Is Capital Back? The Role of Land Ownership and Savings Behavior

March 8, 2017

Abstract

Wealth inequality is a major political concern in most OECD countries. Under this premise we analyze different policy instruments in terms of their impact on wealth inequality and output. In a general equilibrium model, we disaggregate wealth in its capital and land components, and savings in their life-cycle and bequest components. Households are heterogeneous in their taste for leaving bequests. We show that governments have considerable freedom in reducing wealth inequality without sacrificing output: Land rent taxes enhance output due to a portfolio effect and reduce wealth inequality slightly. Bequest taxes have the highest potential to reduce inequality, and their effect on output is moderate. By contrast, we confirm the standard result that capital taxes reduce output strongly, and show that they only have moderate redistributive effects. Furthermore, we find that using the tax proceeds for transfers to the young generations enhances output the most and further reduces wealth inequality.

Keywords Fiscal policy · Wealth distribution · Inequality · Capital tax · Bequests · Land rent tax

JEL Classification D31 · E62 · H23 · H24 · Q24

1. Introduction

Recent empirical findings on wealth and its distribution can be summarized by the following set of stylized facts: The concentration of wealth is increasing (Saez and Zucman, 2016). Land prices drive the evolution of wealth

measured as a fraction of economic output (Homburg, 2015). Bequests are increasing (Piketty and Zucman, 2014) and they are a key determinant of the distribution of wealth (Cagetti and De Nardi, 2008).

To counteract the concentration of wealth, Benhabib et al. (2011) and Piketty and Saez (2013) recommend taxes on capital.[1] These two papers are representative for a common approach to the analysis of wealth inequality in the theoretical literature (for a survey, see Piketty and Zucman, 2015). In their models, wealth distributions with Pareto upper tails are generated through multiplicative shocks to the transmission of wealth. One result of this approach has received much attention through Thomas Piketty's book *Capital in the 21st century* (Piketty, 2014). It holds that inequality is an increasing function of the gap between the after-tax interest rate $\bar{r} = r(1-\tau)$ and the growth rate of the economy g. A higher gap $\bar{r} - g$ implies more inequality, higher capital taxes τ imply less inequality.

However, most evidence shows that capital taxes discourage investment and reduce economic growth.[2] Moreover, in the common approach there is no distinction between capital and wealth (Homburg, 2015), which is inconsistent with empirical findings and leads to contradictory model results as Stiglitz (2015a) points out. Stiglitz highlights the absence of land rents,

---

[1] Although Piketty and Saez (2013) is titled *A Theory of Optimal Inheritance Taxation*, the tax on bequests which they analyze is equivalent to a capital tax (p. 1854, Footnote 4). Accordingly, the title of their working paper version Piketty and Saez (2012) is *A Theory of Optimal Capital Taxation*.

[2] Recently, Straub and Werning (2014) have called the zero-capital-tax result of Judd (1985) and Chamley (1986) into question. However, Straub and Werning rely on the assumption that consumption taxes are not available – their model thus constitutes an "extreme example of an incomplete set of fiscal instruments" as Chari, Nicolini, and Teles, point out in their manuscript *More on the taxation of capital*.

which are fundamental to explain the distribution of wealth.[3] Further, the common approach cannot account for endogenous effects with respect to factor prices, nor does it distinguish between life-cycle and dynastic saving.

The aim of this paper is to fill the gap in the literature on the distributional impact of taxes by making the above mentioned distinctions. Thus, we characterize the scope of action for governments to reduce wealth inequality with taxes on capital income, land rents, and bequests. Further, we determine how output is affected by these instruments. Finally, we do not only take into account the revenue raising side of fiscal policy, but also the spending side. Therefore, we address the question of how different tax revenue recycling options affect the wealth distribution and output.

We show that governments have considerable freedom in reducing wealth inequality without sacrificing output. There is a range of combinations of land rent and bequest tax rates under which output remains unchanged, but public revenues and the wealth distribution can be varied. We identify an asset portfolio effect as an important underlying mechanism: Taxing land rents enhances output by shifting investment towards capital.[4] Finally, recycling revenues to the young generation instead of the old enhances output and reduces inequality.

The rest of the paper is structured as follows. In Section 2 we intro-

---

[3] In contrast to Stiglitz (2015a), Homburg (2015) seems to dismiss the distributional implications of the dynamics of land rent ownership in the conclusion of his article.

[4] Feldstein (1977) was the first to identify the portfolio effect, which Mountford (2004) and Petrucci (2006) further formalized. Edenhofer et al. (2015) extended the analysis of the portfolio effect by introducing a social welfare function as benchmark for evaluating fiscal policy, in particular land rent taxes. The present paper focuses on the economic impacts of fiscal policy and does not consider a social welfare function. Nevertheless, we find that under land rent taxation the winners of the policy could theoretically compensate the losers. Thus, land rent taxation fulfills the Kaldor-Hicks criterion (see Appendix D).

duce a simplified version of our model with sequential generations. Here, we highlight the importance of endogenous prices to justify our choice of a deterministic model with complete markets – an approach which we understand as complementary to Piketty and Saez (2013) and Benhabib et al. (2011), who model individual households' rate of return on capital and the distribution of wealth as determined by stochastic processes. In Section 3 we introduce overlapping generations and land, and subsequently perform the policy instrument analysis in Section 4, which yields the main results of our paper. Sensitivity and robustness of our results are tested in Section 5. Section 6 concludes.

2. A simple model of bequest heterogeneity

In the present section, we develop a simple model of bequest heterogeneity to explain fundamental mechanisms at work. In particular, we demonstrate the importance of the impact of taxes on the interest rate for the distribution of wealth. Land as a production factor and the life cycle savings motive will be introduced in the next section.

Our simple model is based on Acemoglu (2008). To the best of our knowledge, it is the most parsimonious model of an economy in which new generations enter the economy each period and leave bequests to the next generation.

In each period t a new generation arrives in the economy and the old generation leaves the economy. There are N different types of households in each generation, which differ in their preferences. Each type of household $i \in$

$\{1, ..., N\}$ lives for one period, during which it receives income $y_{i,t}$. It divides its income between consumption $c_{i,t}$ and bequests for the next generation $b_{i,t}$, which are taxed at the uniform rate τ_B. A household derives utility from consumption and the "warm glow" (Andreoni, 1989) of leaving net-of-tax bequests:

$$u_{i,t} = \log(c_{i,t}) + \beta_i \log(b_{i,t}(1 - \tau_B)). \tag{1}$$

The budget equation is given by

$$y_{i,t} = w_t + (1 + R_t(1 - \tau_K))b_{i,t-1}(1 - \tau_B) = c_{i,t} + b_{i,t}, \tag{2}$$

where w denotes wage income, R is the rate of return on inherited wealth, that is, the bequests from the previous generation, and $0 < \beta_i < 1$ determines the preference for leaving bequests for the household of type i of the next generation $t + 1$. We assume that capital does not depreciate after use,[5] and that the offspring of a household has the same preferences as its parents.[6] Households may have to pay taxes τ_K on capital income or taxes τ_B on the bequests they receive.

Production is given by a standard neoclassical production function in intensive form $f(k)$ that satisfies the Inada conditions. Then, for the equi-

---

[5] Assuming positive depreciation does not alter the results qualitatively.

[6] For a discussion of the transmission of tastes from one generation to the next, see for example De La Croix and Michel (2002) and Black et al. (2015). Both publications provide evidence suggesting that our simplifying assumption is justified as a first-order approximation.

librium wage rate we have,

$$w_t = f(k_t) - f'(k_t)k_t, \tag{3}$$

and

$$R_t = f'(k_t).$$

We assume that all bequests are invested in capital k used for production:

$$k_{t+1} = \frac{1}{N} \sum_i b_{i,t}.$$

2.1. Basic properties

Households choose the levels of consumption and bequests in order to maximize their utility (1) subject to their budget equation (2). This yields the first-order conditions

$$b_{i,t} = \frac{\beta_i}{1 + \beta_i} y_{i,t} = \varphi_i \Big(w_t + (1 + R_t(1 - \tau_K)) b_{i,t-1}(1 - \tau_B) \Big) \quad \forall t, \tag{4}$$

where $i \in \{1, ..., N\}$ and $\varphi_i := \frac{\beta_i}{1 + \beta_i}$.

With (4) it is possible to deduce a condition on the curvature of the production function which ensures the existence of a steady state (see Appendix A). This condition is, for instance, fulfilled by CES-type production

functions. Then, the steady state level of bequests is given by

$$b_i^* = \frac{w^* \beta_i}{1 + \beta_i - \beta_i \big(1 + R^*(1 - \tau_K)\big)(1 - \tau_B)},$$ (5)

where asterisks denote steady state levels. Further, if a steady state exists, it follows directly from (5) that households with relatively high preference parameters β_i for bequests have higher steady state levels of bequests than households with relatively low preferences for bequests. In other words, if $\beta_i > \beta_j$ for $i, j \in \{1, ..., N\}$, then $b_i^* > b_j^*$. To see this, note that $\frac{\mathrm{d}b_i^*}{\mathrm{d}\beta_i} > 0$ for constant w^* and R^*.

2.2. Fiscal policy

We consider a linear tax on capital income or on bequests which is implemented in the first time period of the model and remains constant for the whole time horizon. The main aim here is to highlight that the impact of the tax on the interest rate is crucial for how the tax affects wealth distribution.

Lemma 1. *Assume a steady state exists (cf. Corollary A, Appendix A).*

1. *An increase in the bequest tax leads to a decrease in wealth inequality, if and only if*

$$\frac{\mathrm{d}R^*}{\mathrm{d}\tau_B} < -\frac{1 + R^*(1 - \tau_K)}{(1 - \tau_K)(1 - \tau_B)}.$$ (6)

2. *An increase in the capital income tax leads to a decrease in wealth*

inequality, if and only if

$$\frac{\mathrm{d}R^*}{\mathrm{d}\tau_K} < \frac{R^*}{1 - \tau_K}. \tag{7}$$

By a decrease in wealth inequality we understand a decreasing steady state bequest ratio b_i^*/b_j^* of households i and j for which $b_i^* > b_j^*$.

