# PARETO-IMPROVING BEQUEST TAXATION

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## Abstract

Altruistic parents may transfer resources to their offspring by providing education, and by leaving bequests. We show that in the presence of wage taxation, a small bequest tax may improve efficiency in an overlapping-generations framework with only intended bequests, by enhancing incentives of parents to invest in their children's education. This result holds even if the wage tax rate is held constant when introducing bequest taxation. We also calculate an optimal mix of wage and bequest taxes with alternative parameter combinations. In all cases, the optimal wage tax rate is clearly higher than the optimal bequest tax rate, but the latter is generally positive when the required government revenue in the economy is sufficiently high.


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# 1 Introduction

Conventional wisdom suggests that taxation of intended bequests gives rise to a typical equity-efficiency trade-off.[1] Whereas advocates emphasize the role of bequest taxation for redistributing wealth, opponents highlight potentially adverse effects on wealth accumulation. (See Gale and Slemrod, 2001, for a review of the debate, and an extensive discussion of estate taxation in the United States.) Especially in the United States, the debate on estate taxation has become ideologically charged. McCaffery (1999) equates estate taxation with grave robbery. A key element of the Bush tax reform was phasing out estate taxation by 2010, on the ground of its claimed detrimental effects on hard work, entrepreneurship, and capital accumulation (see Beach, 2003). On the other side of the debate, over 2,000 American millionaires or billionaires, including William H. Gates Sr. (the father of Bill Gates), George Soros, several members of the Rockefeller family and Ted Turner, have signed a petition to reform but not abolish estate tax. In their view, estate tax is not only the most progressive tax in the United States and an important source of revenue, but also an incentive to charitable giving.

This paper, by contrast, shows that taxation of intended bequests can be justified for pure efficiency reasons. We develop a three-period overlapping-generations model in which altruistic parents face a trade-off between investing in their children's education and leaving bequests. We start from a second-best world in which wage taxation distorts human capital investment. We show that, even if the wage tax rate is held constant, introducing a bequest tax can be Pareto-improving by enhancing incentives of parents to invest in their children's education.

More precisely, our analysis suggests that a positive bequest tax is called for on pure efficiency grounds when the positive effect of bequest taxation on human capital formation is sufficiently high to outweigh the negative effects from reduced wealth accumulation. It is generally not only optimal in the sense that it maximizes an objective

[1] In contrast, taxation of accidental bequests is usually thought of having lump-sum character. See, however, Blumkin and Sadka (2003) for an important modification of this result. They show that the optimal tax on accidental bequests is typically below 100 percent when labor supply is endogenous and there is wage taxation. In this paper, we exclusively focus on intended bequests.

function of a social planner, but even improves utility of all currently living and future generations. We also provide numerical results on the optimal tax structure which demonstrate that the relative weight between a linear tax on bequests and wage income depends positively on the extent of the distortion a wage tax causes on educational investments. The results also suggest that the wage tax rate should be considerably higher than the bequest tax rate, but the latter is generally positive when the required government revenue in the economy is sufficiently high.

Our results markedly differ from those in the previous literature, in which the interaction between bequest and labor income taxation has been analyzed without considering the decision of parents how to allocate resources to children between education and wealth transfer, thereby neglecting effects on human capital investment. Previous literature suggests that the case for taxing bequests is rather weak.[2] For instance, a strong case against bequest taxation comes from infinite-horizon, Ramsey-type models. As it is well-known, this kind of framework can be interpreted as a model of individuals with a Barro-type form of altruism (Barro, 1974) who live one period, so that bequest taxation coincides with capital taxation. Chamley (1986) shows that with an infinite-horizon, the disincentives to accumulate capital and the implied effects on the consumption stream are so strong that the optimal capital tax converges to zero, despite potential benefits from redistribution across heterogeneous agents.[3] Although the zero bequest taxation result is not necessarily valid under finite horizons, it is fair to conclude that a potential desirability of a positive bequest tax in the existing literature typically derives from the possibility of accidental bequests (Blumkin and Sadka, 2003), redistribution effects in heterogeneous agent models (e.g. Cremer and Pestieau, 2001)[4] or, as pointed out by Kopczuk (2001), from negative externalities arising from wealth inequality.[5]

[2] For an excellent survey of the existing literature on optimal bequest taxation under various motives to leave financial bequests, see Cremer and Pestiau (2003).

[3] See also Judd (1985). Whereas optimal taxation is typically examined under perfect competition, Judd (2002) reviews arguments which give rise to the conclusion that under imperfect goods market competition the optimal tax on capital is even negative.

[4] Cremer and Pestieau (2001) analyze the optimal tax schedule when parents have two children with different abilities, but ability is unobservable for the tax authority.

[5] As some authors point out, in principle, estate taxation can have even adverse effects on equality

An optimal mix between wage taxation and bequest taxation has recently been analyzed also by Michel and Pestieau (2004) who assume a "joy of giving" bequest motive. They show that second-best taxation of bequests critically hinges on capital accumulation. Our paper differs from Michel and Pestieau (2004) in various respects. First, we allow parents to transfer resources to their children also through education, while Michel and Pestieau (2004) assume that bequests are the only form of intergenerational transfers. Second, we assume that parents derive utility from the income children receive, rather than from resources they bequeath. Finally, we analyze whether introducing a bequest tax could generate a Pareto-improvement. Michel and Pestieau (2004) focus on the steady state.

We are by far not the first ones to analyze the interplay between bequests and investment in education by parents. Blinder (1976) studies intergenerational transfers and life cycle consumption and remarks that differential tax treatment of intergenerational transfers of human capital and bequests should have consequences on the mix of the two. Ishikawa (1975) analyzes household decisions concerning education and bequests in the absence of taxation. None of these previous contributions addresses our question, namely what are the welfare effects of bequest taxation when parents can invest in their children's education.

Finally, our results have certain similarities with those on capital income taxation in a non-dynastic framework.[6] Jacobs and Bovenberg (2005) analyze optimal linear taxes on capital and labor income with human capital investment and financial savings. They find that the positive tax on capital income serves to alleviate distortions arising from labor income taxation, similar to our result on bequest taxation. An important distinction, however, is that capital income taxation would distort the allocation of consumption over lifetime, while bequest taxes do not distort the allocation

(e.g. Becker, 1974; Tomes, 1981). This may arise when transfers are used by parents to offset inequalities within a family. In this case, estate taxation may mitigate the redistributive effect of wealth transfers which may occur within families. Empirical evidence, however, seems to refute the hypothesis that siblings with lower incomes receive larger inheritances (e.g., Wilhelm, 1996). Kleiber et al. (2005) show in an overlapping-generations model where the level of bequest enters parent's utility that redistributive bequest taxation is an effective tool to decrease wealth inequality.

