted as a security traded in a perfectly integrated world market for risk-free capital. Thereby, the economy under consideration is supposed to be *small* such that its impact on world prices is negligible. From this perspective, our model presumes perfectly integrated bond markets, where only risk-free bonds are traded, and locally segmented equity markets, where (risky and risk-free) local stocks are traded.

Assumption 4 *Agents are offered the unlimited possibility to transfer wealth from time-0 to time-1 by investing in a risk-free zerobond with an exogenous time-0 price* p_0 *and a time-1 payoff* $z_0 = 1$.

The exogenous risk-free interest rate earned by bond investments is given by $r_0 = p_0^{-1} - 1$. Assumption 4 links r_0 to the normalization parameter π_0 from equation (1). Specifically, in equilibrium equation (1) must also hold for the bond and thus $z_0 = (1,1)$ implies $p_0 = \pi_0$. Hence, the equilibrium price of security k is given by

$$p_k = \frac{1}{1+r_0} \times \sum_{s\in\{r;b\}} \phi_s \times \frac{u'(M_s)}{\mathbf{E}[u'(M)]} \times z_{ks} = \frac{1}{1+r_0} \times \frac{\mathbf{E}[u'(M) \times z_k]}{\mathbf{E}[u'(M)]} \tag{2}$$

and *equilibrium state prices* (ESPs) are given by $\pi_s = (1+r_0)^{-1} \times \{u'(M_s)/\mathbf{E}[u'(M)]\} \times \phi_s$, since the corresponding payoffs are given by $\chi_r = (1,0)$ and $\chi_b = (0,1)$. Clearly, with assumption 1 and 3 ESPs are strictly positive. Thus, $q_s = \{u'(M_s)/\mathbf{E}[u'(M)]\} \times \phi_s$ defines a probability measure Q on the state space $\{r;b\}$, such that $p_k = (1+r_0)^{-1} \times \mathbf{E}^Q[z_k]$, where $\mathbf{E}^Q[z_k] = \sum_s q_s \times z_{ks}$, for every security k. Accordingly, Q is called *risk-neutral probability measure* (RNPM).

4. The Model with a Tax Authority

4.1. Basic assumptions

Our analysis is concerned with a rather stylized tax code taxing the economic rent of a portfolio with an uniform linear tax rate. Thereby, the tax code does not distinguish between domestic securities and the risk-free bond. In the single-period model set-up our tax code coincides with a flat withholding tax on capital income including dividends, interests and capital gains.

[10] Note that we can not conclude $\pi_s = \phi_s \times u'(M_s)$ from equation (1). In fact, the only thing we know is $\pi_s = \alpha \times \phi_s \times u'(M_s)$ for some scalar α *(e.g. Duffie, 1996, equation (4)).*

By taxation the government collects tax revenues, which can be used to finance public expenditures. The aggregate of a tax code and the associated expenditure regime is called *policy design*. With respect to the a policy design's expenditure part we examine two polar cases in detail: either tax proceeds are immediately redistributed within the cohort of market participants in form of monetary transfer payments (full-redistribution regime) or the government immediately transfers tax proceeds to non-market participants and market participants receive no redistribution (no-redistribution regime). As is common in the analysis of taxation we presume that the government has a *commitment technology* such that once a policy design is established the government cannot alter it any more (i.e. we neglect the problem of policy design uncertainty here).

To discuss the effect of taxation, we extend our assumptions 1 – 4 as follows:

Assumption 5 *The tax system is a capital income tax system and applies the economic rent of a portfolio as a tax base. The tax function is assumed to be linear with a tax rate* $\tau > 0$ *identical for all agents and all securities. In particular, we assume an immediate loss offset in case of a negative tax base.*

Assumption 6 *After enacting the tax code, government chooses an expenditure policy offering lump-sum redistribution in form of monetary transfer payments. The amount of redistribution offered to the cohort of insiders is denoted by* $L = (L_r, L_b)$. *Insiders are well aware what type of redistribution the authority is going to apply. Moreover, they internalize redistribution in their optimization problem as an additional source of (monetary) income.*

Remark 1 (Assumption 5 and 6) *With respect to assumption 5 and 6 the following is important to note. Basically, our analysis represents a partial equilibrium perspective of the policy designs under consideration. First, if there is a state with a negative aggregate tax rate, then aggregate tax revenues of the public sector are negative in that state. This might either be financed by negative redistribution, savings in other public activities, or access to public debt (financed by foreign agents). Thereby, negative redistribution essentially represents a per-capital tax.*

Finally, assumption 7 ensures that preferences of the stand-in household for (monetary) time-1 income are independent of the statutory policy design.

Assumption 7 *The introduction of a tax authority does not alter beliefs and preferences of the stand-in household for time-1 income.*

Monetary transfer payments allow consumers to purchase additional private consumption and the stand-in household, which mirrors economic behavior of insiders, internalizes redistribution to market participants. Thus, τ and L are essentially the only relevant policy parameters for our analysis and we characterize any policy regime $\mathcal{P}$ by the pair (τ, L).