Proof. Let $i, j \in \{1, ..., N\}$ such that $\beta_i > \beta_j$ and thus $b_i^* > b_j^*$ holds. We define $\psi_i := 1 + \beta_i - \beta_i\big(1 + R^*(1 - \tau_K)\big)(1 - \tau_B)$. Using (5) it is straightforward to calculate whether a marginal increase of a tax increases or decreases the ratio of steady state bequest levels:

1. $\frac{\mathrm{d}}{\mathrm{d}\tau_B}\left(\frac{b_i^*}{b_j^*}\right) = \overbrace{\frac{\beta_i}{\beta_j}(\beta_i - \beta_j)\psi_i^{-2}}^{>0}\left[\big(1 + R^*(1 - \tau_K)\big) + \frac{\mathrm{d}R^*}{\mathrm{d}\tau_B}(1 - \tau_K)(1 - \tau_B)\right]$

2. $\frac{\mathrm{d}}{\mathrm{d}\tau_K}\left(\frac{b_i^*}{b_j^*}\right) = \underbrace{\frac{\beta_i}{\beta_j}(\beta_i - \beta_j)\psi_i^{-2}(1 - \tau_B)}_{>0}\left[\frac{\mathrm{d}R^*}{\mathrm{d}\tau_K}(1 - \tau_K) - R^*\right]$ □

□

    The intuition behind conditions (6) and (7) is that wages, which all households receive equally and which are linked to the interest rate R via equation (3), should not decrease too much. In other words, if the tax burden on labor becomes too high, capital and bequest taxation could even increase inequality. If conditions (6) or (7) hold, there is an upper bound for the marginal product of capital $f'(k)$, and thus a lower bound for the capital stock, output, and wages.

    For the objective of the present paper, the most important conclusion from the above lemma is that prices matter for a comprehensive policy in-

strument analysis. Lemma 1 implies that any statement about the impact of taxes on the distribution of wealth should consider how the taxes affect factor prices endogenously. In Section 3 we will build on this insight to derive more precisely how taxes affect an economy with heterogeneous agents and land when prices are endogenous. Thereby, our study can be understood as complementary to the common approach to the analysis of wealth inequality that Benhabib et al. (2011) and Piketty and Saez (2013) pursue, who assume that the interest rate is exogenously given.

3. An overlapping generations model with bequest heterogeneity and land

We extend the analytical model described in Section 2 by introducing land and by assuming that agents live for two periods instead of only one. Thus, in each period there are two generations that overlap. We make this assumption to differentiate between the life-cycle savings motive and the savings motive for leaving bequests, and also in order to have a market for land, on which old households may sell their land to young ones. Land thus serves both as a fixed factor of production and an alternative asset for households' investments.

We first give a model description. Then, in Section 3.2, we briefly explain our calibration method.

3.1. Model description

The economy consists of N different types of households, which differ with respect to their preferences and live for two periods. Further, there is one

representative firm and the government. The different preferences of each type of households imply different levels of wealth. Similar to the analytical model of sequential generations in Section 2, we observe that also in the model with overlapping generations, higher preferences for bequests imply higher steady state levels of wealth. For the rest of the paper we set $N = 5$ and use the index i to identify the household belonging to the ith wealth quintile, where households are ordered from lowest to highest preferences for bequests. We assume that the offspring of a household has the same preferences as its parents. Further, we shall assume that one time step represents a period of 30 years (one generation). All variables are stated in per capita terms.

3.1.1. Households

The utility of households is given by an isoelastic function with elasticity parameter η. It depends on their consumption when young $c_{i,t}^y$, consumption when old $c_{i,t+1}^o$, and net bequests left to their children $b_{i,t+1}(1 - \tau_B)$, on which the government may levy bequest taxes.

$$u\left(c_{i,t}^y, c_{i,t+1}^o, b_{i,t+1}\right) = \frac{(c_{i,t}^y)^{1-\eta} + \mu_i(c_{i,t+1}^o)^{1-\eta} + \beta_i\left(b_{i,t+1}(1 - \tau_B)\right)^{1-\eta}}{1 - \eta} \tag{8}$$

For the parameters we assume that $\mu_i, \beta_i \in (0, 1)$. Households maximize their utility subject to the following budget equations.

$$c_{i,t}^y + s_{i,t} = w_t + b_{i,t}(1 - \tau_B) \tag{9}$$

$$s_{i,t} = k_{i,t+1}^s + p_t l_{i,t+1} \tag{10}$$

$$c_{i,t+1}^o + b_{i,t+1} = (1 + R_{t+1}(1 - \tau_K))k_{i,t+1}^s + l_{i,t+1}(p_{t+1} + q_{t+1}(1 - \tau_L)) \tag{11}$$

In period t a young household i earns wage income w_t, receives bequests from the currently old generation, and pays taxes on the bequests. The household uses its income to consume or save. Savings $s_{i,t}$ can be invested in capital $k^s_{i,t+1}$ or land $l_{i,t+1}$, which are assumed to be productive in the next period and may be taxed at rates τ_K and τ_L, respectively. We assume that capital is the numeraire good and land has the price p. When households are old, they receive the return on their investments according to the interest rate R_{t+1}, the price of land p_{t+1}, and the land rent q_{t+1}. We define household wealth $v_{i,t}$ as the sum of the values of the stocks of capital and land, and also the returns to investments in these stocks. Old households use their wealth to consume or to leave bequests for the next generation, which is expressen in (11). Thus, it holds that $v_{i,t} = c^o_{i,t+1} + b_{i,t+1}$.

Note that we assume a fixed labor supply here. Our model framework could easily be extended to include an endogenous labor supply. However, it turns out that the results we obtain are independent of whether labor supply is fixed or endogenous. Thus, we abstract from a labor-leisure choice here, to keep the analysis as tractable as possible.

The first-order conditions of the households' optimizations are given by the budget equations (9) - (11) and

$$(c^o_{i,t+1})^\eta = \mu_i(1 + R_{t+1}(1 - \tau_K))(c^y_{i,t})^\eta \tag{12}$$

$$\beta_i(1 - \tau_B)^{1-\eta}(c^o_{i,t+1})^\eta = \mu_i b^\eta_{i,t+1} \tag{13}$$

$$\frac{p_{t+1} + q_{t+1}(1 - \tau_L)}{p_t} = 1 + R_{t+1}(1 - \tau_K). \tag{14}$$

To gain a better intuition for the model and in particular how land prices are determined, note that the no-arbitrage condition (14) could also be reformulated as the discounted sum of future rents (to see this, use induction):

$$p_t = \sum_{i=1}^{T-t} \frac{\widetilde{q}_{t+i}}{\prod_{j=1}^{i}(1 + \widetilde{R}_{t+j})}, \tag{15}$$

where $\widetilde{q}_t := q_t(1 - \tau_L)$ and $\widetilde{R}_t := R_t(1 - \tau_K)$. The no-arbitrage condition (14) ensures that households invest in capital and land in such a way that the returns are equalized across the two assets. The returns are determined by the aggregate quantities of the input factors. Beyond this, the no-arbitrage condition does not impose any restrictions on how the asset portfolios of individual households are composed.[7]

3.1.2. Firm

The representative firm produces one type of final good using capital k, land l and labor, where the latter two are assumed to be fixed factors. We assume that the production function is of CES type. In intensive form it is defined as

$$f(k_t) = A_0[\alpha k_t^{\sigma} + \gamma l^{\sigma} + 1 - \alpha - \gamma]^{\frac{1}{\sigma}},$$

where A_0 is total factor productivity and $\sigma = \frac{\epsilon - 1}{\epsilon}$ is determined by the elasticity of substitution ϵ. The firm's demand for capital k_t equals the

---

[7] We shall make use of the convention that all households choose the same asset composition. More precisely, in every period t there is an $X_t > 0$ such that $X_t = k_{i,t}^s / l_{i,t}$ for all $i \in \{1, ..., N\}$. We use this convention because there is an infinite continuum of possible combinations of individual asset portfolio compositions of each household i which have no bearing on any of our results.

aggregate of capital that is supplied by households $k_{i,t}^s$. The clearing of factor markets is described by

$$k_t = \frac{1}{N} \sum_{i=1}^{N} k_{i,t}^s \quad \text{and} \quad l = \frac{1}{N} \sum_{i=1}^{N} l_{i,t}.$$

In each period the firm maximizes its profit, which we assume to be zero due to perfect competition. Thus, the first-order conditions are

$$f_k(k_t) = R_t \quad \text{and} \quad f_l(k_t) = q_t,$$

and wages are given by $w_t = f(k_t) - R_t k_t - q_t l$.

3.1.3. Government

The government levies taxes on capital income τ_K, land rents τ_L, or bequests τ_B. Throughout Section 4.1, we assume that public revenues g_t are used for public consumption which has no effect on the economy. In Section 4.2 we relax this assumption and analyze alternative recycling schemes.

$$g_t = \tau_K R_t k_t + \tau_L q_t l + \frac{1}{N} \sum_i \tau_B \, b_{i,t}.$$

3.2. Calibration

The heterogeneity of household preferences and the introduction of land as an additional factor of production yield complex results, which go beyond that which is analytically tractable.[8] Since we cannot obtain closed form

---

[8] For example, the analytical method applied by Mountford (2004) to a dynamic system with two state variables already leads to inconclusive results if the number of states is

solutions, we solve the model numerically using GAMS (Brooke et al., 2005).

To calibrate the model, we fix the capital income tax rate at its approximate OECD average, and set the land rent and bequest tax rates to be zero. Then, we use GAMS to calculate those control variables that minimize the quadratic difference between the model output in the steady state and the empirically observed data. This difference is the objective of the minimization problem. The control variables of the minimization problem are the parameters of production technology, the parameters determining household behavior, and the initial endowments with capital and land. The model output that we compare with observed data is comprised of the model's steady state levels of output and households' wealth, the level of capital, and the ratio of the values of capital and land. The empirically observed data is the average OECD data for output and household wealth (OECD, 2015) and the average OECD level of capital and the ratio of values of capital and land (OECD, 2016, Dataset 9B). The values that we find for the parameters of household behavior (β_i, μ_i, η) and production technology (α, γ, ϵ, A_0), and the initial endowments (k_0, l_0) are summarized in Table B.1 in Appendix B. A comparison of the data with the model output can be found in Table B.2.

Our calibration method is flexible enough to be applied to data of a specific country, too. However, we have decided to calibrate the model to the more generic case of average values, since we aim at identifying underlying effects. We expect that our results will not change qualitatively in an analogous analysis calibrated to a specific country.

---

increased by one dimension (i.e. bequests are added to his model) and households are still assumed to be homogeneous.

There are more control variables than model output values that need to be matched with empirical data. *A priori*, this means that the same steady-state distribution of wealth could be reproduced with different sets of behavioral and technology parameters and initial endowments. However, we are confident to have ruled out any possible ambiguity. The rigorous assessment of different parametrizations shows that our results are robust with respect to most parameters. The sensitivity analysis in Section 5 summarizes our findings and presents a detailed analysis of those parameters that have a non-trivial effect on our results.

4. Main results – policy instrument analysis

We use the model described in the previous section to analyze the impact of fiscal policy on the distribution of wealth, the level of output, and the magnitude of tax revenues in the steady state. We consider taxes on capital income, land rents, and bequests. We concentrate on the steady state because the transition from the initial state to the steady state reveals no additional insights.

In Section 4.1, we focus on the revenue side of fiscal policy and show that governments have considerable freedom in reducing wealth inequality without sacrificing output. Here, we assume that the public revenues are not used for a specific purpose. This assumption will be relaxed in Section 4.2, in which we consider different ways of using the public funds generated by fiscal policy. In particular, we show that using the tax revenues for transfers to young generations reduces inequality and increases output relative to a

scenario in which those transfers go to the old generation.