[6] See Salanié (2003, ch. 6) for an excellent review of the literature on capital income taxation.

of individual consumption over lifetime, but may distort the allocation of resources between parents' own consumption and transfers to their children. Moreover, Jacobs and Bovenberg (2005) do not consider intergenerational transfers or altruism, which is the focus of this paper.

In the coming section, we present the basic structure of the model. In section 3, we analyze the equilibrium, particularly focusing on the question under which conditions bequest taxation leads to a Pareto-improvement. Section 4 provides numerical illustrations on the optimal (linear) tax structure. The last section concludes. All proofs are relegated to an appendix.

# 2 The Model

We consider a small open overlapping-generations economy with a public sector.

## 2.1 Production of Final Output

In every period, a single homogeneous consumption good is produced according to a neoclassical, constant-returns-to-scale production technology. Output at time $t$, $Y_t$, is

$$Y_t = F(K_t, H_t) \equiv H_t f(k_t), \quad k_t \equiv K_t/H_t, \tag{1}$$

where $K_t$ and $H_t$ are the amounts of physical capital and human capital employed in period $t$, respectively, the latter being measured in efficiency units. $f(\cdot)$ is a strictly monotonicly increasing and strictly concave function which fulfills $\lim_{k\to\infty} f'(k) = 0$ and $\lim_{k\to 0^+} f'(k) = \infty$.[7]

Output is sold to a perfectly competitive world market, with output price normalized to unity. The rate of return to capital, $r_t$, is internationally given and time-invariant, i.e., $r_t = \bar{r}$. That is, we analyze a small open economy framework with perfectly mobile capital.[8]

[7] The capital-skill complementarity underlying production function (1) is empirically well supported; see e.g. Goldin and Katz (1998).

[8] In a closed economy or a large open economy, changes in bequest taxes would also change the

Profit maximization of the representative firm in any period $t$ implies that $\bar{r} = f'(k_t)$. Thus, $k_t = (f')^{-1}(\bar{r}) \equiv \bar{k}$. The wage rate per efficiency unit of human capital, $w_t$, reads $w_t = f(\bar{k}) - \bar{k}f'(\bar{k}) \equiv \bar{w}$ and output is given by $Y_t = H_t f(\bar{k})$.

## 2.2 Individuals and Education Technology

In each period $t$, a unit mass of identical individuals (generation $t$) is born. An individual lives three periods. In the first period (childhood), individuals live by their parents and acquire education. In the second period (working age), individuals supply their human capital to the labor market, give birth to one child, invest in their children's human capital,[9] and save for old age. In their final period of life (retirement age), they allocate their income between consumption and transfers to their offspring, from now on labeled "bequests". For simplicity, suppose that the financial market is perfect and there is no human capital risk.

An individual born in period $t$ (a member of generation $t$) with parental investment $e_t$ (in units of the consumption good) in education acquires

$$h_{t+1} = h(e_t), \tag{2}$$

units of human capital in $t+1$, where $h(\cdot)$ is a strictly monotonicly increasing and strictly concave function which fulfills $\lim_{e\to\infty} h'(e) = 0$ and $\lim_{e\to 0^+} h'(e) = \infty$.[10] As individuals are identical and of unit mass, the aggregate human capital stock is given by $H_{t+1} = h_{t+1}$. Let $s_{t+1}$ denote the amount of savings of a member of generation $t$

interest rate, through their effects on aggregate savings. Such induced effects are, however, likely only of second-order importance. Moreover, the small open economy assumption allows our results to be applicable to the state level in the United States, as well as to the European countries. Even though most of the debate on bequest taxation in the United States has concerned federal estate taxes, the issue is important at the state level as well. U.S. states differ widely in their estate taxes. The U.S. federal estate tax has allowed a dollar-for-dollar credit for state inheritance taxes, effectively encouraging states to collect taxes at least at the same rate as the federal government (Minnesota House of Representatives Research Department, 2004).

[9] Human capital investments can be thought of as both nonschooling forms of training and private schooling.

[10] For a similar specification and a discussion of diminishing returns to human capital investment, see e.g. Galor and Moav (2004), among others.

for retirement. Initially, at $t = 1$, both savings of the currently old generation (born in $t = -1$), $s_0$, and the education level of the current middle-aged generation (born at $t = 0$), $e_0$, are given. (Hence, the initial stock of human capital, $H_1 = h(e_0)$ is given.)

Utility $U_t$ of a member of generation $t$ is defined over consumption levels $c_{2,t+1}$ and $c_{3,t+2}$ in the working and retirement age, respectively, and *disposable* income of the offspring (born in $t + 1$) in its working age, $I_{t+2}$.[11] Assuming additively separable utility, we have

$$U_t = u_2(c_{2,t+1}) + \beta V(c_{3,t+2}, I_{t+2}), \tag{3}$$

$$V(c_{3,t+2}, I_{t+2}) = u_3(c_{3,t+2}) + v(I_{t+2}), \tag{4}$$

where $u_2(\cdot)$, $u_3(\cdot)$ and $v(\cdot)$ are strictly monotonic increasing and strictly concave functions, and $\beta \in (0, 1)$ is a discount factor. The altruism motive reflects the notion that parents care about the economic situation of their offspring. It may be called "joy-of-children-receiving-income", in contrast to the often assumed "joy-of-giving" motive, in which the bequeathed amount of resources enters utility.[12] Assuming the former rather than the latter seems more plausible in the present context, in which parents also finance the human capital investment of children. By contrast, joy of giving with respect to education finance would imply that parents value education per se, rather than as a means to earn income. Our "joy-of-children-receiving-income" motivation is linked to Gradstein and Justman (1997), who assume that parents care about the earnings capacity of children. However, in their model gross rather than net income of children enters parents' utility and parents do not leave financial bequests. Moreover, our bequest motive is related to Blinder (1976) and Carroll (2000), who assume that the after-tax bequest enters parents' utility function.

[11] At the cost of some notational complexity, we could introduce either an exogenous consumption for children, or assume that the utility function of the middle-aged parents would have the family consumption as its argument, this being optimally allocated between the parent and the child.

[12] The "dynastic" altruism motive suggested by Barro (1974) in which parents care about the well-being of their offspring (thus an individual acts as if it would be infinitively-living) has been dismissed on empirical grounds (Wilhelm, 1996; Altonji, Hayashi, and Kotlikoff, 1997). For an important early contribution on giving with impure altruism, see Andreoni (1989) in which people obtain utility ("warm glow") from giving itself.

## 2.3 Public Sector

Following the optimal taxation literature, we ask how the government should finance a given level of expenditure $\bar{G} \geq 0$. For this purpose, it may levy a proportional tax on wage income, with tax rate $\tau_w$, or a proportional tax on bequests, with tax rate $\tau_b$. For simplicity, suppose there are no other taxes.[13] Tax revenue in any period which exceeds the revenue requirement $\bar{G}$ is paid out lump-sum to middle-aged individuals. Thus, public transfers are received in the same period of life in which taxes are paid and the government budget is balanced each period.