Remark 2 (Assumption 7) *Our model assumes that government collects tax payments in order to solely grant (monetary) transfer payments, which allow to purchase additional private consumption (assumption 6). In that case, assumption 7 seems quite plausible. However, if tax revenues shall be utilized for public projects providing public goods, assumption 7 implicitly presumes that either there are no public goods or, alternatively, if there are public goods, that insiders' preferences for public goods and monetary time-1 income are (perfectly) separable. While the assumptions necessary in the latter case seem quite strict, they are fairly standard in much of the public economics literature. In particular, all references discussed in the literature review section (implicitly) rely on variants of assumption 7. With some effort, the approach adopted here might also be interpreted as allowing for public goods, however for the cost of quite strict assumptions concerning public production technologies and preferences for public goods.*

Remark 3 (After-tax riskfree interest rate) *Given a policy design $\mathcal{P}$ that is characterized by (τ, L) the state-s after-tax payoff of security k is given by $z^{\mathcal{P}}_{ks} = z_{ks} - \tau \times (z_{ks} - p^{\mathcal{P}}_k)$, where $p^{\mathcal{P}}_k$ denotes its time-0 price given $\mathcal{P}$. Furthermore, let $r^{\mathcal{P}}_k = z^{\mathcal{P}}_k / p^{\mathcal{P}}_k - 1$ and $\eta^{\mathcal{P}}_k = z_k / p^{\mathcal{P}}_k - 1$ denote the security's after-tax return and its pre-tax equivalent, respectively. Clearly, our tax code implies $r^{\mathcal{P}}_k = (1-\tau) \times \eta^{\mathcal{P}}_k$ for all domestic securities. The same holds true for the risk-free zerobond. Thereby, the pre-tax return of the zerobond is given by $\eta^{\mathcal{P}}_0 = r_0$, since its price is exogenous to the model economy, i.e. $p^{\mathcal{P}}_0 = p_0$ for all $\mathcal{P}$ (assumption 4). This, of course, implies $r^{\mathcal{P}}_0 = (1-\tau) \times r_0$.*

In state s the stand-in household's tax base is $B^{\mathcal{P}}_s = \sum_{k=1}^{K} (z_{ks} - p^{\mathcal{P}}_k)$, and its tax bill in state s sums up to $\tau \times B^{\mathcal{P}}_s$.[11] Accordingly, we define $T^{\mathcal{P}}_s = -\sum_{k=1}^{K} \tau \times (z_{ks} - p^{\mathcal{P}}_k)$. Note, that $T^{\mathcal{P}}_s < 0$ ($T^{\mathcal{P}}_s > 0$) indicates that taxation reduces (increases) time-1 income of the stand-in household. However, there is also redistribution and the *net-effect* of $\mathcal{P}$, which is defined as the sum of tax payments T plus redistribution L, determines the overall effect for time-1 income of the stand-in household. Furthermore, due to assumption 7 it is only the net-effect of $\mathcal{P}$ that induces the corresponding equilibrium effect. Thus, $\mathcal{P}$-associated equilibrium security prices are given by

$$p^{\mathcal{P}}_k = \sum_{s \in \{r,b\}} \pi^{\mathcal{P}}_s \times z^{\mathcal{P}}_{ks} = \frac{1}{1 + r^{\mathcal{P}}_0} \times \mathbf{E}\left[\frac{u'(M + (T^{\mathcal{P}} + L))}{\mathbf{E}[u'(M + (T^{\mathcal{P}} + L))]} \times z^{\mathcal{P}}_k\right]. \tag{3}$$

The first part of the equation elucidates the idea to disentangle the pricing effect of a particular policy design $\mathcal{P}$, i.e. the shift from p_k to $p^{\mathcal{P}}_k$, into two sub-effects:

[11] Note that none of the insiders is actually trading in the risk-free zerobond. Hence, there are no tax revenues from from bond investments.

P: on the one hand there is a *payoff effect,* i.e. the effect that the tax component of the policy design affects after-tax payoffs promised by the security ($z_k \rightarrow z_k^{\mathcal{P}}$),

E: on the other hand there is an *equilibrium effect,* i.e. the effect that the policy design affects ESPs ($\pi \rightarrow \pi^{\mathcal{P}}$).

Taking a closer look, the second part of the above equation, which is due to

$$\pi_s^{\mathcal{P}} = \frac{1}{1+r_0^{\mathcal{P}}} \times q_s^{\mathcal{P}} = \frac{1}{1+r_0^{\mathcal{P}}} \times \frac{u'(M_s + (T_s^{\mathcal{P}} + L_s))}{\mathbf{E}[u'(M + (T^{\mathcal{P}} + L))]} \times \phi_s, \quad \text{for all } s \in \{r, b\}, \tag{4}$$

illustrates that the equilibrium effect again may be disentangled into two sub-effects

E.1: an effect for the risk-free after-tax interest rate ($r_0 \rightarrow r_0^{\mathcal{P}}$),

E.2: an effect for the stand-in household's marginal utilities and corresponding risk-neutral probabilities ($q_0 \rightarrow q_0^{\mathcal{P}}$).