4.1. The revenue side of fiscal policy

4.1.1. The policy-option space of output, redistribution, and public revenue

We evaluate fiscal policy along three dimensions: Their impact on output, their consequences for the wealth distribution, and their potential to raise public revenue.

We summarize our main result in Figure 1. The graphs show the feasible combinations of output f^*, the Gini coefficient of the wealth distribution $\{v_i^*\}_{i=1,\dots,5}$, and the magnitude of public revenues g^* in the steady state if only one of the three tax instruments is used at a time. If taxes are set to zero, per capita output is about 1 million US\$ per time step (30 years) and the Gini coefficient of the wealth distribution has a value of about 0.63. This point is marked by the intersection of the two dashed lines.

As the tax rates are increased above zero, respectively, we observe that all taxes reduce the Gini coefficient. Output increases under the land rent tax and decreases under the capital income tax. The bequest tax reduces output only slightly. Capital income and bequest taxes achieve higher public revenues than the land rent tax.[9]

The distribution of wealth depends on how fiscal policy affects the two components of the young households' income, i.e., wages and bequests. Rich households draw a higher proportion of their income from bequests than the poor. When a tax affects the two sources of income differently, the

---

[9] In the robustness analysis of our results in Section E.2.1.1, we will show that the potential to raise public revenues with the bequest tax crucially depends on the elasticity parameter η of households' utility function.
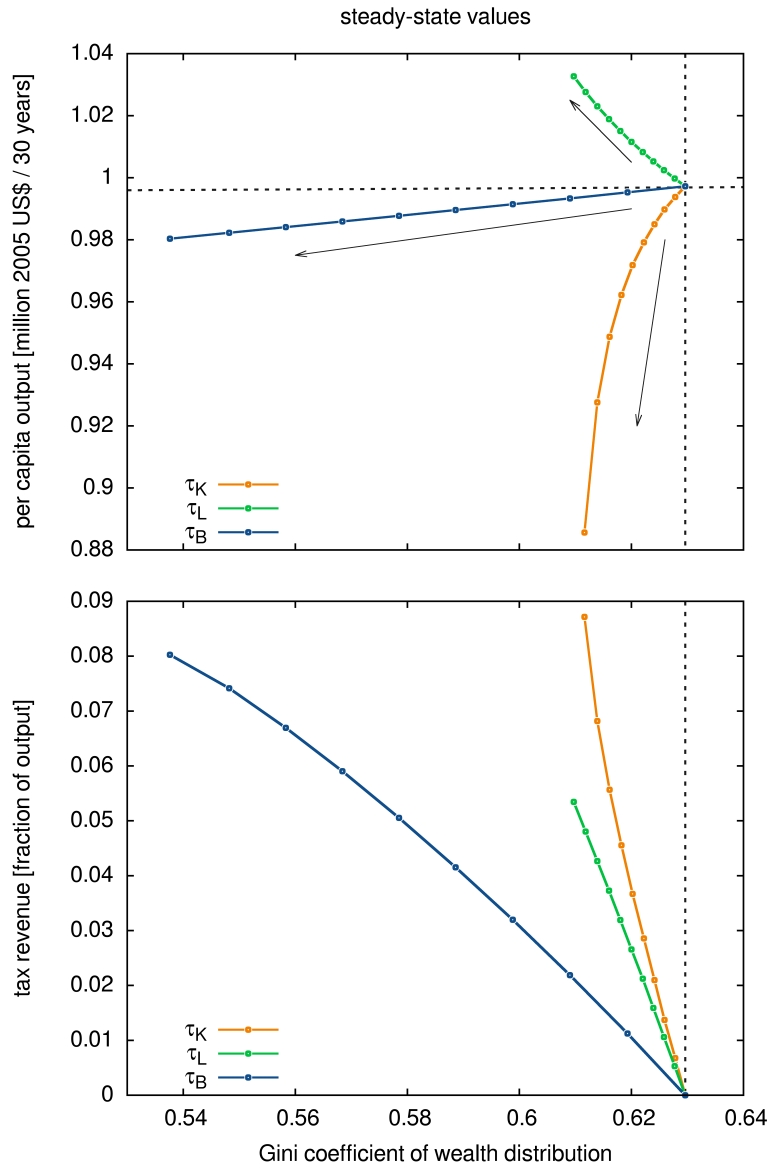
Figure 1: Depending on which tax instrument is used, the government may achieve different coordinates in the policy-option space of output, redistribution, and public revenue. Each curve represents the set of coordinates which are achievable with the use of one single tax instrument. The arrows in the upper panel indicate increases in the respective tax rate. The data points are chosen for tax rates in steps of 10%. They range from 0% to 100% for the land rent tax, and from 0% to 90% for the capital income and the bequest tax. Note that capital income and bequest tax rates of 100% produce extreme results which we have left out here for expositional reasons.

Household i	$\tau_K = 0.2$	$\tau_L = 0.2$	$\tau_B = 0.2$	$\tau_K = 0.7$	$\tau_L = 0.7$	$\tau_B = 0.7$
Income y^*						
1	99.0	100.7	99.5	93.8	103	98
2	99.0	100.7	99.5	93.8	103	98
3	98.9	100.5	98.9	93.4	102	96
4	98.7	100.3	97.5	92.5	101	91
5	97.4	98.9	91.0	88.2	97	73
Bequests b^*						
1	95.7	97.2	101.4	81.9	90	103
2	95.7	97.2	101.4	81.9	90	103
3	95.6	97.0	100.8	81.6	89	101
4	95.4	96.8	99.4	80.8	88	97
5	94.1	95.5	92.8	77.1	84	77

Table 1: Different tax instruments and rates imply different reductions in the steady state levels of income and bequests. We assume that only one tax is implemented at a time. The numbers give the respective percentage of the case in which no taxes are implemented. All tax instruments reduce the income and the received bequests of rich households by a greater fraction than that of poor households.

distribution of wealth will change accordingly. It turns out that the capital income tax and the land rent tax reduce the after tax return to savings $1 + R^*(1 - \tau_K) = 1 + \frac{q^*}{p^*}(1 - \tau_L)$, which discourages savings and thus reduces bequests. Moreover, taxes on bequests received from their parents reduce households' income, and thus such taxes also have the tendency to reduce the bequests that households leave to their offspring. We shall refer to this as the *income effect of bequest taxes*. Households whose income consists of a comparably high share of bequests are affected more strongly by the income effect of bequest taxes than households who receive most of their income as wages. As a consequence, each tax instrument reduces the income of richer households by a higher proportion than the income of poorer ones – all taxes have a progressive effect on the distribution of wealth (see Table 1).

The level of output is influenced by households' choices on whether to invest in land or capital. Since land and labor are fixed[10], fiscal policy that stimulates (hampers) investment in capital will unambiguously increase (decrease) output. While a bequest tax only indirectly affects asset prices, taxes on capital income and land rents have a relatively strong impact. As the relative prices of assets change, households will react by changing the composition of their portfolio. A graphical exposition of this fact is given in Appendix C, Figure C.1. Since the tax on land rents shifts investment toward capital, output actually increases. The capital income tax has the exact opposite effect.

While the observed effects of land rent and capital income taxation are quite straightforward, the effects of the bequest tax are governed by the interplay of households' incomes and their substitution behavior. The immediate effect of increasing the bequest tax is to reduce households' income, which follows from the budget equations. This is again the income effect of bequest taxation. A second immediate effect of bequest taxes is that they also increase demand for bequests relative to consumption in both periods of life, which follows from households' first-order conditions (12) and (13). We shall refer to this as the *substitution effect of bequest taxation*, since the bequest tax induces households to substitute bequests for consumption.

Table 1 reveals that for relatively rich households the income effect outweighs the substitution effect of bequest taxation, as their bequests drop under an increase of the bequest tax. For the poorer households the oppo-

---

[10] Recall that the results we obtain are independent of whether labor supply is fixed or endogenous. Thus, we abstract from a labor-leisure choice here, to keep the analysis as tractable as possible.

site is true. For example, households of type $i = 5$ (i.e. the richest quintile) reduce their bequests by more than 7% if the bequest tax is increased from zero to 20%. Poor households, by contrast, *increase* their bequests by 1.4% in reaction so such a tax hike. The bequest tax discourages the rich from saving for the purpose of leaving bequests, but encourages the poor to do so. Thus, it has a strong potential for wealth redistribution from the rich to the poor. With the bequest tax the Gini coefficient can be reduced to a significantly lower level than with the taxes on land rents or capital income.

The latter two have natural limits. Once all land rents are taxed away, there is no more scope for further tax increases and wealth redistribution. As capital income taxes are increased, investment in the main source of productivity is choked, and the economy collapses.

The qualitative results on the impact of the three tax instruments on the policy option space are robust with respect to an extensive set of different model assumptions, as our sensitivity analysis shows (cf. Sections 5 and E.2).

4.1.2. Output-neutral tax reform.

Several combinations (τ_L, τ_B) of land rent tax and bequest tax rates can redistribute wealth while at least maintaining the same steady state level of output.[11] In Figure 2 we show how the Gini coefficient changes under different combinations of bequest and land rent tax rates which do not reduce the steady state level of output below the level of the benchmark case in which

---

[11] This can be made plausible by recalling Figure 1. Compare the set of coordinates in the policy-option space that can be reached with the land rent tax alone – the green curve – with the coordinates in the policy-option space that can be reached with the bequest tax – the blue curve. When implementing a mix of both taxes it is likely that the coordinates that can be thus reached lie between the green and the blue curve.
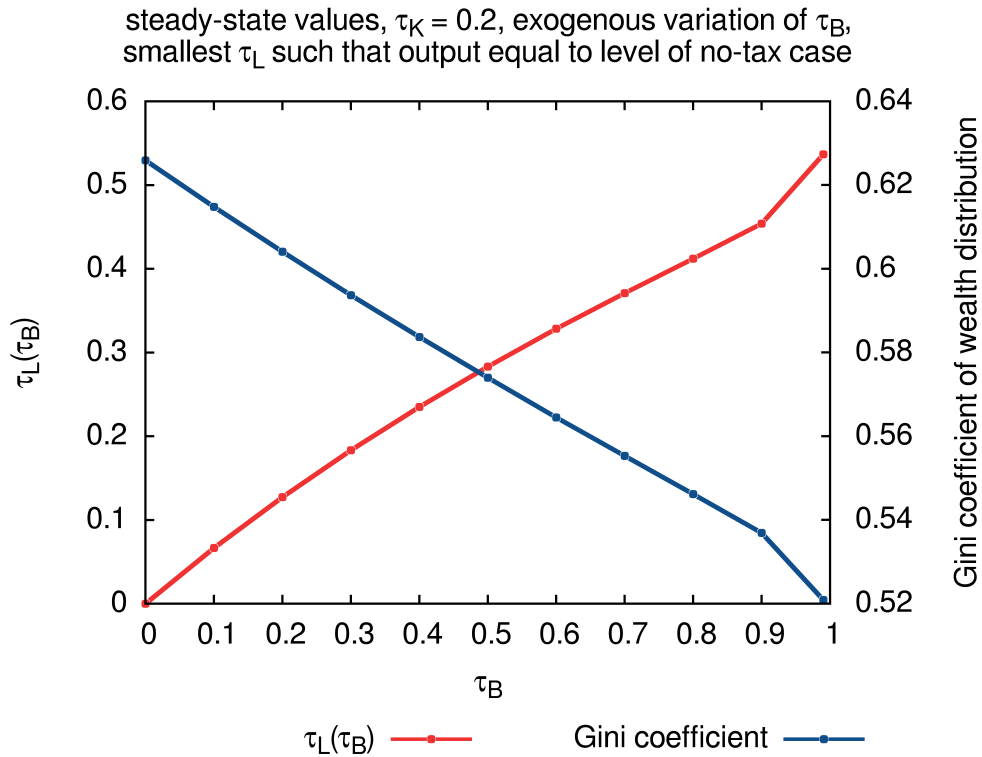
Figure 2: Combinations of bequest- and land rent taxes that imply the same steady-state level of output as in the benchmark case in which $\tau_K = 0.2, \tau_L = \tau_B = 0$.