# 3 Equilibrium Analysis

This section analyzes the equilibrium for given tax rates. First, individual decisions are studied. Second, we examine the evolution of the level of human capital investment and the level of bequests. Third, and most important, we analyze the impact of bequest taxation on individual utility. In particular, we ask: Can bequest taxation improve efficiency, i.e., raise welfare of all generations from the time when a bequest tax is introduced onwards?

## 3.1 Individual Decisions

Let $T_{t+1}$ and $b_{t+1}$ denote a possible lump-sum transfer from the government and the pre-tax bequest received by a member of generation $t$ in her working age (i.e. in $t+1$), respectively. Thus, disposable income of a member of generation $t$ at date $t+1$ is given by

$$I_{t+1} = (1-\tau_w)\bar{w}h(e_t) + (1-\tau_b)b_{t+1} + T_{t+1} \tag{5}$$

and the government budget constraint in period $t+1$ is

$$\tau_w \bar{w}h(e_t) + \tau_b b_{t+1} = \bar{G} + T_{t+1}. \tag{6}$$

[13] Labor income taxation is the main source of government revenue in all advanced countries, so that interactions between wage and bequest taxation are the most interesting ones. See, however, section 4 for a discussion of the additional role of education subsidies in our framework.

Individual budget constraints at date $t+1$ and $t+2$ are given by

$$c_{2,t+1} + s_{t+1} + e_{t+1} = I_{t+1}, \tag{7}$$

$$c_{3,t+2} + b_{t+2} = (1+\bar{r})s_{t+1}, \tag{8}$$

where $s_{t+1}$ denotes working-life savings for retirement. Lump-sum transfers from the public sector to children are taken as given by parents when optimizing. Throughout the paper, we focus on interior solutions of the utility maximization problem in each period. Using (3)-(8), it is straightforward to show that a member of generation $t$ in $t+1$ (with income $I_{t+1}$) chooses savings for her old age ($s_{t+1}$), educational investment for her child ($e_{t+1}$) in her working age and bequests in retirement age ($b_{t+2}$) according to first-order conditions

$$\frac{u_2'(c_{2,t+1})}{\beta u_3'(c_{3,t+2})} = 1+\bar{r}, \tag{9}$$

$$\frac{u_2'(c_{2,t+1})}{\beta v'(I_{t+2})} = (1-\tau_w)\bar{w}h'(e_{t+1}), \tag{10}$$

and

$$\frac{u_3'(c_{3,t+2})}{v'(I_{t+2})} = 1-\tau_b, \tag{11}$$

respectively. Optimality condition (9) is standard: the marginal rate of substitution between present and future consumption is equal to the interest rate factor. According to (10), the marginal rate of substitution between present consumption and children's income equals the marginal (net) return of children to human capital investment, whereas (11) says that the marginal rate of substitution between future consumption and (future) bequests equals the net receiving of children per unit of bequests, $1-\tau_b$.

For later use, note that parental decisions imply that a member of generation $t$ receives income

$$I_{t+1} = \bar{w}h(e_t) + b_{t+1} - \bar{G} \tag{12}$$

in $t+1$, according to (5) and (6).[14]

[14] Note that combining (8), (11) and (12) implies $u_3'((1+\bar{r})s_0 - b_1) = (1-\tau_b)v'(\bar{w}h(e_0) + b_1 - \bar{G})$, i.e., bequest $b_1$ left by members of the initially old generation is determined by initial conditions:

## 3.2 Educational Investments

We first look at educational investments. By combining (9)-(11) and observing $h''(\cdot) < 0$, it is easy to see that the following results hold.

**Proposition 1.** (Education.) *For any $t \geq 1$, human capital investment, $e_t \equiv e^*(\tau_b, \tau_w)$, is time-invariant, unique, and implicitly given by*

$$(1 - \tau_w)\bar{w}h'(e^*) = (1 - \tau_b)(1 + \bar{r}). \tag{13}$$

**Corollary 1.** *Educational investment $e^*$ and thus, for all $t \geq 1$ equilibrium output, $Y_{t+1} = h(e^*)f(\bar{k}) \equiv Y^*$, are increasing in $\tau_b$ and decreasing in $\tau_w$.*

According to Proposition 1, the optimal educational investment, $e^*$, is reached when the marginal after-tax return to education equals the after-tax return on one unit of bequest when invested in the financial market. An important implication of this is that $e^*$ and thus the gross domestic product, $Y^*$, is increasing in the degree of bequest taxation (Corollary 1). This is because an increase in $\tau_b$ induces parents, who care about net income of their offspring, to substitute away from financial transfers (in retirement age) and invest more in children's education (in working age). This result is novel in the literature on bequest taxation. The other result – that higher earnings taxation (i.e., an increase in $\tau_w$) reduces incentives to invest in education – is standard and straightforward.

## 3.3 Bequest Taxation and Efficiency

We now turn to the question whether bequest taxation can lead to a Pareto-improvement. The wage tax rate $\tau_w$ is kept constant throughout the analysis, and the lump-sum transfer adjusts to balance the government budget when $\tau_b$ is changed. Note that this is a rather demanding test for the desirability of a bequest tax. In a first-best world, levying a distortionary tax (like the bequest tax considered here) and redistributing

investment $e_0$ in their offspring's education and savings $s_0$ in their working age.

its revenue in a lump-sum fashion obviously lowers efficiency. In the remainder of this section, we consider a small tax on bequests levied from period 2 onwards which is announced in period 1. We find (as proven, like all subsequent formal results, in the appendix)

**Lemma 1.** *By levying a small bequest tax from period 2 onwards, (i) the currently middle-aged generation unambiguously gains (is unaffected) if* $\tau_w > (=) 0$*, and (ii) a Pareto-improvement occurs if and only if*

$$\frac{1+\bar{r}+\tau_w}{1-\tau_w}\left.\frac{\partial e^*}{\partial \tau_b}\right|_{\tau_b=0}+\left.\frac{\partial b_{t+1}}{\partial \tau_b}\right|_{\tau_b=0}\geq 0 \qquad (14)$$

*for* $t \geq 1$.

For the initially middle-aged generation, income ($I_1$) is not affected by the bequest tax from period 2 onwards. (Consequently, also utility of the initially old generation is unaffected.) The increase in utility of members of the initially middle-aged generation (when $\tau_w > 0$), stated in part (i) of Lemma 1, is due to the positive impact of an introduction of a small bequest tax $\tau_b$ on human capital investment (Corollary 1), which positively affects their offspring's income. Regarding the generations born *after* the initially middle-aged, two potentially counteracting effects are relevant. The first one is again the unambiguously positive impact of $\tau_b$ on $e^*(\tau_b, \tau_w)$, according to Corollary 1. However, the effect on welfare also depends on how the bequests received from parents are affected. Thus, if the amount of intergenerational transfers declines, utility may decline after introducing bequest taxation despite the positive effect from an increase in human capital investments. Hence, a priori, it is not clear whether bequest taxes can improve efficiency. The positive impact of bequest taxation on human capital formation has to be weighted against the potential reduction in bequests.