Note, that in principle all three effects may occur for any policy design comprising a capital income tax code. Furthermore, equation (3) and (4) point out that under assumption 6 (and 7), the effect of a particular policy design is not only determined by the tax code alone but also by the expenditure component of the policy design (in particular with respect to effect E.2).

4.2. A kind of reversed adjusted present value approach

Subsequently, we call a security with a pre-tax payoff that is positively (negatively) correlated to the aggregate pre-tax payoff of the market portfolio *procyclical* (*countercyclical*). In our simple binomial model economy, security k is procyclical (countercyclical), if (and only if) its time-1 pre-tax payoff in the recession state is smaller (larger) that its boom-state equivalent, i.e. if (and only if) $z_{kb} - z_{kr} > 0$ ($z_{kb} - z_{kr} < 0$).[12]

To gain further insight into the pricing effect, the following lemma examines (i) the value of tax payments associated to a security traded in the local (equity) market, (ii) the pricing effect for a non-taxed payoff, and presents (iii) a kind of *reversed adjusted present value approach* to determine the market value of a local stock.[13] It turns out, that if the policy design affects the RNPM of the economy the result in all three cases is sensitive with respect to the the variability

[12]From an asset pricing perspective, a procyclical (countercyclical) security is characterized by a positive (negative) beta-coefficient. Moreover, as it is well-known, as long as the stand-in household is risk-averse the expected after-tax excess return (*risk-premium*) $r_{k,ex}^{\mathcal{P}} = \mathbf{E}\left[z_k^{\mathcal{P}} / p_k^{\mathcal{P}} - r_0^{\mathcal{P}} - 1\right]$ is positive for a procyclical security k. In contrast, for countercyclical securities the expected after-tax excess return is negative, since countercyclical provide a kind of hedge against income uncertainty.

[13]*Myers (1974)* introduced the *adjusted present value* approach of corporate finance theory in order to determine the value of a levered firm in the presence of tax-exempt interest payments of corporate debt.

of associated payoffs before taxes, i.e. with respect to the *cyclicality* of the payoff. A proof for the lemma is found in appendix A

Lemma 1 (Pricing effect for a general policy design) *Suppose the government enforces a policy design $\mathcal{P}$. Then, the following holds:*

(L-1.a) The market value of tax payments $t_k^{\mathcal{P}}$ associated with security k is given by[14]

$$p^{\mathcal{P}}(t_k^{\mathcal{P}}) = \frac{\tau \times r_0}{1 + r_0^{\mathcal{P}}} \times \left[(1 + r_0) \times p_k + (z_{kb} - z_{kr}) \times \left(q_b^{\mathcal{P}} - q_b\right)\right]. \tag{5}$$

(L-1.b) The market value of a tax-exempt payoff $y = (y_r, y_b)$ is given by

$$p^{\mathcal{P}}(y) = \frac{1}{1 + r_0^{\mathcal{P}}} \times \left[(1 + r_0) \times p(y) + (y_b - y_r) \times \left(q_b^{\mathcal{P}} - q_b\right)\right]. \tag{6}$$

(L-1.c) The price of a taxed security k is given by the price of its tax-exempt equivalent minus the market value of its tax payments, i.e. $p_k^{\mathcal{P}} = p^{\mathcal{P}}(z_k) - p^{\mathcal{P}}(t_k^{\mathcal{P}})$ (reversed adjusted present value approach). In particular,

$$p_k^{\mathcal{P}} = p_k + \frac{z_{kb} - z_{kr}}{1 + r_0} \times (q_b^{\mathcal{P}} - q_b), \tag{7}$$

where on the r.h.s. only the last term depends upon the prevailing policy design.

Essentially, (L-1.a) and (L-1.b) are *ceteris paribus* analyses of the implications of the payoff and the equilibrium effect, respectively, upon the pricing effect. It is shown that in both cases the *ceteris paribus* effect depends upon

- whether there is an equilibrium effect for the RNPM of the economy, i.e. whether there is an equilibrium effect E.2,
- the level of the exogenous interest rate before taxes,
- the prevailing tax rate (in particular, since it determines the prevailing after-tax interest rate $r_0^{\mathcal{P}}$), and
- the cyclicality of the corresponding pre-tax payoff.

Specifically, if there is an equilibrium effect for the RNPM, then both *ceteris paribus* effects are (affine) linear functions in the variability of the corresponding before-tax payoffs, where the latter is measured by the difference between the boom and the recession pre-tax payoff.

[14]Note, here that $T_s^{\mathcal{P}} = -\sum_{k=1}^{K} t_{ks}$ for all s.

Accordingly, for risk-free securities both *ceteris paribus* examined in (L-1.a) and (L-1.b) are only sensitive with respect to the prevailing tax rate but independent of the equilibrium effect for the RNPM.