$\tau_K = 0.2$, and $\tau_L = \tau_B = 0$. The assumed fixed capital income tax rate of 20% is roughly in line with the corresponding average tax rate in OECD countries.

It turns out that a typical OECD government has considerable freedom in choosing the desired value of the Gini coefficient without having to bear any costs in terms of forgone output. In our experiment, the Gini coefficient may be reduced from its benchmark value 0.63 down to almost 0.52, and public revenues increase from 1.4% to about 11% of output, as Table 2 shows.

| | | | public revenue per capita | |
τ_B	τ_L	Gini	[10^3 2005 US\$/30 years]	[fraction of output]
0.00	0.00	0.63	14	1.4%
0.10	0.07	0.62	28	2.8%
0.20	0.13	0.60	40	4.0%
0.30	0.18	0.59	52	5.3%
0.40	0.24	0.58	63	6.4%
0.50	0.28	0.57	73	7.4%
0.60	0.33	0.57	82	8.3%
0.70	0.37	0.56	91	9.2%
0.80	0.41	0.55	98	9.9%
0.90	0.45	0.54	105	10.6%
0.999	0.54	0.52	104	10.5%

Table 2: Combinations of bequest and land rent taxes that imply the same steady-state level of output ($f^* = 0.99$ million 2005 US\$ / 30 years) as in the benchmark case in which $\tau_K = 0.2, \tau_L = \tau_B = 0$.

4.2. The spending side of fiscal policy

So far, we have only considered the revenue side of fiscal policy. Thereby we have assumed that the public revenues do not feed back into the economy. However, since public revenues are an endogenous variable and can become quite substantial, we now turn to the analysis of alternative uses of these revenues. Here, we show how different ways of recycling the revenues as lump-sum transfers to young and old households affect the policy-option space. In Section E.2.2, we also consider the alternative case of productivity enhancing public spending, for example through infrastructure investments.

4.2.1. Lump-sum transfers to young and old households

We analyze the impacts of different transfer schemes by varying the distribution parameter $\delta \in [0, 1]$. Its value indicates the fraction of total transfers going to the old generation. Now, the budget equations of the young and the

22

old households living in period t are given by

$$c_{i,t}^y + s_{i,t} = w_t + b_{i,t}(1 - \tau_B) + (1 - \delta)g_t,$$

$$c_{i,t}^o + b_{i,t} = (1 + R_t(1 - \tau_K))k_{i,t}^s + l_{i,t}(p_t + q_t(1 - \tau_L)) + \delta g_t.$$

As Figure 3 shows, it makes a significant difference whether the government transfers the public revenues only to young households ($\delta = 0$), only to old households ($\delta = 1$), or to both[12]. The more the government directs transfers to the young, the higher the level of output in the steady state will be and the more equal wealth will be distributed.

---

[12]Here, we use $\delta = \frac{1}{2}$. In general, of course, any $0 < \delta < 1$ implies transfers to both.
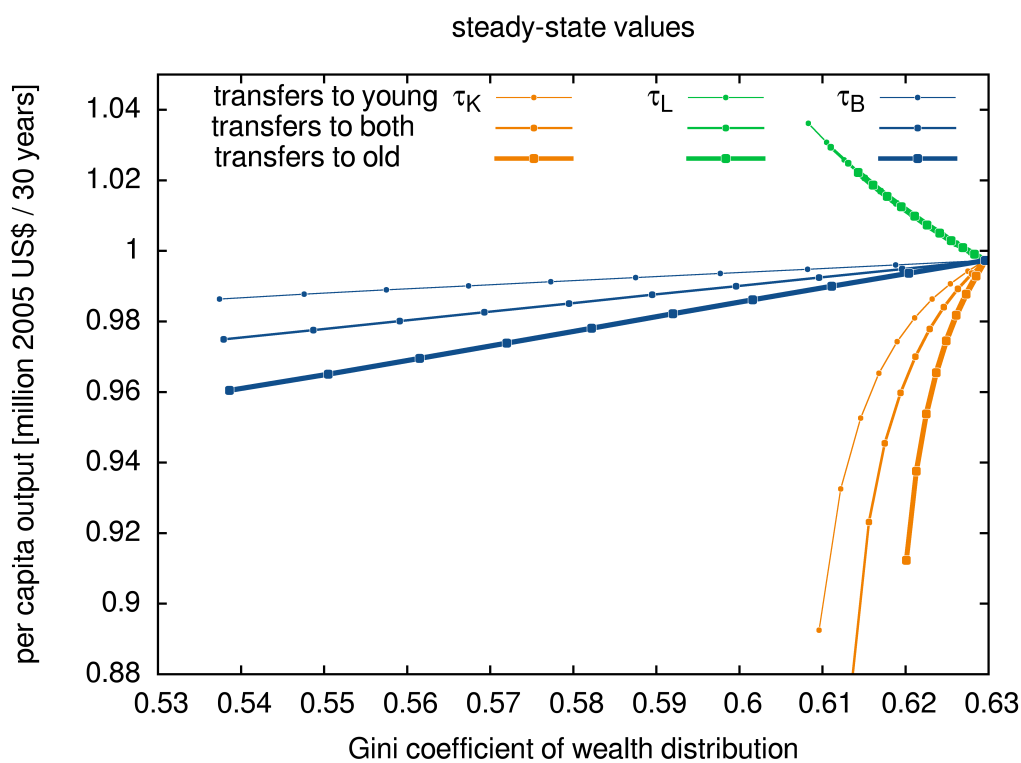
Figure 3: Impact of different recycling schemes on output and the distribution of wealth.

If a transfer increases a young household's income, it directly increases consumption as well as savings (a direct income effect), and thus also capital supply and output. By contrast, a transfer to old households can in principle increase savings only indirectly. Through the direct income effect the old consume more and leave more bequests. Leaving more bequests increases the income of the descendants. However, it turns out that transfers to the old actually reduce savings. The income effect is overcompensated by a *savings substitution effect*: Since young households anticipate the higher income in old age, they save less. The savings substitution effect is stronger for those households that have relatively low preferences for leaving bequests (and,

24

thus, for savings). The overcompensation of the income effect through the savings substitution effect explains why the Gini coefficient increases and the output level decreases with δ.

It is worth mentioning that there is a relatively low threshold for the percentage of transfers which go to the old ($0 < \delta < 0.5$) above which the savings substitution effect is so strong, that steady state output falls below the case in which public revenues are not even fed back into the economy (see Appendix C, Figure C.3).

If the government uses the bequest tax, public revenues are highest under recycling scheme $\delta = 1$. The more transfers are directed to the young, the lower the bequest tax revenues become. Revenues from land rent and capital income taxes show no substantial change under variation of δ.[13] This difference is due to the fact that, unlike with the factor taxes, the choice of the redistribution parameter δ directly changes the tax base of the bequest tax.

5. Robustness checks and sensitivity analysis

This section summarizes the robustness of our main results with respect to different assumptions about model specifications. In particular, we report how the policy option space (cf. Figure 1) changes under different parameter choices and we discuss the alternative assumption that the government finances infrastructure investments instead of lump-sum transfers to households. Table 3 summarizes our findings of the robustness checks. A more

---

[13] See Appendix C, Figure C.2 for a graphical exposition of this fact.

25

Variation	Effect
Utility parameter η	Potential to redistribute wealth increases with η. With higher η, τ_B may increase output. Savings behavior of households is affected.
Substitution elasticity ϵ	No qualitative, but relatively strong quantitative impact on policy option space.
Taxes used for infrastructure	Hardly any qualitative impact, only τ_K and τ_B reveal the expected U-shaped curve in policy option space

Table 3: Overview of robustness checks with non-trivial changes of model results.

detailed account of the sensitivity analysis is given in the separately available supplementary material.

To test the sensitivity of our results to the parameter choice, we have performed a one-at-a-time variation of all model parameters. For the variation of each parameter we have subsequently recalibrated all other parameters such that the standard policy case ($\tau_K = 20\%$, $\tau_B = \tau_L = 0$) reproduces the observed data again. For most tested parameters, we find that a variation has no significant qualitative nor quantitative effect on our results. Only the elasticity parameters of the utility function η and the production function ϵ reveal a non-trivial relationship between parameter choice and model results.

Varying the substitution elasticity of the production function ϵ does not change the policy options space qualitatively, but has a relatively strong quantitative impact. The preference parameter η, however, has a minor influence on the qualitative impact of taxes. Assuming a higher η increases the potential to redistribute wealth with the taxes on the two types of assets, the capital income and the land rent tax. With a higher η the bequest tax may actually increase the steady-state level of output relative to the no-tax-case a

little. The reason behind the impact of varying η is that it influences households' savings behavior as indicated by their first-order conditions (12) and (13). Nevertheless, the main differences between the three tax instruments remain the same under the variation of η.

Further, our results are independent of whether labor supply is fixed or determined endogenously.

Finally, our results remain robust under the alternative assumption that tax revenues are not recycled as lump-sum transfers but instead are used for infrastructure investments. Thus, following Barro (1990), Baxter and King (1993), and Turnovsky (1997), we have analysed a scenario in which total factor productivity A_t depends on tax revenues g_t according to

$$A_t = A_0 \psi_1 (g_t + \psi_2)^{\psi_3},$$

where parameters ψ_i, $i = 1, 2, 3$ are chosen appropriately. We find no unexpected or counterintuitive results. Higher tax revenue leads to an increase in output. All taxes remain progressive in their impact on the distribution of wealth. Land rent taxation unambiguously increases output. The only qualitative change is that capital income and bequest taxation leads to an inverted U-shape in the policy option space due to the fact that for low tax rates the marginal benefits of additional infrastructure exceed their costs (and for high rates vice versa).