As general conclusions are difficult to obtain, we attempt to gain insight into this issue from an example which allows explicit analytical solutions. From now on we consider utility specifications

$$u_2(c) = u_3(c) = \ln c \quad \text{and} \quad v(I) = \ln(I - \chi), \tag{15}$$

where $\chi > 0$ may be interpreted as "subsistence income" of children from the perspective of parents. It is a measure of the strength of the bequest motive. To simplify further, let us also employ the standard specification

$$\beta(1 + \bar{r}) = 1. \tag{16}$$

Moreover, let us define

$$\Gamma^*(\tau_b, \tau_w) \equiv (1 + \beta)\chi - (\beta + \tau_b)\left(\bar{w}h(e^*(\tau_b, \tau_w)) - \bar{G}\right) - (1 - \tau_b)e^*(\tau_b, \tau_w), \tag{17}$$

$$\Gamma_0(\tau_b, \tau_w) \equiv (1+\beta)\chi+(\beta+\tau_b)\bar{G}-(1+\beta)\bar{w}h(e^*(\tau_b, \tau_w))+(1-\tau_b)\left[\bar{w}h(e_0) - e^*(\tau_b, \tau_w)\right]. \tag{18}$$

Note that both expressions are positive if $\chi$ is sufficiently large, which is presumed for the next result.

**Lemma 2.** *Under specifications (15) and (16), if $\Gamma^* > 0$ and $\Gamma_0 > 0$, then the evolution of bequests is characterized by*

$$b_2 = \frac{\Gamma_0(\tau_b, \tau_w)}{1 + \beta + \beta(1 - \tau_b)} + c(\tau_b)b_1 \equiv B_0(b_1; \tau_b, \tau_w) \tag{19}$$

*and, for $t \geq 1$,*

$$b_{t+2} = \frac{\Gamma^*(\tau_b, \tau_w)}{1 + \beta + \beta(1 - \tau_b)} + c(\tau_b)b_{t+1} \equiv B^*(b_{t+1}; \tau_b, \tau_w), \tag{20}$$

*where*

$$c(\tau_b) \equiv \frac{1 - \tau_b}{1 + \beta + \beta(1 - \tau_b)} < 1. \tag{21}$$

*Thus, intergenerational transfers converge to steady state level*

$$b^*(\tau_b, \tau_w) \equiv \frac{\Gamma^*(\tau_b, \tau_w)}{2\beta + \tau_b(1-\beta)} > 0. \tag{22}$$

The presumptions in Lemma 2 thus imply that a unique and stable steady state with a positive amount of bequest exists. In order to examine the dynamic process and the welfare implications of introducing a bequest tax, we suppose that the economy is initially in a steady state with no bequest taxation ($\tau_b = 0$) and balanced government budget with zero lump-sum transfers ($T = 0$). That is, defining revenue from wage income taxation as $R_w(\tau_b, \tau_w) \equiv \tau_w \bar{w} h(e^*(\tau_b, \tau_w)$, we set the wage tax rate at $\tau_w = \tau_w^0$ as given by $R_w(0, \tau_w^0) = \bar{G}$; moreover, initial conditions $e_0 = e^*(0, \tau_w^0)$ and $b_1 = b^*(0, \tau_w^0)$. The next result implies that to establish a Pareto-improvement we only need to check whether the introduction of a bequest tax in $t = 1$ benefits the initially young generation (i.e., raises $U_1$) and the steady state generation (i.e., raises $U_t$ as $t \to \infty$).

**Lemma 3.** *Suppose $e_0 = e^*(0, \tau_w^0)$ and $b_1 = b^*(0, \tau_w^0)$. Under the presumptions of Lemma 2, announcing in period $t = 1$ that a small tax is levied on bequests from period 2 onwards raises efficiency if condition (14) holds for both $t = 1$ and $t \to \infty$.*

Recall from Lemma 1 that a Pareto-improvement is obtained when the amount of bequest is not reduced too much in response to the introduction of the bequest tax from period 2 onwards. Fig. 1 shows the evolution of bequests *after* introduction of the bequest tax. Let $\hat{b}$ be the level of bequest such that, when starting at $\hat{b}$ in period 1, bequests immediately jump to the steady state level $b^*$ in period 2. If $b_1 < \hat{b}$, the amount of bequests increases over time from period 2 onwards. Thus, if the generation which is middle-aged when the bequest tax is introduced does not reduce bequests $b_2$ too much, so that generation 1 is made better off, all generations are made better off. That is, if condition (14) holds for $t = 1$, it holds for all $t > 1$ as well. In contrast, if $b_1 > \hat{b}$, bequests decrease over time from period 2 onwards, eventually reaching steady state value $b^*$ (point A in Fig. 1). Thus, if $b^*$ is not reduced too much by the bequest