Accordingly, (L-1.c) shows that for a security with a risk-free pre-tax payoff there is no pricing effect (no matter what policy design is examined). Clearly, this is a direct implication of (a) the linear tax code, (b) markets that are in equilibrium, i.e. there is no arbitrage and (c) assumption 4, i.e. the assumption of perfectly integrated bond markets: if the tax code offers immediate tax loss offset, the risk-free international bond trades for an exogenous price, and the local equity market does not offer arbitrage opportunities to its participants, then any risk-free local stock must trade for a price that is independent of the tax rate. However, for securities promising risky before-tax payoffs there is a pricing effect, as soon as there is an equilibrium effect for the RNPM (effect E.2). More specifically, for risky securities the pricing effect of the policy design under consideration is determined by the level of the exogenous risk-free interest rate before taxes, the effect of the policy design upon the RNPM of the economy, i.e. effect E.2, and the variability of the security's payoffs before taxes. And again, the pricing effect is an (affine) linear function in the variability of the corresponding pre-tax payoff.

Remark 4 (Tax rate sensitivity of the pricing effect) *It is interesting to note, that the level of the prevailing tax rate affects the pricing effect only indirectly via* $(q_b^{\mathcal{P}} - q_b)$*, since all direct effects cancel out.*

Now, what determines the overall pricing effect for a risky security? Suppose there is an equilibrium effect causing $q_b^{\mathcal{P}} > q_b$, meaning that the economy becomes less risk averse with respect to after-tax payoffs. For procyclical securities this implies that corresponding tax payments become more valuable but also the the tax-exempt equivalent. Thereby, the second *ceteris paribus* effect overrules the first one by the factor $(1+r_0)/(\tau \times r_0)$. Thus, the overall pricing effect for a procyclical security, i.e. a security offering higher pre-tax payoffs in the boom state (compared to the recession state), is positive. Clearly, things are the other way around for countercyclical securities or if the equilibrium effect is characterized by $q_b^{\mathcal{P}} < q_b$.

Remark 5 (Pricing effect for a shift in the RNPM) *In case of an equilibrium effect for the RNPM, i.e.* $q_b^{\mathcal{P}} - q_b \neq 0$*, the lemma predicts a differentiating pricing effect, which will imply a substitution effect on the household portfolio level. This finding is in sharp contrast to the small open economy finding in Sandmo (1989).*

5. Two polar expenditure regimes

In this section we examine two polar assumptions concerning the expenditure part of the policy design in detail: the *no-redistribution regime* characterized by $L_b = L_r = 0$ and the *full-redistribution regime* characterized by $L_s = -T_s^{\mathcal{P}}$. The corresponding policy designs are labeled $\mathcal{N}$ and $\mathcal{F}$, respectively.

5.1. The no-redistribution regime

The policy design $\mathcal{N}$ comprising a no-redistribution regime serves as a starting point. In case of the no-redistribution regime, the net-effect of the policy design is given by $N_s^{\mathcal{N}} = T_s^{\mathcal{N}}$, meaning that the associated equilibrium effect is completely determined by the tax code under consideration.

We start by analyzing the sensitivity of the RNPM with respect to the tax rate τ. In case of the no-redistribution regime, the state-s risk-neutral probability is given by

$$q_s^{\mathcal{N}} = \frac{u'((1-\tau) \times M_s + \tau p_M^{\mathcal{N}})}{\mathbf{E}[u'((1-\tau) \times M + \tau p_M^{\mathcal{N}})]} \times \phi_s. \tag{8}$$

Among others, the tax rate-sensitivity of $q_s^{\mathcal{N}}$ depends upon u, $\mathbf{E}[M]$ and $M_b - M_s$. Instead of assuming that preferences of the stand-in household satisfy certain conditions, our analysis presumes that the economy under consideration is *sufficiently volatile* in the sense of the following assumption 8. The subsequent remark points out that assumption 8 is less restrictive then it seems to be at a first glance.

Assumption 8 *For all tax rates, the aggregate tax base of the stand-in household is negative in the recession state. Formally,* $B_r^{\mathcal{N}} \leq 0$ *for all* $\tau \in [0,1]$.

Remark 6 (Assumption 8) *Assumption 8 presumes that in the recession state aggregate capital losses of the market portfolio are larger than associated dividends. Essentially, assumption 8 is equivalent to the assumption that the aggregated time-1 pre-tax payoff of the market portfolio* M *is sufficiently volatile. Appendix B shows that assumption 8 is equivalent to* $M_r \leq q_b^{\mathcal{N}}/(q_b^{\mathcal{N}} + r_0) \times M_b$. *The latter, for instance, holds if (a)* $r_0 = 0$ *or (b)* $M_r \leq (1 + r_0/\phi_b)^{-1} \times M_b$.

With assumption 8 the numerator of equation (8) is constant or decreases in the recession state. In case of the boom state, however, it increases. Since the adjustment works for the two states in the opposite direction, the effect of the numerator dominates the effect in the denominator and we arrive at the following proposition, which is proved on appendix C.

Proposition 1 (RNPM under no-redistribution) Suppose the government enforces a fixed policy design with a no-redistribution regime component. Then, the risk-neutral probability for the recession state decreases in the tax rate, whereas for the boom state it increases in the tax rate.

The intuition of the proposition is the following: taxation reduces the variability of time-1 security income after taxes. Specifically, since the tax code provides full loss offset volatility reduces to zero for $\tau = 1$. In other words, time-1 income and corresponding marginal utilities become deterministic as τ approaches 1. Thus, $\lim_{\tau\to 1} q_s^{\mathcal{N}} = \phi_s$.