6. Conclusion

Is capital back? Thomas Piketty and Gabriel Zucman claim that this is the case by highlighting that the currently observed increased levels of inequality are due to a concentration of capital ownership at the top (Piketty, 2014, Piketty and Zucman, 2014). Recent literature, however, suggests that land ownership and bequest heterogeneity play a more important role in the process of wealth concentration (Homburg, 2015; Stiglitz, 2015a; Stiglitz, 2015b; Kopczuk, 2013). We illustrate this in an overlapping generations model that accounts for both features.

Our conclusions differ from Piketty's. Life-cycle saving (when invested in capital) should be left untaxed, while taxing bequests has a higher scope for redistribution at lower policy costs. Further, taxing the land rent component of wealth has a moderate scope for redistribution and strongly enhances output, due to a beneficial portfolio effect: Households shift investments away from the fixed factor land towards capital. The increase in capital investments directly increases output. Accordingly, capital income taxes reduce output since they discourage capital investments.

Atkinson (2015) takes up the idea of the stakeholder society (Ackerman and Alstott, 1999) and proposes, among other measures, to reduce inequality by endowing young households with a one-time transfer at adulthood. That transfer, according to Atkinson, should be financed by a wealth or inheritance tax. We demonstrate that financing such a transfer indeed reduces inequality. We find that the more the transfers are directed to the young and the less they are directed at the old, the higher output in steady state is and the

more equal the wealth distribution is. In this case, reducing inequality goes hand in hand with enhancing output.

While heterogeneity in bequests is a key driver of the wealth distribution, it is not the only one which has been suggested by the literature. Entrepreneurial risk taking, income inequality, or higher rates of return on high asset levels (Quadrini and Ríos-Rull, 1997), as well as differences in education (Pfeffer and Killewald, 2015) also may play an important role in determining the shape of the distribution and how it changes over time. The quantitative importance of each factor is still an open research question, and the design of tax policies crucially depends on its answer. Accordingly, our results will differ from findings based on other assumptions about the drivers of wealth inequality. Extending our analysis of policy instruments to a framework with multiple drivers of wealth inequality could yield valuable insights.

There is a further promising avenue for future research based on the present article. The policy instrument analysis conducted here has focused only on the impact of exogenously determined tax reforms on the steady state. It would be desirable to embed our analysis within a framework of optimal taxation and social welfare maximization, and thus derive the socially optimal policy mix.

References

Acemoglu, D., 2008. Introduction to modern economic growth. MIT Press.

Ackerman, B., Alstott, A., 1999. The stakeholder society. Yale University Press.

Allen, R., 1938. Mathematical analysis for economists. Macmillan and Co.

Andreoni, J., 1989. Giving with impure altruism: applications to charity and Ricardian equivalence. The Journal of Political Economy , 1447–1458.

Atkinson, A.B., 2015. Inequality: What Can Be Done? Harvard University Press.

Barro, R., 1990. Government spending in a simple model of endogenous growth. Journal of Political Economy 98, 103–125.

Baxter, M., King, R.G., 1993. Fiscal policy in general equilibrium. The American Economic Review 83, 315–334.

Benhabib, J., Bisin, A., Zhu, S., 2011. The Distribution of Wealth and Fiscal Policy in Economies With Finitely Lived Agents. Econometrica 79, 123–157.

Black, S.E., Devereux, P.J., Lundborg, P., Majlesi, K., 2015. Poor Little Rich Kids? The Determinants of the Intergenerational Transmission of Wealth. Working Paper 21409. National Bureau of Economic Research.

Brooke, A., Kendrick, D., Meeraus, A., Raman, R., Rosenthal, R., 2005. GAMS – A Users Guide. GAMS Development Corporation.

Cagetti, M., De Nardi, M., 2008. Wealth inequality: Data and models. Macroeconomic Dynamics 12, 285–313.

Chamley, C., 1986. Optimal Taxation of Capital Income in General Equilibrium with Infinite Lives. Econometrica 54, 607–622.

De La Croix, D., Michel, P., 2002. A theory of economic growth: Dynamics and policy in overlapping generations. Cambridge University Press.

Edenhofer, O., Mattauch, L., Siegmeier, J., 2015. Hypergeorgism: When rent taxation is socially optimal. FinanzArchiv: Public Finance Analysis 71, 474–505.

Feldstein, M., 1977. The surprising incidence of a tax on pure rent: A new answer to an old question. The Journal of Political Economy 85, 349–360.

Homburg, S., 2015. Critical remarks on Piketty's Capital in the Twenty-first Century. Applied Economics 47, 1401–1406.

Judd, K.L., 1985. Redistributive taxation in a simple perfect foresight model. Journal of Public Economics 28, 59–83.

Kopczuk, W., 2013. Taxation of Intergenerational Transfers and Wealth, in: Auerbach, A.J., Chetty, R., Feldstein, M., Saez, E. (Eds.), Handbook of Public Economics, Volume 5. Newnes.

Mountford, A., 2004. Global analysis of an overlapping generations economy with land. Macroeconomic Dynamics 8, 582–595.

OECD, 2015. In It Together: Why Less Inequality Benefits All. Figure 6.14 – Wealth composition ... OECD Publishing, Paris. http://dx.doi.org/10.1787/888933208607.

OECD, 2016. Annual National Accounts – Detailed Tables and Simplified Accounts. https://stats.oecd.org/Index.aspx?DataSetCode=SNA_TABLE9B.

Petrucci, A., 2006. The incidence of a tax on pure rent in a small open economy. Journal of Public Economics 90, 921–933.

Pfeffer, F.T., Killewald, A., 2015. How Rigid is the Wealth Structure and Why? Inter-and Multigenerational Associations in Family Wealth. Research Report 15-845. Population Studies Center.

Piketty, T., 2014. Capital in the 21st Century. Belknap Press.

Piketty, T., Saez, E., 2012. A Theory of Optimal Capital Taxation. Working Paper 17989. National Bureau of Economic Research.

Piketty, T., Saez, E., 2013. A theory of optimal inheritance taxation. Econometrica 81, 1851–1886.

Piketty, T., Zucman, G., 2014. Capital is Back: Wealth-Income Ratios in Rich Countries 1700–2010. The Quarterly Journal of Economics 129, 1255–1310.

Piketty, T., Zucman, G., 2015. Wealth and inheritance in the long run. Elsevier Handbook of Income Distribution 2.

Quadrini, V., Ríos-Rull, J.V., 1997. Understanding the US distribution of wealth. Federal Reserve Bank of Minneapolis Quarterly Review 21, 22–36.

Saez, E., Zucman, G., 2016. Wealth inequality in the united states since 1913: Evidence from capitalized income tax data. The Quarterly Journal of Economics. DOI: 10.1093/qje/qjw004.

Stiglitz, J.E., 2015a. New Theoretical Perspectives on the Distribution of Income and Wealth among Individuals: Part III: Life Cycle Savings vs. Inherited Savings. Working Paper 21191. National Bureau of Economic Research.

Stiglitz, J.E., 2015b. The origin of inequality, and policies to contain it. National Tax Journal 68, 425–448.

Straub, L., Werning, I., 2014. Positive Long Run Capital Taxation: Chamley-Judd Revisited. Working Paper 20441. National Bureau of Economic Research.

Turnovsky, S.J., 1997. Fiscal policy in a growing economy with public capital. Macroeconomic Dynamics 1, 615–639.

A. Mathematical tools

Here we develop some mathematical tools to analyze the simple model from Section 2.

Lemma A. *If there exists a period t' such that for all $i \in \{1, ..., N\}$ it holds that $b_{i,t'} = b_{i,t'+1} > 0$, then there are b^* and k^* such that $k_{t'+l} = k^*$ and $b_{i,t'+l} = b_i^* \quad \forall l \geq 1$.*

Proof. Let t' be such that $b_{i,t'} = b_{i,t'+1} \ \forall i$. Then it follows that

$$k_{t'+2} = \frac{1}{N} \sum_i b_{i,t'+1} = \frac{1}{N} \sum_i b_{i,t'} = k_{t'+1},$$

which implies $w_{t'+1} = w_{t'+2}$ and $R_{t'+1} = R_{t'+2}$. Using this we have

$$
\begin{aligned}
b_{i,t'+2} &= \varphi_i \Big(w_{t'+2} + (1 + R_{t'+2}(1 - \tau_K)) b_{i,t+1}(1 - \tau_B) \Big) \\
&= \varphi_i \Big(w_{t'+1} + (1 + R_{t'+1}(1 - \tau_K)) b_{i,t}(1 - \tau_B) \Big) \\
&= b_{i,t'+1}.
\end{aligned}
$$

The iteration of these two steps closes the proof. $\qquad\square$

34

Corollary A. *If the condition*

$$\lim_{k \to \infty} f''(k)(\beta_i f(k) - k) = 0 \tag{16}$$

holds for all i (e.g., when the production function is of CES- or Cobb-Douglas type), there exists a steady state with capital-labor ratio k^*, bequest levels $b_i^* = \frac{w^* \beta_i}{1 - \beta_i R^*}$, and factor prices w^*, R^*.

Proof. Considering Lemma A we have to show that for some $t' \in \mathbb{N}$ the equations

$$b_i := b_{i,t'} = b_{i,t'+1} > 0, \quad i \in \{1, ..., N\} \tag{17}$$

have a solution, respectively. To see this, we use equation (4), which states that

$$b_{i,t'+1} = \varphi_i \Big(w_{t'+1} + (1 + R_{t'+1}(1 - \tau_K)) b_{i,t}(1 - \tau_B) \Big).$$

W.l.o.g. we assume that $\tau_B = 0 = \tau_K$. Plugging in equation (17), we have

$$b_i = \varphi_i(w_{t'+1} + (1 + R_{t'+1})b_i)$$

$$\iff \quad b_i = \frac{\varphi_i w_{t'+1}}{1 - \varphi_i(1 + R_{t'+1})} \quad \forall i. \tag{18}$$

When equation (17) holds, we always have $\varphi_i(1 + R_{t'+1}) < 1$. This can be seen by using equation (4), from which follows that

$$b_i = \varphi_i(w_{t'+1} + (1 + R_{t'+1})b_i) \iff (1 + R_{t'+1})b_i\varphi_i = b_i - \varphi_i w_{t'+1},$$

$$\iff (1 + R_{t'+1})\varphi_i = 1 - \underbrace{\frac{\varphi_i w_{t'+1}}{b_i}}_{>0} < 1. \qquad (19)$$

It remains to be shown that under condition (16) the equations (18) have a solution. To see this, let's define

$$\psi(b_i) := \frac{\varphi_i w_{t'+1}}{1 - \varphi_i(1 + R_{t'+1})}.$$

Due to constant returns to scale in the production function we have

$$\psi(b_i) = \varphi_i \frac{f(k_{t'+1}) - f'(k_{t'+1})k_{t'+1}}{1 - \varphi_i(1 + f'(k_{t'+1}))}.$$