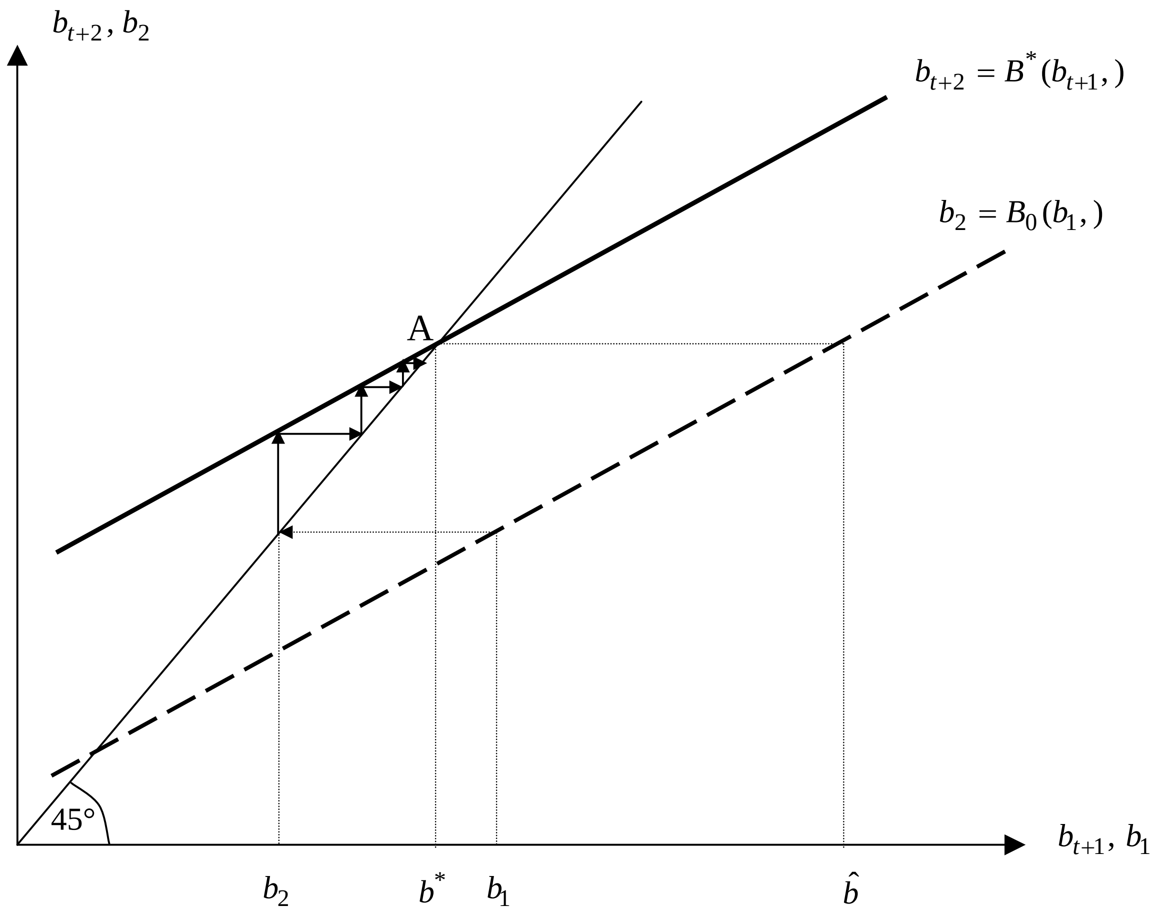


**Figure 1:** The evolution of bequests, illustrated for the case $b^* < b_1 < \hat{b}$ .

tax, also bequests during the transition to the steady state will decline sufficiently little so to leave every generation better off.

To obtain explicit characterizations in what follows, we further specify

$$h(e) = e^{1/2}. \tag{23}$$

Then (13) and (16) imply that

$$e^*(\tau_b, \tau_w) = \frac{1}{4}\left[\frac{\beta(1-\tau_w)\bar{w}}{1-\tau_b}\right]^2. \tag{24}$$

**Lemma 4.** *Under specifications (15), (16) and (23).*
*(i)* $\partial R_w / \partial \tau_w > (=, <) 0$ *if and only if* $\tau_w < (=, >) 0.5$.
*(ii)* $b^*(0, \tau_w^0) > 0$ *if and only if* $e^*(0, \tau_w^0) < (1+\beta)\chi/3 \equiv \bar{e}(\beta, \chi)$.
*(iii) For both* $t = 1$ *and* $t \to \infty$, $\partial b_{t+1}/\partial \tau_b|_{\tau_b = 0} < 0$.

Part (i) of Lemma 4 shows that a Laffer effect with respect to labor income taxation does not occur if tax rate $\tau_w$ is sufficiently small. Part (ii) of Lemma 4 implies that steady state bequests in absence of bequest taxation, $b^*(0, \tau_w^0)$ are positive if the bequest motive, measured by $\chi$, is sufficiently strong. Finally, part (iii) implies that intergenerational transfers decline in all periods after introduction of a small bequest tax.

We are now ready to study under which circumstances the introduction of a bequest tax, despite its negative effect on the level of bequests, raises efficiency.

**Proposition 2.** *Suppose* $e_0 = e^*(0, \tau_w^0) < \bar{e}(\beta, \chi)$ *and* $b_1 = b^*(0, \tau_w^0)$. *Under specifications (15), (16) and (23), levying a small bequest tax improves welfare of each generation if* $\tau_w^0 > \bar{\tau}_w(\beta)$ *and* $e_0 \geq \underline{e}(\tau_w^0, \beta, \chi)$, *where*

$$\bar{\tau}_w(\beta) \equiv \frac{2-\beta}{2+\beta(4\beta+1)}, \tag{25}$$

*with* $\bar{\tau}_w(\beta) \in (0, 1)$, *and*

$$\underline{e}(\tau_w^0, \beta, \chi) \equiv \frac{(1-\tau_w^0)(1-\beta)(1+\beta)\chi}{\tau_w^0\left(1+5\beta+8\beta^2\right)-1-\beta}, \tag{26}$$

*with* $\underline{e}(\tau_w^0, \beta, \chi) \in (0, \bar{e}(\beta, \chi))$.

According to Proposition 2, if the initial wage tax rate is sufficiently high ($\tau_w^0 > \bar{\tau}_w(\beta)$), i.e., the human capital investment decision is severely distorted by labor income taxation, a bequest tax may be efficiency-enhancing even if not used to lower the wage tax. (For instance, if $\beta = 0.9$, as used in the numerical analysis of the optimal tax structure in the next section, we have $\bar{\tau}_w(\beta) \approx 0.18$.) In this case, the incentive to raise educational investment may dominate the effect from a reduction in the amount of bequests on utility. Under the specifications of functional forms considered in Proposition 2, efficiency and welfare are indeed raised if, in addition to $\tau_w^0 > \bar{\tau}_w(\beta)$, incentives to invest in education (and thus $e_0 = e^*(0, \tau_w^0)$) are sufficiently high[15] (but low enough to induce positive bequests in the initial steady state; see Lemma 4 (ii)).

# 4 Optimal Tax Structure

In the previous section, we proved that introducing a small bequest tax may raise efficiency, even if the wage tax rate is kept constant. In this section, we analyze what would be an optimally chosen combination of wage and bequest taxation, with a given government revenue requirement. To abstract from transition issues, we focus on maximizing the utility of steady-state generations,[16] assuming that the government budget is balanced in each period.

According to (3), (4), (12), (7) and (8), the social planner's optimization problem

[15] This is ensured if the wage rate $\bar{w}$ is sufficiently high, i.e., the economy is technologically advanced. To see this, recall $e^*(0, \tau_w) = \left[\beta(1-\tau_w)\bar{w}\right]^2/4$ and note that $\underline{e}$ as given in (26) is independent of $\bar{w}$.