The following corollary reports that the boom state ESP is always decreasing in the tax rate. In general the effect for the recession state ESP may be ambiguous, however if $r_0 = 0$ the sensitivity is monotonic.

Corollary 1 (ESPs under no-redistribution) *Suppose the government enforces a fixed policy design with a no-redistribution regime component.*

(C-1.a) The ESP for the boom state is increasing in the tax rate.

(C-1.b) If $r_0 = 0$, then the ESP for the recession state decreases in the tax rate.

Proof: To begin with, note that $\pi_b^{\mathcal{N}} = \left(1 + r_0^{\mathcal{N}}\right)^{-1} \times q_b^{\mathcal{N}}$. Therewith corollary becomes an immediate application of proposition 1. In particular, for part (a) note that

$$\frac{\partial}{\partial\tau}\pi_b^{\mathcal{N}} = \frac{r_0}{(1+r_0^{\mathcal{N}})} \times q_b^{\mathcal{N}} + \frac{1}{1+r_0^{\mathcal{N}}} \times \frac{\partial}{\partial\tau} q_b^{\mathcal{N}} > 0.$$

and for part (b) note that $r_0 = 0$ implies $q_s^{\mathcal{N}} = \pi_s^{\mathcal{N}}$ for all states s. □

The following proposition applies proposition 1 and combines it with the payoff effect in order to derive the price effect of taxation in case of a no-redistribution regime. In particular, it points out that (a) the price effect is sensitive with respect to the variability of a security's time-1 payoff before taxes and (b) the sign of the price effect is sensitive with respect to correlation between the security's pre-tax payoff and the pre-tax payoff of the market portfolio.

Proposition 2 (Pricing effect under no-redistribution) Suppose the government enforces a fixed policy design with a no-redistribution regime component. Then, the price effect for any security depends (affine) linearly upon the pre-tax variability of its time-1 pre-tax payoff. In particular, for any security the following holds true:

(P-2.a) if the correlation of the security's payoff with the aggregate payoff of the market portfolio is positive, its equilibrium after-tax price increases in the tax rate,

(P-2.b) if the correlation of the security's payoff with the aggregate payoff of the market portfolio is negative, its equilibrium after-tax price decreases in the tax rate, or

Proof: The proposition is an immediate implication of lemma (L-1.c) and proposition 1. Specifically, the latter shows that under no-redistribution an increasing tax rate produces an increasing risk-neutral probability for the recession state, i.e. $q_b^{\mathcal{N}} - q_b > 0$ for all $\mathcal{N}$ with strictly positive tax rate. Thus, if $z_{kb} - z_{kr}$ is positive (negative or zero), an increasing tax rate leads to an increasing (decreasing or stable) equilibrium price of security k. □

The market portfolio is basically a procyclical security, since $M_b - M_r > 0$. Therefore, in case of the no-redistribution regime, our model predicts a negative sensitivity of the *ex-ante expected equity premium* with respect to the tax rate, since today's price of the market portfolio is positively correlated to the prevailing tax rate. The latter also implies that the *observed ex-post equity premium* is positively correlated to the prevailing tax rate.

Remark 7 *We analyze the no-redistribution regime assuming a non-positive tax base in the recession state (assumption 8). This assumption is necessary to derive results independent of agents preferences. Our results remain valid without this assumption if we impose restrictions on agents preferences similar to the ones discussed in Stiglitz (1969). Discussing the full-redistribution regime in the next section we can omit the assumption of the negative tax base. Nevertheless, we will obtain preference-free results.*

5.2. The full-redistribution regime

In this section we study the effect of an economic income tax code accompanied by a full redistribution regime. The corresponding policy design $\mathcal{F} = (\tau, L)$ is characterized by $L = -T^{\mathcal{F}}$. That is the redistribution exactly offsets the tax payments and thus the net-effect for the stand-in household sums up to zero for the full-redistribution regime. However, due to our assumption of an exogenous risk-free interest rate the full-redistribution regime still induces an equilibrium effect. This is reported in the following corollary.

Corollary 2 (RNPM and ESPs under full-redistribution) *Suppose the government enforces a fixed policy design with a full-redistribution regime component. Then, the following holds:*

(C-2.a) the risk-neutral probabilities are independent of the tax rate,

(C-2.b) the state prices are strictly increasing in the tax rate.

Proof: Under full-redistribution the net-effect of the policy regime is zero. Thus, equation (4) and $q_s^{\mathcal{P}} = \pi_s^{\mathcal{P}} / (\pi_r^{\mathcal{P}} + \pi_b^{\mathcal{P}})$, which holds for any policy design $\mathcal{P}$, give part (a). Moreover, the risk-free after-tax return $r_0^{\mathcal{P}} = (1-\tau) \times r_0$ is strictly decreasing in the tax rate. Then, equation (4) also gives part (b). □

With corollary 2 it is easy to prove that our model predicts equilibrium security prices that are independent of the prevailing tax rate.

Proposition 3 (Pricing effect under full redistribution) Suppose the government enforces a fixed policy design with a full-redistribution regime component. Then, the equilibrium price of any security traded in the model is independent of the tax rate.