It is straightforward to calculate the first derivative of ψ with respect to b_i. Note that $k_{t'+1} = \frac{1}{N}\sum_j b_j$, so $\frac{\mathrm{d}}{\mathrm{d}b_i}k_{t'+1}(b_i) = \frac{1}{N}$. Thus it holds that

$$\psi'(b_i) = \underbrace{\frac{\varphi_i f''(k_{t'+1})}{(1 - \varphi_i(1 + f'(k_{t'+1})))^2 N}}_{<0} \left[\varphi_i f(k_{t'+1}) - k_{t'+1}(1 - \varphi_i)\right],$$

and

$$
\psi'(b_i) \begin{cases} > 0 \ , & \text{if } 0 > \varphi_i f(k_{t'+1}) - k_{t'+1}(1 - \varphi_i) \\[2mm] = 0 \ , & \text{if } 0 = \varphi_i f(k_{t'+1}) - k_{t'+1}(1 - \varphi_i) \\[2mm] < 0 \ , & \text{if } 0 < \varphi_i f(k_{t'+1}) - k_{t'+1}(1 - \varphi_i) \end{cases}
$$

Due to the monotonicity of the production function, there is only one non-zero value of $k_{t'+1}$ at which it is equal to $\frac{\varphi_i}{1-\varphi_i} f(k_{t'+1})$. Thus, as b_i increases from 0 on, ψ first falls monotonically, then reaches its minimum, and from then on increases monotonically. Depending on the values of the other b_j, $j \neq i$, the capital stock $k_{t'+1}$ could already be greater than $\varphi_i f'$ when $b_i = 0$. Now taking the limit of ψ', we see that

$$
\lim_{b_i \to \infty} \psi'(b_i) = \lim_{b_i \to \infty} \frac{\beta_i}{N} f''(\beta_i f - k_{t'+1}).
$$

So if equation (16) holds, then ψ approaches some constant value. From equation (19) we know that ψ is always positive. Thus, it must have at least one intersection with the function that maps b_i to itself, which is equivalent to the existence of a solution to equation (18). □

B. Model parameters and calibration

Preferences	Elasticity parameter	η	0.96
	Preferences for consumption when old	μ_1	0.070
		μ_2	0.070
		μ_3	0.095
		μ_4	0.152
		μ_5	0.468
	Preferences for leaving bequests	β_1	0.0001
		β_2	0.0001
		β_3	0.025
		β_4	0.082
		β_5	0.398
Production	Share parameter of capital	α	0.2
	Share parameter of land	γ	0.08
	Elasticity of substitution	ϵ	0.78
	Total factor productivity	A_0	481.9
Tax rates	Capital income tax	τ_K	0.2
	Land rent tax	τ_L	0
	Bequest tax	τ_B	0
Other	Initial capital	k_0	84,000 US\$ per capita
	Initial land	l_0	9.2 land units per capita

Table B.1: Benchmark parameters that reproduce observed data on the wealth distribution in OECD countries.

	Average OECD data	Model output
GDP per capita	990,000 US$ per generation	989,780 US$ per generation
Gini coefficient	0.75	0.63
Capital	110,000 US$	98,157 US$
Capital-land ratio	1.53	1.88
Wealth holdings of the five quintiles		
Q1	2,356 US$	81,786 US$
Q2	48,790 US$	81,786 US$
Q3	136,132 US$	138,588 US$
Q4	262,057 US$	269,558 US$
Q5	922,703 US$	924,335 US$

Table B.2: Comparison of average OECD data and model output. Data taken from OECD (2015) and OECD (2016), currency in 2005 US$, one generation equals 30 years.

C. Additional figures and data
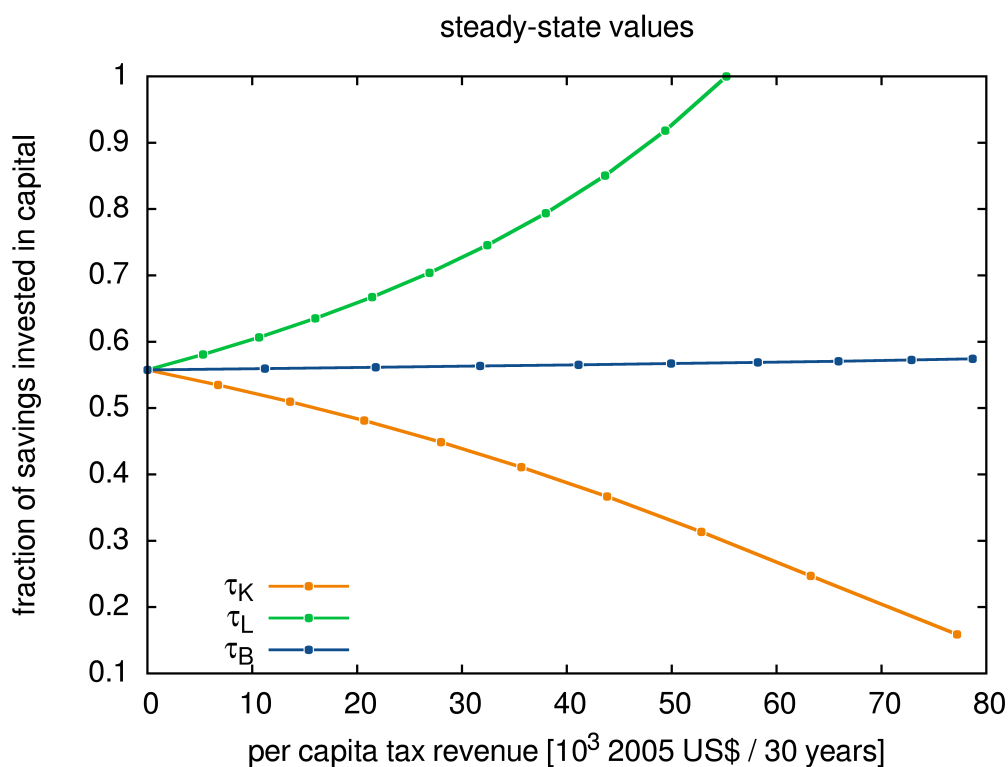
Figure C.1: Aggregate composition of assets (cf. Section 4.1) under variation of fiscal policy. Fiscal policy that stimulates (hampers) investment in capital will unambiguously increase (decrease) output. While a bequest tax only indirectly affects asset prices, taxes on capital income and land rents have a relatively strong impact. As the relative prices of assets change, households react by changing the composition of their portfolio. Since the tax on land rents shifts investment toward capital, output actually increases. The capital income tax has the exact opposite effect.
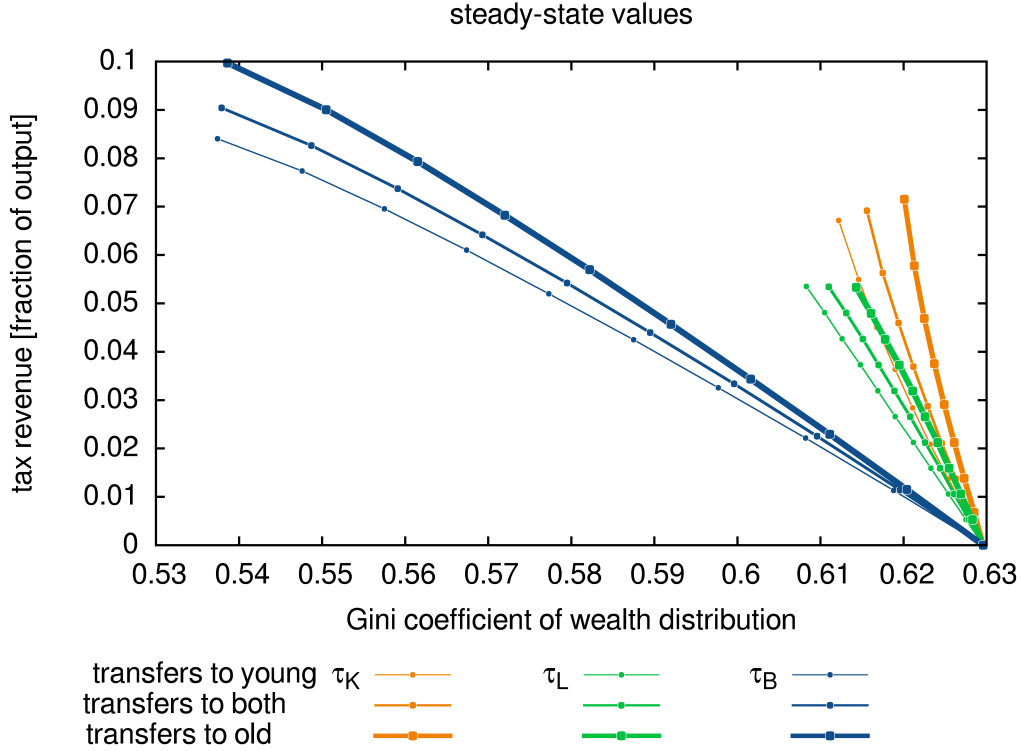
Figure C.2: The revenue raising potential of fiscal policy depends on the recycling scheme used. For all policy instruments, public revenues are higher the higher the share of transfers to the old. However, this effect makes a visible difference only in the case of the bequest tax τ_B. Figure 3 shows how the choice of the transfer scheme affects output.

	tax rate	tax revenue			output		
		τ_K	τ_L	τ_B	τ_K	τ_L	τ_B
$\epsilon = 0.58$	0.2	11	6	22	990	999	993
	0.5	24	29	52	977	1007	990
	0.7	53	40	71	959	1013	987
$\epsilon = 0.94$	0.2	32	10	19	990	1016	996
	0.5	78	25	39	947	1026	975
	0.7	105	35	44	896	1034	962

Table C.3: Steady-state level of tax revenues and output per capita [10^3 2005 US\$ / 30 years] for variation of substitution elasticity ϵ under subsequent recalibration of all other parameters.
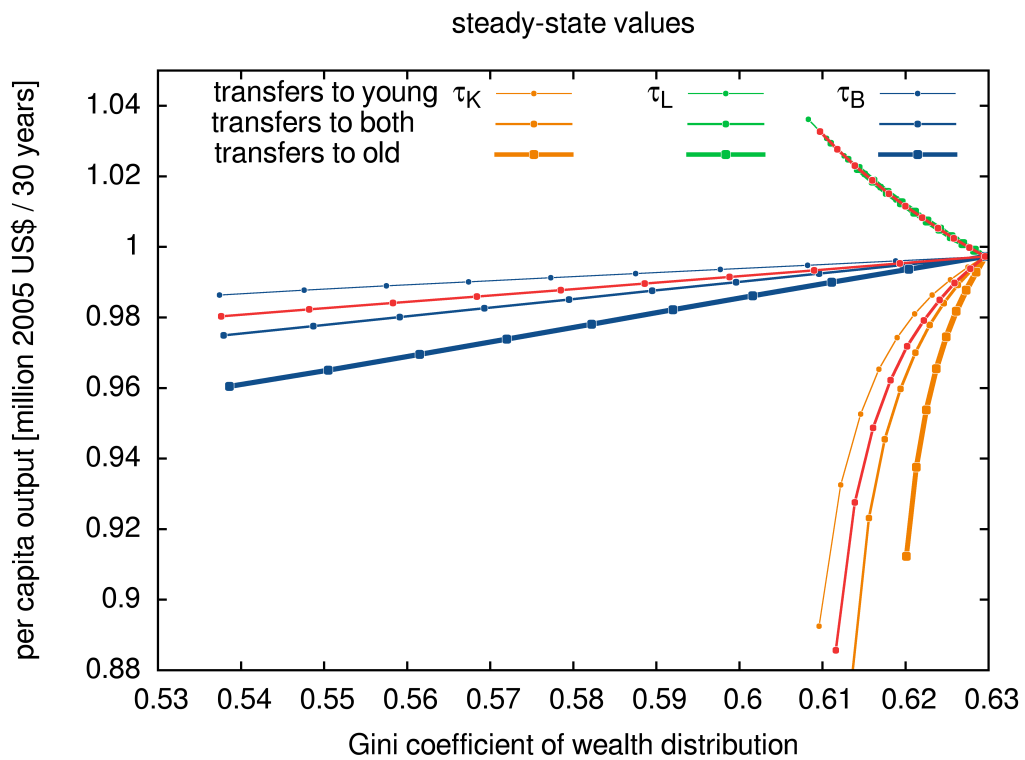
Figure C.3: Impact of different recycling schemes on output and on the wealth distribution (cf. Figure 3). The red lines mark the option space for the case in which public revenues are not redistributed.