[16] As shown in the proof of Proposition 2, introducing a small bequest tax leads to a Pareto improvement if it benefits the steady state generation. This suggests that all generations are made better off under the optimal tax mix for steady state generations, compared to a situation where there is only wage taxation.

is then given by

$$\max_{\tau_b,\tau_w} \left\{u_2(\bar{w}h(e^*) + b^* - \bar{G} - s^* - e^*) + \beta u_3((1+\bar{r})s^* - b^*) + \beta v(\bar{w}h(e^*) + b^* - \bar{G})\right\} \tag{27}$$

$$\text{s.t. } \tau_w \bar{w}h(e^*) + \tau_b b^* = \bar{G}. \tag{28}$$

Tab. 1 shows numerical results for the optimal tax rates, denoted $\tau_w^{opt}$, $\tau_b^{opt}$, for different government expenditures with an assumption that $\bar{w} = 1$ and $\beta = 0.9$, for varying levels of $\chi$ and $\bar{G}$.

| $\chi$ | $\bar{G}$ | $\tau_w^0$ | $\tau_w^{opt}$ | $\tau_b^{opt}$ | $\frac{b^*(0,\tau_w^0)}{\bar{w}h(e^*(0,\tau_w^0))}$ | $\frac{b^*(\tau_b^{opt},\tau_w^{opt})}{\bar{w}h(e^*(\tau_b^{opt},\tau_w^{opt}))}$ |
|---|---|---|---|---|---|---|
| 0.4 | 0 | 0 | 0.048 | -0.112 | 0.188 | 0.423 |
| 0.4 | 0.02 | 0.047 | 0.079 | -0.065 | 0.269 | 0.416 |
| 0.4 | 0.04 | 0.099 | 0.109 | -0.019 | 0.365 | 0.412 |
| 0.4 | 0.06 | 0.158 | 0.140 | 0.027 | 0.484 | 0.409 |
| 0.4 | 0.08 | 0.231 | 0.170 | 0.071 | 0.644 | 0.408 |
| 0.4 | 0.10 | 0.333 | 0.199 | 0.115 | 0.907 | 0.409 |
| 0.5 | 0 | 0 | 0.056 | -0.084 | 0.423 | 0.660 |
| 0.5 | 0.02 | 0.047 | 0.081 | -0.046 | 0.515 | 0.656 |
| 0.5 | 0.04 | 0.099 | 0.106 | -0.008 | 0.625 | 0.653 |
| 0.5 | 0.06 | 0.158 | 0.130 | 0.029 | 0.762 | 0.652 |
| 0.5 | 0.08 | 0.231 | 0.154 | 0.065 | 0.949 | 0.652 |
| 0.5 | 0.10 | 0.333 | 0.178 | 0.100 | 1.259 | 0.654 |

**Table 1.** Optimal tax rates

Our numerical results suggest certain general patterns. First of all, the optimal bequest tax rate is generally positive when government revenue requirement, $\bar{G}$, is sufficiently high. This is consistent with the intuition of Proposition 2: Using bequest taxes can raise efficiency when an excessive use of a wage tax would be too distorting. With a low revenue requirement, however, it is optimal to moderately tax wages and use tax revenue to subsidize bequests. Moreover, also when $\bar{G}$ is high, the optimal bequest tax rate is significantly lower than the wage tax rate. The intuition for these results is the following. Investment in human capital exhibits decreasing returns to scale, while financial markets provide constant returns to scale. At the same time as taxing wages reduces investment in human capital, it also increases the rate of return to marginal investment. This partly counteracts the distortion created by the tax wedge. When the government chooses tax rates to balance marginal distortions from collecting any given revenue, it is optimal to distort human capital investment relatively more. For the same reason, when $\bar{G}$ is low, taxing the return to education and subsidizing bequests may improve the welfare of the steady-state generations by encouraging parents to transfer in aggregate more resources to their children. Also note that optimal tax rates are non-zero even in the case where $\bar{G} = 0$. This result arises because parents care about children's income rather than taking into account the impact of intergenerational transfers on their offspring's utility (unlike in dynastic altruism models which follow Barro, 1974).

Second, an increase in public expenditures $\bar{G}$ results in an increase in both tax rates $\tau_b^{opt}$ and $\tau_w^{opt}$ as well as in the ratio between the bequest tax rate and the wage tax rate, $\tau_b^{opt}/\tau_w^{opt}$ (that is, optimal bequest tax rate increases faster than the optimal wage tax rate). With a zero revenue requirement, this ratio is negative, then increasing and approaching unity as $\bar{G}$ increases.

In the last two columns of Tab. 1, we also report the size of bequests relative to the wage income that children receive over their working period, both in the initial situation (without bequest tax) and under the optimal tax mix. The relative size of bequests is increasing in the strength of parents' motive to transfer resources to their children, measured by parameter $\chi$. (Recall that $b^*$ is increasing in $\chi$, whereas $e^*$ is independent of $\chi$.) In the absence of bequest taxation, increasing the wage tax rate results in parents transferring relatively more resources through bequests. In the examples we report, in the absence of bequest taxes, the size of bequests varies between 19 and 91 percent of the lifetime wage income with $\chi = 0.4$, and between 42 and 126 percent with $\chi = 0.5$. When the bequest tax rate is set optimally, the range is 41 to 42 percent with $\chi = 0.4$ and 65 to 66 percent with $\chi = 0.5$. This suggests that optimal taxation stabilizes the composition of intergenerational transfers when the general level of public expenditures changes.

So far, we have abstracted from the instrument of education subsidies for stimulating educational investment. Partly, this may be justified because human capital investments are often unobservable to tax authorities, in a similar manner as the optimal tax literature typically posits that work effort is not observable.[17] Nevertheless, one may ask if the potentially beneficial role of using bequest taxes suggested by our preceding analysis still holds when education subsidies are feasible. For this purpose, suppose each unit of investment in education, $e$, is subsidized by a constant rate $\tau_e$. A numerical analysis of this extended model with optimally chosen education subsidies, focusing again on the steady state, suggests that education should indeed be subsidized, at a rate of similar magnitude as the optimal wage tax rate (results not shown).[18] Importantly, however, the main insight from Tab. 1, that bequests should be subsidized with a low government requirement $\bar{G}$ and taxed for a high level of $\bar{G}$, is unaffected. Thus, the qualitative results on the optimality of taxing bequests with a large public sector hold even when education subsidies are available.

# 5 Conclusion

Altruistic parents may transfer resources to their offspring by providing education and by leaving bequests. Parental altruism is often seen as an argument against bequest taxation, the reason being that bequest taxation would distort the accumulation of capital intergenerationally in the same way as capital income taxation would distort consumption profile and savings over the individual life cycle. In this paper we show that this intuition needs no longer hold true in the presence of education and wage

[17] Trostel (1993) estimates that about a quarter of the costs of education are non-verifiable, even when abstracting from any effort costs. In their paper on human capital investment and capital income taxation, Jacobs and Bovenberg (2005) find that taxing capital income is optimal with subsidies to human capital investment when at least a share of these investments is non-verifiable.

[18] Numerical results are provided in supplementary material which is available from the authors upon request.

taxation. Wage taxes reduce the rate of return that children receive on parental investments in education. This induces parents, who value the after-tax resources that their children receive, to reduce investment in education, and leave bequests instead. We show that a small bequest tax may improve efficiency in an overlapping-generations framework with only intended bequests, even when the labor income tax remains unchanged. This is because the bequest tax may mitigate the distortion of educational investment caused by wage taxation.

In addition to deriving a general criterion for the desirability of a small bequest tax when the wage tax rate is left unchanged, we also analyze what would be an optimal mix of wage taxes and bequest taxes with given government revenue requirement. Certain clear patterns emerge. First of all, the optimal bequest tax is generally positive when the government revenue requirement is sufficiently high, although always lower than the wage tax rate. Moreover, our analysis suggests that, when the government revenue requirement increases, the ratio between the bequest tax and the wage tax should increase.