Proof: The proposition is an immediate implication of lemma (L-1.c) and corollary (C-2.a). □

This result is of particular interest. It states that linear taxation of the economic rent accompanied by a full-redistribution regime is a *neutral* policy design for our asset pricing model with a risk-averse stand-in household, an exogenous risk-free rate and bounded supply of domestic assets. Thereby, neutral refers to the fact that the equilibrium security prices predicted by our model are independent of the tax rate.[15]

Clearly, the assumption of an economic income tax code as well as the assumption an exogenous risfree interest rate are vitally important for our neutrality result. To see this, note that in case of a full-redistribution regime, there is no net-effect of the policy design and the stand-in household anticipates this. Thus, the RNPM is unaffected by the policy design.[16] However, only the two assumptions mentioned above ensure that this implies that there is no effect for equilibrium security prices and one might expect significantly different results for different tax codes or even for an economic income tax code in a pure closed model economy with endogenous interest rate.

Remark 8 (The analysis of *Gordon (1985)*) *Our results for the no-redistribution regime are quite similar to the results of the two-period mean-variance analysis in Gordon (1985). However, in case of a flat tax, the neutrality result of Gordon (1985) requires that the capital income tax is in effect an excess return tax, which clearly separates the analysis of Gordon from the analysis above.*

6. Conclusion

We aim at extending the public finance literature for an asset pricing perspective and examine the effect of a change in the capital income tax rate upon equilibrium state-prices, corresponding risk-neutral probabilities and security prices in a model economy with perfectly integrated bond markets but locally segmented equity markets. Instead of analyzing any particular country's tax regime, we consider a highly stylized tax system that applies the economic rent (de-

[15] There are also other concepts of *'tax neutrality'* to be found in the literature. For example *Samuelson (1964)* analyzes the neutrality of an economic income tax system with respect to heterogeneous investor-specific tax rates. He concludes that (given exogenous returns of securities) the economic rent is the only way to define tax deductible depreciations that guarantee an optimization decision which is independent of the tax rate. *Jensen (2003, 2004)* extends the analysis of *Samuelson* to the uncertainty case.

[16] In our single-period model economy this result is independent of (a) the tax code under consideration and (b) the assumption of an exogenous risk-free interest rate.

fined as the sum of dividends and capital gains) as the tax base. Thereby, we note that taxation of capital income produces risky tax proceeds and we account for this fact by allowing for lump-sum redistribution.

Applying the state-price pricing approach allows us to disentangle the effect of taxation in two sub-effects: the payoff effect and the equilibrium effect. While the payoff effect captures the wedge between security payoffs and after-tax capital income, the equilibrium effect characterizes the effect of taxation (and corresponding redistribution) upon economic well-being of the stand-in pricing household. To analyze the pricing effect of taxation, we examine the value of a security's tax payments and the pricing effect for a tax-exempt payoff. It turns out, that the value of tax payments is a simple function in equilibrium price of the security in the presence of taxation. The pricing effect for a non-taxed payoff, however, is a function in the equilibrium price of the claim in a non-taxed world and the variability of the payoff before taxes. Moreover, applying a kind of *reversed adjusted present value approach*, we find that the pricing effect of a particular security is determined by the variability of the security's before-tax payoffs, the effect for the risk-neutral probability measure and the level of the riskfree before-tax interest rate.

In our applications, we examine two polar expenditure regimes in detail: the no-redistribution regime and the full-redistribution regime. Our model predicts that for both redistribution regimes a shift in the tax rate affects equilibrium state prices of the economy. However, only in case of the no-redistribution regime risk-neutral probabilities are sensitive to the level of the tax rate. More specifically, we show that in case of the no-redistribution regime our model predicts a pricing effect that is an (affine) linear function in the variability of the security's pre-tax payoffs and the sign of the pricing effect is sensitive with respect to the sign of the correlation of the security's payoff with the market portfolio. Moreover, since the market portfolio is positively correlated to aggregate endowment, our model predicts for the no-redistribution regime a negative sensitivity of the ex-ante expected equity premium with respect to the tax rate, i.e. an increasing tax rate implies an decreasing expected equity premium and vice versa. However, if in contrast tax proceeds are redistributed within the cohort of market participants, what basically characterizes the full-redistribution regime, the equilibrium effect and the payoff effect exactly cancel out. Thus, although state prices are sensitive with respect to the tax rate, equilibrium security prices are not.

Summing up, we note that our applications predicts quite contrary effects of taxation depending on the corresponding redistribution regime. Although, the question which model is more appropriate remains an empirical one, there seem to be two arguments in favor of the no-redistribution regime. First, it is not clear at all whether individuals really account for government transfers in their portfolio choice decisions. Second, there is empirical evidence for limited market participation as pioneered by *Mankiw and Zeldes (1991)* and it seems fair to presume that redistribution does not solely go to privileged market participants but specifically to relatively poor non-market participants.

Acknowledgement

We are grateful for valuable comments of Bjarne A. Jensen, Alfons J. Weichenrieder, three anonymous referees, participants of the *Second Leipzig Workshop on Mathematics and Economics* (Leipzig, February 7, 2004), the *2004 Workshop Unternehmensbewertung* (Hannover, June 12, 2004), and the *8th Conference of the Swiss Society for Financial Market Research* (Zurich, April 8, 2005).