D. Kaldor-Hicks criterion

Even though we find that recycling all public revenues to the young as lump-sum transfers enhances output and reduced inequality, a Pareto improvement is not possible. However, we find that at least there are cases in which the Kaldor-Hicks criterion is fulfilled. Consider, for instance, the case in which all land rents are skimmed off and redistributed to the young ($\tau_L = 1$, $\delta = 0$) shown in Figure D.4. Absent any additional transfer mechanism between winners and losers, the households belonging to the first old generation always bear the burden, except those in the lowest wealth quintile $i = 1$, whose utility does not change under the 100% land rent tax. Further, not only the first old generation, but in fact all generations belonging to the top wealth quintile $i = 5$ suffer under the tax.
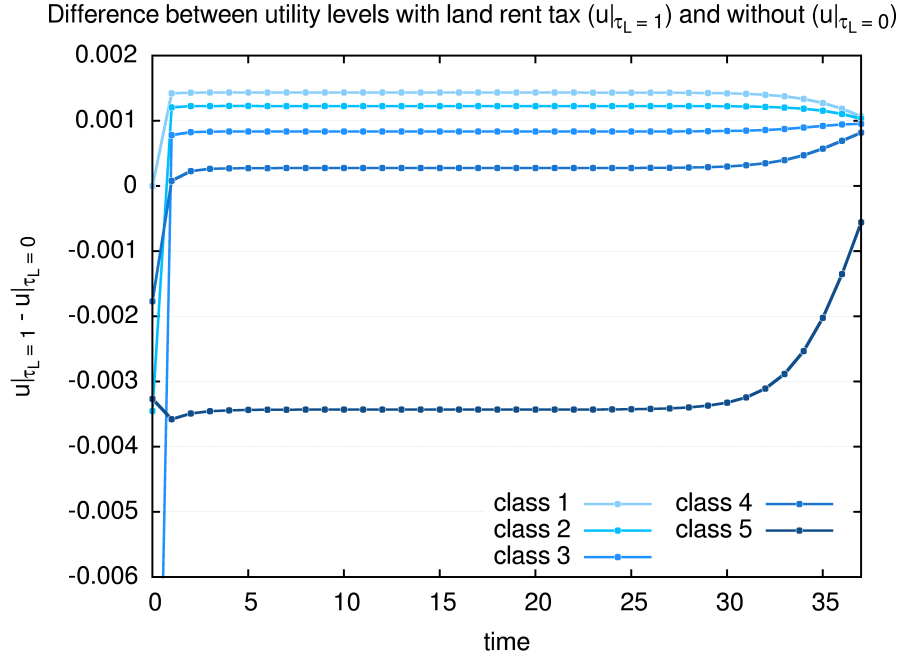
Figure D.4: When land rents are taxed at 100% and recycled as lump-sum transfers to the young, the first old generation and the richest households bear the burden. Their utility under taxation is less than without taxation, i.e., $u|_{\tau_L=1} - u|_{\tau_L=0} < 0$. All other households benefit from the policy.

Now, we introduce a mechanism which allows intertemporal transfers between households. Instead of the lump-sum transfers from public revenues g_t, young and old households may now receive a transfer or have to pay a lump-sum tax X. Their budget equations thus are

$$c^y_{i,t} + s_{i,t} = w_t + b_{i,t}(1 - \tau_B) + X^y_{i,t}$$

$$c^o_{i,t} + b_{i,t} = (1 + R_t(1 - \tau_K))k^s_{i,t} + l_{i,t}(p_t + q_t(1 - \tau_L)) + X^o_{i,t}.$$

Further, we assume that funds can be shifted over time via banking and borrowing at the market interest rate R. Then, for the total volume of the transfers it has to hold that

$$\sum_t \frac{g_t}{\Pi_{s=1}^t (1 + R_s)} \geq \frac{1}{N} \sum_{i,t} \frac{X_{i,t}^y + X_{i,t}^o}{\Pi_{s=1}^t (1 + R_s)}.$$

Our numerical experiments confirm that there are feasible combinations of $\{X_{i,t}^y, X_{i,t}^o\}_{i=1,\ldots,N,\ t=1,\ldots,T}$ such that the winners of the 100% land rent tax can compensate the losers, i.e., that

$$u_{i,t}|_{\tau_L=1} \geq u_{i,t}|_{\tau_L=0} \quad \forall i, t.$$

E. Supplementary material

The material in this section is intended to be published as separately available electronic supplementary material. It contains background information about the model on which the analysis is based.

E.1. Basic dynamic model properties

We observe that the model described in Section 3.1 converges to a steady state. Figure E.5 exemplarily shows the transition of the households' wealth to the respective steady state levels. Analogous results hold for all other variables including the price of land p_t (see Figure E.6). The land price may be formulated as a sum of future rents – recall equation (15). This suggest that the land price might vary over time and the observed steady-state may not be well defined. However, due to discounting, those rents that lie in the more distant future are discounted to such an extent, that also the land price remains constant and the observed steady state is well behaved.
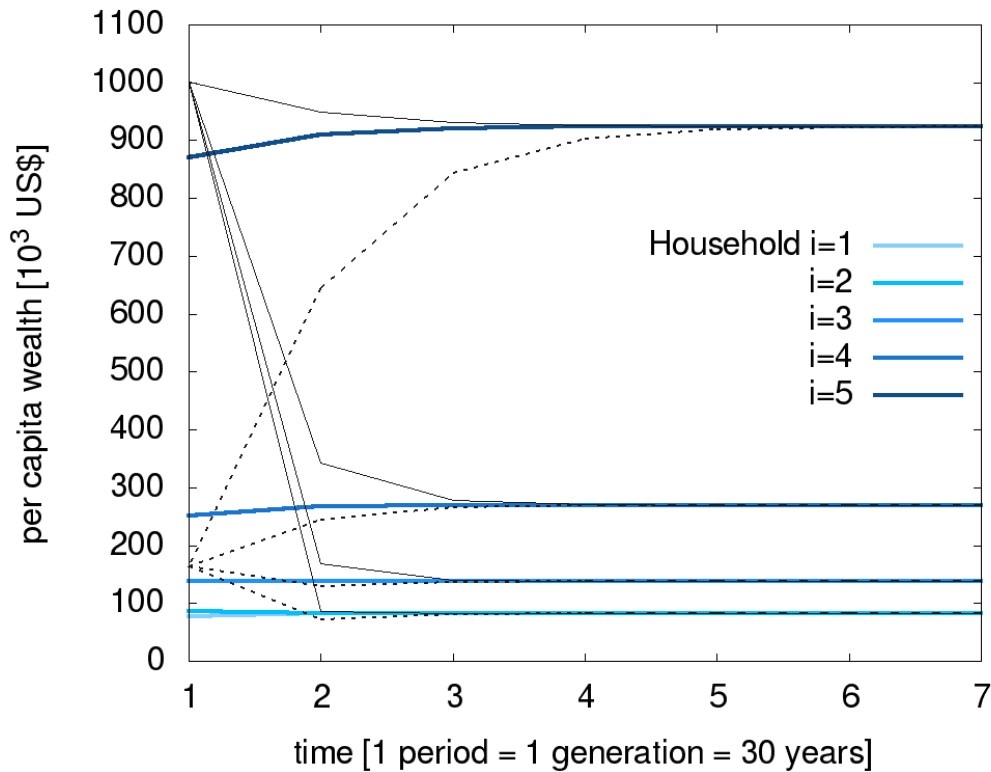
Figure E.5: Transition of wealth distribution to steady state for heterogeneous (bold lines) and identical initial distribution of wealth (thin lines).

Moreover, we also observe that the steady state is independent of the initial values of the households' wealth. Regardless of whether the initial wealth is distributed equally among all types of households or not, and regardless of the initial level of capital, the systems converges to the same steady state.