Our results have certain surprising implications for the U.S. debate on estate taxation. Currently, descendants of only 2 percent of Americans who die pay estate taxes. Even proponents of the estate tax are willing to raise the exempted amount further. We find that this policy, while popular, need not be optimal. It might well be optimal to tax also smaller bequest, possibly at a relatively low rate, and use the tax revenue to lower wage taxes. Such policy would boost the incentives of altruistic parents among the currently exempted 98 percent of population to transfer resources to their children more through education. Taken seriously, such policy advice would suggest, paraphrasing Mark Twain, that the rumors of the imminent demise of the death tax are greatly exaggerated.

# Appendix

**Proof of Lemma 1.** Part (i) is proven first. Note that the currently middle-aged generation is born in $t = 0$. Also note from (12) that their income, $I_1$, is initially given, as $e_0$ and $b_1$ (the latter depending on both $e_0$ and $s_0$) are given. Observing $e_1 = e^*$, we have

$$U_0 = u_2(I_1 - s_1 - e^*) + \beta u_3((1+\bar{r})s_1 - b_2) + \beta v(\bar{w}h(e^*) + b_2 - \bar{G}), \tag{A.1}$$

according to (3), (4), (12), (7) and (8). Differentiating with respect to $\tau_b$, using (by applying the envelope theorem) both $u_2'(c_{2,1}) = (1+\bar{r})\beta u_3'(c_{3,2})$ and $v'(I_2) = u_3'(c_{3,2})/(1-\tau_b)$, according to (9) and (11), and, finally, using $\bar{w}h'(e^*)/(1-\tau_b) = (1+\bar{r})/(1-\tau_w)$, according to (13), leads to

$$\frac{\partial U_0}{\partial \tau_b} = \beta u_3'(c_{3,2}) \left[ (1+\bar{r}) \frac{\tau_w}{1-\tau_w} \frac{\partial e^*}{\partial \tau_b} + \frac{\tau_b}{1-\tau_b} \frac{\partial b_2}{\partial \tau_b} \right]. \tag{A.2}$$

Thus, $\partial U_0 / \partial \tau_b|_{\tau_b = 0} > (=)0$ if $\tau_w > (=)0$, according to Corollary 1. This confirms part (i).

We now turn to part (ii). Utility of generation $t \geq 1$ is

$$U_t = u_2(\bar{w}h(e_t) + b_{t+1} - \bar{G} - s_{t+1} - e_{t+1}) + \beta u_3((1+\bar{r})s_{t+1} - b_{t+2}) + \beta v(\bar{w}h(e_{t+1}) + b_{t+2} - \bar{G}). \tag{A.3}$$

Taking into account that $e_{t+1} = e^*$ for all $t \geq 0$ stays the same, differentiating and using first-order condition (10) w.r.t. $s_{t+1}$ gives

$$\frac{\partial U_t}{\partial \tau_b} = u_2' \bar{w} h' \frac{\partial e^*}{\partial \tau_b} + u_2' \frac{\partial b_{t+1}}{\partial \tau_b} - u_2' \frac{\partial e^*}{\partial \tau_b} - \beta u_3' \frac{\partial b_{t+2}}{\partial \tau_b} + \beta v' \bar{w} h' \frac{\partial e^*}{\partial \tau_b} + \beta v' \frac{\partial b_{t+2}}{\partial \tau_b}. \tag{A.4}$$

As before, this simplifies as

$$\begin{aligned} \frac{\partial U_t}{\partial \tau_b} &= (1+\bar{r})\beta u_3' \bar{w} h' \frac{\partial e^*}{\partial \tau_b} + (1+\bar{r})\beta u_3' \frac{\partial b_{t+1}}{\partial \tau_b} - (1+\bar{r})\beta u_3' \frac{\partial e^*}{\partial \tau_b} \\ &\quad - \beta u_3' \frac{\partial b_{t+2}}{\partial \tau_b} + \beta \frac{u_3'}{1-\tau_b} \bar{w} h' \frac{\partial e^*}{\partial \tau_b} + \beta \frac{u_3'}{1-\tau_b} \frac{\partial b_{t+2}}{\partial \tau_b}. \end{aligned} \tag{A.5}$$

We obtain condition (14) by using (13), factoring out $\beta u_3'(1+\bar{r})$ and evaluating at $\tau_b = 0$. ■

**Proof of Lemma 2.** Substituting $c_{2,t+1} = I_{t+1} - s_{t+1} - e_{t+1}$ and $c_{3,t+2} = (1 + \bar{r})s_{t+1} - b_{t+2}$ from (7) and (8), respectively, into (9), and using $u_2(c) = u_3(c) = \ln c$, leads to

$$s_{t+1} = \frac{\beta(1+\bar{r})\left(I_{t+1} - e_{t+1}\right) + b_{t+2}}{(1+\bar{r})(1+\beta)} \tag{A.6}$$

for all $t \geq 0$. Moreover, substituting $c_{3,t+2} = (1+\bar{r})s_{t+1} - b_{t+2}$ from (8) into (11), and using $u_3(c) = \ln c$ and $v(I) = \ln(I - \chi)$ yields $I_{t+2} - \chi = (1 - \tau_b)\left[(1+\bar{r})s_{t+1} - b_{t+2}\right]$. Substituting (12) and (A.6) into this expression and using both $e_{t+1} = e^*$ for $t \geq 0$ and $\beta(1+\bar{r}) = 1$ from specification (16) implies that bequests evolve over time according to (19) and (20). As $c(\tau_b) < 1$, the dynamic process governing the evolution of bequests is stable. Finally, setting $b_{t+1} = b_{t+2} \equiv b^*$ in (20), observing (21) and solving for $b^*$ gives us (22). This concludes the proof. ■

**Proof of Lemma 3.** If $\tau_b > 0$, then $e_0 < e^*(\tau_b, \tau_w^0)$, according to Corollary 1. Consequently, we have $\Gamma_0(\tau_b, \tau_w) < \Gamma^*(\tau_b, \tau_w)$, according to (17) and (18), and thus, $B_0(b; \cdot) < B^*(b; \cdot)$, according to (19) and (20). Fig. 1 depicts $b_2 = B_0(b_1; \cdot)$ as dashed line and $b_{t+2} = B^*(b_{t+1}; \cdot)$ as solid line for $\tau_b > 0$. The steady state level of bequest with $\tau_b > 0$, $b^*$, is given by point A. Let $\hat{b}$ be given by $B_0(\hat{b}; \cdot) = b^*$. Now if $b_1 < \hat{b}$ as in Fig. 1, then $b_2 < b^*$ and, for all $t \geq 1$, $b_{t+2}$ increases over time to $b^*$. In this case, if condition (14) holds for $t = 1$, it also holds for all $t > 1$. If $b_1 = \hat{b}$, then $b_2 = b_{t+2} = b^*$ for all $t \geq 1$. Finally, if $b_1 > \hat{b}$, then $b_2 > b^*$ and, for all $t \geq 1$, $b_{t+2}$ decreases over time to $b^*$. In this case, if condition (14) holds for $t \to \infty$ (i.e., for $b_{t+1} = b^*$), it also holds for all $t \geq 1$. This concludes the proof. ■