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Appendix

A. Proof of lemma 1

This appendix proofs lemma 1. We start with an observation.

Observation: For any policy design $\mathcal{P}$ we have $q_r^{\mathcal{P}} + q_b^{\mathcal{P}} = q_r + q_b = 1$, which implies $q_b^{\mathcal{P}} - q_b = -(q_r^{\mathcal{P}} - q_r)$. Thus, for any pair (a_r, a_b) we may write

$$\sum_{s\in\{r,b\}} q_s^{\mathcal{P}} \times a_s = \sum_{s\in\{r,b\}} q_s \times a_s + (a_b - a_r) \times (q_b^{\mathcal{P}} - q_b). \tag{A.1}$$

Proof of (L-1.a): Recall, that $z_{ks}^{\mathcal{P}} = (1-\tau) \times z_{ks} + \tau \times p_k^{\mathcal{P}}$. Thus, corresponding tax payments are given by $t_{ks}^{\mathcal{P}} = \tau \times z_{ks} - \tau \times p_k^{\mathcal{P}}$. Next, we have to determine $p_k^{\mathcal{P}}$. Therefore, note

$$\begin{aligned} p_k^{\mathcal{P}} &= \frac{1}{1+r_0^{\mathcal{P}}} \times \sum_{s\in\{r,b\}} q_s^{\mathcal{P}} \times z_k^{\mathcal{P}} \\ &= \frac{1}{1+r_0^{\mathcal{P}}} \times \sum_{s\in\{r,b\}} q_s^{\mathcal{P}} \times (1-\tau) \times z_{ks} + \frac{\tau}{1+r_0^{\mathcal{P}}} \times p_k^{\mathcal{P}} \\ &= \frac{1}{1+r_0} \times \sum_{s\in\{r,b\}} q_s^{\mathcal{P}} \times z_{ks}. \end{aligned} \tag{A.2}$$

Therewith,

$$\begin{aligned} p^{\mathcal{P}}(t_k^{\mathcal{P}}) &= \frac{1}{1+r_0^{\mathcal{P}}} \times \sum_{s\in\{r,b\}} q_s^{\mathcal{P}} \times (\tau \times z_{ks} - \tau \times p_k^{\mathcal{P}}) \\ &= \frac{\tau}{1+r_0^{\mathcal{P}}} \times \sum_{s\in\{r,b\}} q_s^{\mathcal{P}} \times z_{ks} - \frac{\tau}{1+r_0^{\mathcal{P}}} \times \frac{1}{1+r_0} \times \sum_{s\in\{r,b\}} q_s^{\mathcal{P}} \times z_{ks} \\ &= \frac{\tau \times r_0}{1+r_0^{\mathcal{P}}} \times \sum_{s\in\{r,b\}} q_s^{\mathcal{P}} \times z_{ks} \end{aligned}$$

and applying equation (A.1) yields

$$p^{\mathcal{P}}(t_k^{\mathcal{P}}) = \frac{\tau \times r_0}{1+r_0^{\mathcal{P}}} \times \left[(1+r_0) \times p_k + (z_{kb} - z_{kr}) \times \left(q_b^{\mathcal{P}} - q_b\right)\right].$$

which proofs (L-1.a).

Proof of (L-1.b): Consider a tax-exempt payoff $y = (y_r, y_b)$. Given the policy design $\mathcal{P}$ the market value of y is given by

$$p^{\mathcal{P}}(y) = \frac{1}{1+r_0^{\mathcal{P}}} \times \sum_{s\in\{r,b\}} q_s^{\mathcal{P}} \times y_s.$$

Applying equation (A.1) this may be re-written as

$$\begin{aligned} p^{\mathcal{P}}(y) &= \frac{1}{1+r_0^{\mathcal{P}}} \times \left[\sum_{s\in\{r,b\}} q_s \times y_s + (y_b - y_r) \times (q_b^{\mathcal{P}} - q_b)\right] \\ &= \frac{1}{1+r_0^{\mathcal{P}}} \times \left[(1+r_0) \times p(y) + (y_b - y_r) \times \left(q_b^{\mathcal{P}} - q_b\right)\right], \end{aligned}$$

which proofs (L-1.b).

Proof of (L-1.c): First, note that the equilibrium price of security k is given by applying equation (A.1) to equation (A.2) in order to obtain

$$p_k^{\mathcal{P}} = p_k + \frac{z_{kb} - z_{kr}}{1 + r_0} \times (q_b^{\mathcal{P}} - q_b). \quad \text{(A.3)}$$

On the other hand, simple algebraic rearrangements show that equation (A.3) gives a reversed adjusted present value of security k, meaning $p_k^{\mathcal{P}} = p^{\mathcal{P}}(z_k) - p^{\mathcal{P}}(t_k)$. This proofs the rest of the lemma.