**Proof of Lemma 4.** Part (i) is confirmed by substituting (24) into $R_w = \tau_w \bar{w}\left(e^*\right)^{1/2}$. To prove part (ii), note that

$$b^*(0, \tau_w^0) = \frac{(1+\beta)\chi - \beta(1-\tau_w^0)\bar{w}h(e^*(0,\tau_w^0)) - e^*(0,\tau_w^0)}{2\beta}, \tag{A.7}$$

according to (17), (22) and (by definition of $\tau_w^0$) $\bar{w}h(e^*(0,\tau_w^0)) - \bar{G} = (1-\tau_w^0)\bar{w}h(e^*(0,\tau_w^0))$. Using $h(e) = e^{1/2}$ and substituting $e^*(0,\tau_w) = \left[\beta(1-\tau_w)\bar{w}\right]^2/4$ from (24) into (A.7) leads to

$$b^*(0,\tau_w^0) = \frac{(1+\beta)\chi - 3e^*(0,\tau_w^0)}{2\beta} \tag{A.8}$$

which confirms part (ii). Regarding part (iii), take partial derivatives of (22) and (19) with respect to $\tau_b$, by using (17) and (18), respectively. By evaluating the resulting expressions at $(\tau_b, \tau_w) = (0, \tau_w^0)$ and noting that

$$\left.\frac{\partial e^*(\tau_b,\tau_w)}{\partial \tau_b}\right|_{\tau_b=0} = 2e^*(0,\tau_w), \tag{A.9}$$

according to (24), we obtain

$$\left.\frac{\partial b^*(\tau_b,\tau_w^0)}{\partial \tau_b}\right|_{\tau_b=0} = -\frac{(1-\tau_w^0)\bar{w}h(e^*(0,\tau_w^0)) + \left(2\frac{2-\tau_w^0}{1-\tau_w^0} - 1\right)e^*(0,\tau_w^0) + (1-\beta)b^*(0,\tau_w^0)}{2\beta} \tag{A.10}$$

and

$$\left.\frac{\partial B_0(b_1;\tau_b,\tau_w^0)}{\partial \tau_b}\right|_{\tau_b=0} = -\frac{(1-\tau_w^0)\bar{w}h(e^*(0,\tau_w^0)) + \left(2\frac{1+\beta(2-\tau_w^0)}{\beta(1-\tau_w^0)} - 1\right)e^*(0,\tau_w^0) + (1-\beta)b_1}{1+2\beta}. \tag{A.11}$$

Both derivatives are negative. This concludes the proof. ■

**Proof of Proposition 2.**[19] First, note that $e_0 < \bar{e}(\beta,\chi)$ implies $b_1 > 0$, according to part (ii) of Lemma 4. According to Lemma 3 and the presumptions of Proposition 2, a Pareto-improvement is reached if

$$\Omega^* \equiv \frac{\frac{1}{\beta} + \tau_w^0}{1-\tau_w^0}\left.\frac{\partial e^*(\tau_b,\tau_w^0)}{\partial \tau_b}\right|_{\tau_b=0} + \left.\frac{\partial b^*(\tau_b,\tau_w^0)}{\partial \tau_b}\right|_{\tau_b=0} \geq 0 \tag{A.12}$$

and

$$\Omega_0 \equiv \frac{\frac{1}{\beta} + \tau_w^0}{1-\tau_w^0}\left.\frac{\partial e^*(\tau_b,\tau_w^0)}{\partial \tau_b}\right|_{\tau_b=0} + \left.\frac{\partial B_0(b^*(0,\tau_w^0);\tau_b,\tau_w^0)}{\partial \tau_b}\right|_{\tau_b=0} \geq 0 \tag{A.13}$$

simultaneously hold.

We begin to check (A.12). It is tedious but straightforward to show that substituting

[19] A more detailed proof is presented in a technical appendix, available from the authors upon request.

(A.9) and (A.10) into (A.12) and using (A.8) implies

$$\Omega^* = \frac{1+\beta}{4\beta^2}\left(\frac{e_0}{1-\tau_w^0}\left[\frac{(1+5\beta+8\beta^2)\tau_w^0}{1+\beta} - 1\right] - (1-\beta)\chi\right). \tag{A.14}$$

Thus, $\Omega^* \geq 0$ if and only if

$$\tau_w^0 > \frac{1+\beta}{1+5\beta+8\beta^2} \equiv q^*(\beta). \tag{A.15}$$

and $e_0 \geq \underline{e}(\tau_w^0, \beta, \chi)$ simultaneously hold, using the definition of $\underline{e}$ in (26). One can show that $\underline{e}(\tau_w^0, \beta, \chi) < \bar{e}(\beta, \chi)$ if and only if $\tau_w^0 > \bar{\tau}_w(\beta)$. Moreover, $\bar{\tau}_w(\beta) > q^*(\beta)$. Thus, $\tau_w^0 > \bar{\tau}_w(\beta)$ implies $\tau_w^0 > q^*(\beta)$. From (25), it is also easy to see that $\bar{\tau}_w(\beta) < 1$.

Now we turn to derive an expression for $\Omega_0$. It is again tedious but straightforward to show that substituting (A.9) and (A.11) into (A.13) and using $b_1 = b^*(0, \tau_w^0)$ as given in (A.8) implies

$$\Omega_0 = \frac{1+\beta}{2\beta(1+2\beta)}\left(\frac{e_0}{1-\tau_w^0}\left[(1+8\beta)\tau_w^0 - 1\right] - (1-\beta)\chi\right), \tag{A.16}$$

Thus, (A.13) is fulfilled if and only if

$$\tau_w^0 > \frac{1}{1+8\beta} \equiv q_0(\beta) \tag{A.17}$$

and

$$e_0 \geq \frac{(1-\beta)\chi(1-\tau_w^0)}{(1+8\beta)\tau_w^0 - 1} \equiv \underline{\underline{e}}(\tau_w^0, \beta, \chi) \tag{A.18}$$

simultaneously hold. One can show that $\tau_w^0 > \bar{\tau}_w(\beta)$ implies $\tau_w^0 > q_0(\beta)$. Moreover, it is straightforward to check that $\underline{e}(\tau_w^0, \beta, \chi) > \underline{\underline{e}}(\tau_w^0, \beta, \chi)$, according to (26) and (A.18). Thus, if $\Omega^* \geq 0$, then $\Omega_0 > 0$. This concludes the proof. ■

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