B. Discussion of assumption 8

To gain some insight into assumption 8 note that for any policy design $\mathcal{P}$ with an economic income tax component equation (A.2) holds. Hence, the price of the aggregate market portfolio $p_M^{\mathcal{P}}$ is given by

$$p_M^{\mathcal{P}} = \sum_{k=1}^{K} p_k^{\mathcal{P}} = \sum_{s \in \{r,b\}} \frac{q_s^{\mathcal{P}}}{1 + r_0} \times M_s.$$

Accordingly, $M_r - \sum_k p_k^{\mathcal{P}} \leq 0$, becomes equivalent to

$$M_r \leq \sum_{s \in \{r,b\}} \frac{q_s^{\mathcal{P}}}{1 + r_0} \times M_s = \frac{q_b^{\mathcal{P}}}{q_b^{\mathcal{P}} + r_0} \times M_b. \quad \text{(B.1)}$$

Clearly, for $r_0 = 0$ assumption 2 implies that condition (B.1) holds for any policy design $\mathcal{P}$. Moreover, for the special case of a no-redistribution regime $q_s^{\mathcal{N}}$ is given by equation (8). With assumption 2 and 3 this immediately implies $q_b^{\mathcal{N}} \leq \phi_s$, since $(1-\tau) \times M_b + \tau p_M^{\mathcal{N}} > (1-\tau) \times M_r + \tau p_M^{\mathcal{N}}$ and $u' > 0$ as well as $u'' < 0$. Thus, rewriting condition (B.1) for $\mathcal{N}$ as $M_r \leq \left(1 + r_0 / q_b^{\mathcal{N}}\right)^{-1} \times M_b$ implies that $M_r \leq (1 + r_0/\phi_b)^{-1} \times M_b$ is also a sufficient condition for (B.1).

C. Proof of Proposition 1

This appendix proves proposition 1, where the government is supposed to implement a no-redistribution regime. Therefore, let $\mathcal{N}_1$ and $\mathcal{N}_2$ denote to policy designs with no-redistribution expenditure component and associated tax rates that satisfy $\tau_1 < \tau_2$. Then

$$u'(M_r + T_r^{\mathcal{N}_2}) \leq u'(M_r + T_r^{\mathcal{N}_1})$$
$$u'(M_b + T_b^{\mathcal{N}_2}) > u'(M_b + T_b^{\mathcal{N}_1}),$$

since by assumption 8 we have $T_r^{\mathcal{N}_2} \geq T_r^{\mathcal{N}_1} \geq 0$ and $T_b^{\mathcal{N}_2} \leq T_b^{\mathcal{N}_1} \leq 0$. Defining a_r and a_b by

$$a_r = \frac{u'(M_r + T_r^{\mathcal{N}_2})}{u'(M_r + T_r^{\mathcal{N}_1})} \leq 1$$
$$a_b = \frac{u'(M_b + T_b^{\mathcal{N}_2})}{u'(M_b + T_b^{\mathcal{N}_1})} > 1$$

we may write

$$\mathbf{E}[u'(M+T^{\mathcal{N}_2})] = a_r \times \sum_{s\in\{r,b\}} \phi_s \times \frac{a_s}{a_r} \times u'(M_s+T_s^{\mathcal{N}_1})$$

and

$$\mathbf{E}[u'(M+T^{\mathcal{N}_2})] = a_b \times \sum_{s\in\{r,b\}} \phi_s \times \frac{a_s}{a_b} \times u'(M_s+T_s^{\mathcal{N}_1})$$

In particular, this implies

$$a_r \times \mathbf{E}[u'(M+T^{\mathcal{N}_1})] < \mathbf{E}[u'(M+T^{\mathcal{N}_2})] < a_b \times \mathbf{E}[u'(M+T^{\mathcal{N}_1})]$$

since $a_r \leq 1, a_b > 1$ and $\phi(r)$ as well as $\phi(b)$ are greater zero (assumption 1). Now, note that $a_r \times \mathbf{E}[u'(M+T^{\mathcal{N}_1})] < \mathbf{E}[u'(M+T^{\mathcal{N}_2})]$ is equivalent to

$$\frac{a_r}{\mathbf{E}[u'(M+T^{\mathcal{N}_2})]} < \frac{1}{\mathbf{E}[u'(M+T^{\mathcal{N}_2})]}.$$

Multiplying the last inequality with $u'(M_r+T_r^{\mathcal{N}_1})$ yields

$$\frac{u'(M_r+T_r^{\mathcal{N}_2})}{\mathbf{E}[u'(M+T^{\mathcal{N}_2})]} \leq \frac{u'(M_r+T_r^{\mathcal{N}_1})}{\mathbf{E}[u'(M+T^{\mathcal{N}_1})]}.$$

The latter, however, implies $q_r^{\mathcal{N}_2} \leq q_r^{\mathcal{N}_1}$. Going a similar way yields

$$\frac{u'(M_b+T_b^{\mathcal{N}_2})}{\mathbf{E}[u'(M+T^{\mathcal{N}_2})]} \geq \frac{u'(M_b+T_b^{\mathcal{N}_1})}{\mathbf{E}[u'(M+T^{\mathcal{N}_1})]}$$

and, thus, $q_b^{\mathcal{N}_2} \geq q_b^{\mathcal{N}_1}$.

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