The convergence behavior is robust under an extensive variation of the model parameters. It is consistent with the result that the simple model described in Section 2 has a steady state (Corollary A). Furthermore, it is also consistent with Mountford (2004) who shows the existence of a steady state for a more simple model of an overlapping generations economy with land, but without bequests and heterogeneous agents. Due to the complexity
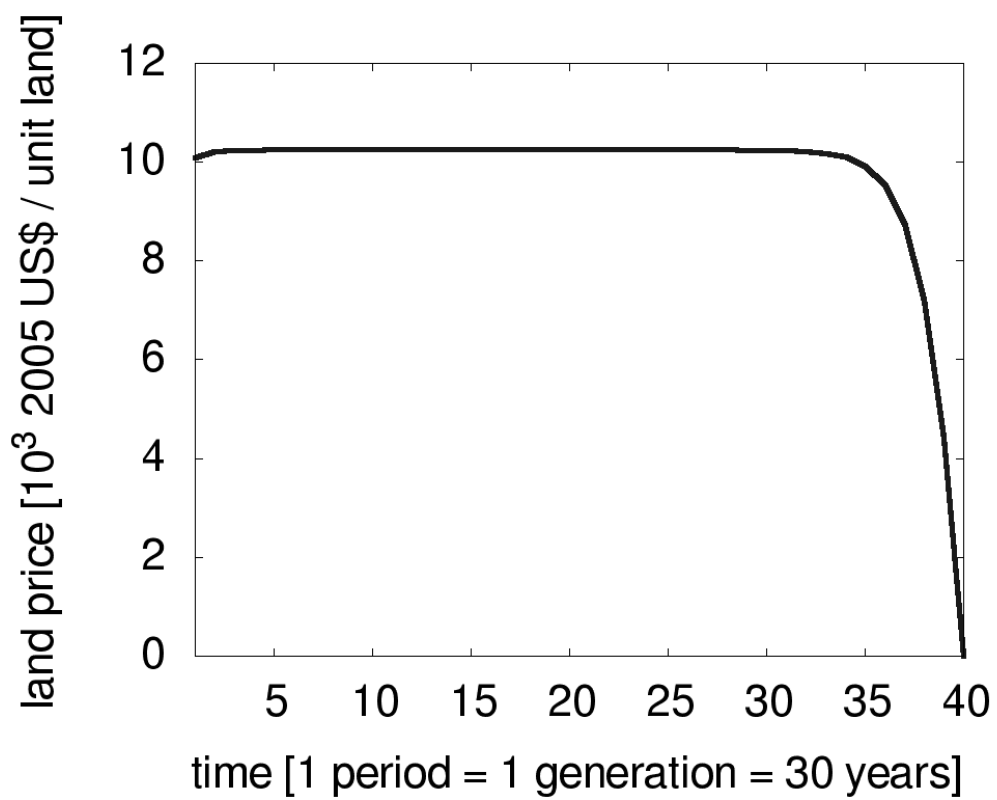
Figure E.6: Analogous to all other variables, for example household wealth (see Figure E.5), also the land price converges to a steady state.
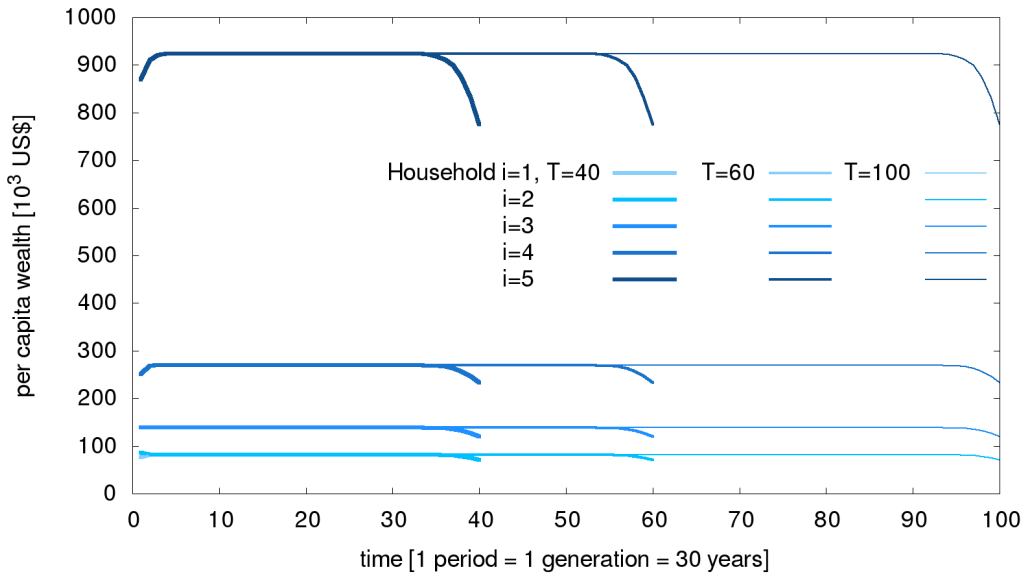
Figure E.7: The steady state is independent of the exact number of periods.

of our model, we cannot apply the analytical approach of the latter author and thus cannot provide closed form solutions.

Finally, since we solve the model numerically, we approximate the infinite time horizon of the underlying analytical model by a relatively high number of periods. The numerical model thus has only a finite number of periods, and in a small region near the final period T, the system departs from the steady state. Nevertheless, we are able to show that the steady state to which the system converges is independent of the exact number of periods, as Figure E.7 shows.

E.2. Robustness checks and sensitivity analysis

In this section we discuss the robustness of our main results with respect to different assumptions about model specifications. In Section E.2.1, we describe how the policy option space (cf. Figure 1) changes under different

49

parameter choices. Then, in Section E.2.2, we discuss the alternative assumption that the government finances infrastructure investments with the tax revenues – instead of recycling them as lump-sum transfers.

E.2.1. Sensitivity analysis of the impacts of fiscal policy

We have calibrated the model parameters to match observed data on the distribution of wealth in OECD countries (OECD, 2015) under the assumption that the capital income tax rate τ_K is 20%, while land and bequests are not taxed – we shall refer to this as the standard policy case. To test the sensitivity of our results to the parameter choice, we have performed a one-at-a-time variation of all model parameters. For each variation of one specific parameter we have subsequently recalibrated all other parameters such that the standard policy case reproduces the observed data again.

For most tested parameters, we find that a variation has no significant qualitative nor quantitative effect on our results. However, the elasticity parameters of the utility function η and of the production function ϵ reveal a non-trivial relationship between parameter choice and model results. Thus, in the following we only present the results of separate variations of η and ϵ. Neither the simultaneous variation of the latter two parameters, nor simultaneous variations of multiple other randomly chosen parameters provided any further insights.

E.2.1.1   Utility function

The elasticity parameter of the utility function η has a significant impact on the distribution of wealth and, moreover, on output, even when taxes
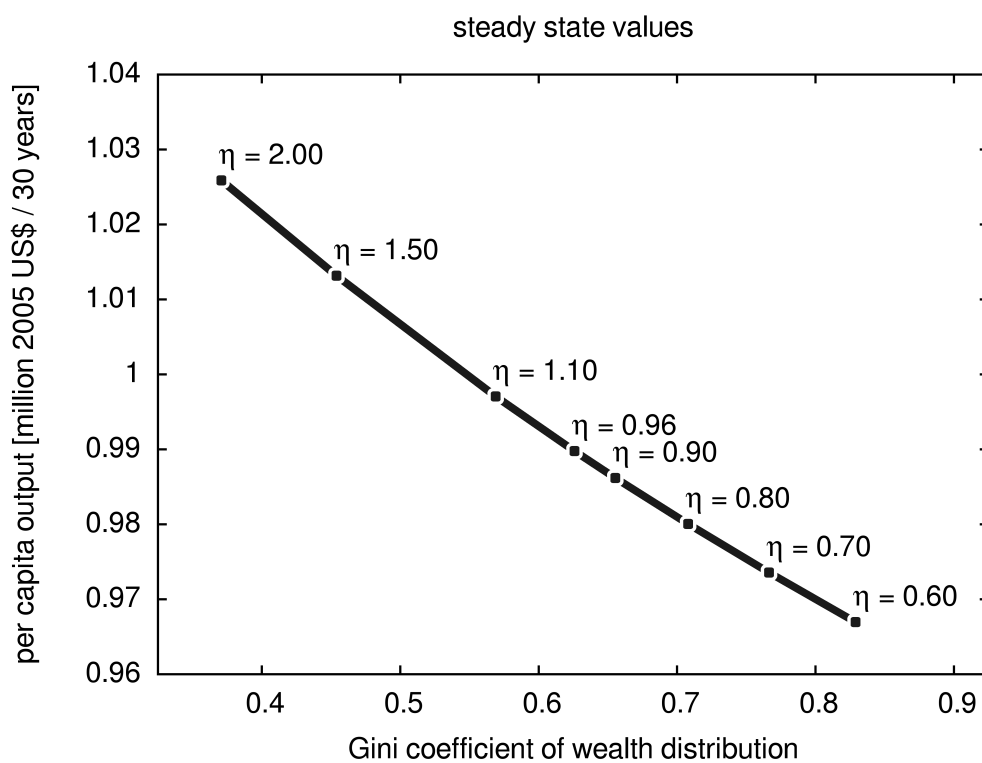
50

steady state values

Figure E.8: Variation of preference parameter η without recalibration to observed data. Benchmark case: $\eta = 0.96$.

are not taken into account. Ceteris paribus, the steady state level of output increases with η, while the Gini coefficient decreases (see Figure E.8). The reason is that households' substitution behavior depends on η. The first-order conditions (12) and (13) determine the relative demand for consumption and bequests. Consequently, higher values of η induce poorer households to save more, while it does not discourage rich households from leaving bequests (Table C.3 shows how households allocate their income for the two extreme values of our variation of η). Taken together, an increase in η increases total wealth, in particular capital, and thus also output.

Now, consider the parameter variation under recalibration of all other

	Household i	$\eta = 0.6$	$\eta = 2$	Change induced by an increase of η
Consumption when young $(c^y)^*$	1	829.2585	739.187	-10.86%
	2	829.2585	739.187	-10.86%
	3	821.8775	738.3317	-10.17%
	4	807.0379	715.0366	-11.40%
	5	728.4397	629.3391	-13.60%
Consumption when old $(c^o)^*$	1	26.7518	221.8373	729.24%
	2	26.7518	221.8373	729.24%
	3	44.0329	258.0221	485.98%
	4	94.7063	316.1662	233.84%
	5	554.4741	487.6745	-12.05%
Bequests b^*	1	0.0005	8.3727	1674440.00%
	2	0.0005	8.3727	1674440.00%
	3	4.7676	132.4384	2677.88%
	4	33.8988	232.3042	585.29%
	5	423.0243	449.6506	6.29%

Table E.4: Consumption and bequests for low and high values of elasticity parameters. The third column reports the percentage change induced by an increase of η from a low value of 0.6 to a high value of 2. The benchmark value of η is 0.96.

parameters. Figure E.9 shows that the behavior of the economy in reaction to fiscal policy is sensitive to changes in the elasticity parameter. First, note that the potential to redistribute wealth with the capital income or the land rent tax increases with the elasticity parameter η. This is because increasing η implies that the tax-induced reduction in the after tax rate of return to savings $1 + R^*(1-\tau_K) = 1 + \frac{q^*}{p^*}(1-\tau_L)$ induces a stronger behavioral response. In our model, for higher η, richer households reduce their savings more strongly in reaction to increases in capital income or land rent taxes than poorer households.

In contrast, the government's scope for wealth redistribution via the bequest tax decreases as η increases. The bequest tax is progressive due to the income effect it induces.[14] For higher values of η, however, the substitution effect of bequest taxation gains in importance relative to the income effect, and thus, the bequest tax becomes less progressive.

Further, Figure E.9 reveals that reactions to the bequest tax in term of steady-state levels of output are qualitatively different for different values of η. When η is relatively high, the bequest tax has the tendency to increases output, in particular for higher tax rates. The opposite is the case for lower values. The variation illustrated in Figure E.9 shows us how η determines the relative size of income and substitution effects of the bequest tax (see also the discussion in Section 4.1.1). For high η, the tax-induced substitution effect of bequest taxation outweighs the income effect, households redirect their income away from consumption towards leaving bequests. Thereby they

---

[14] As explained in Section 4.1.1, rich households' income includes a higher proportion of bequests. Bequest taxes thus reduce their income by a higher factor than the incomes of poorer households.
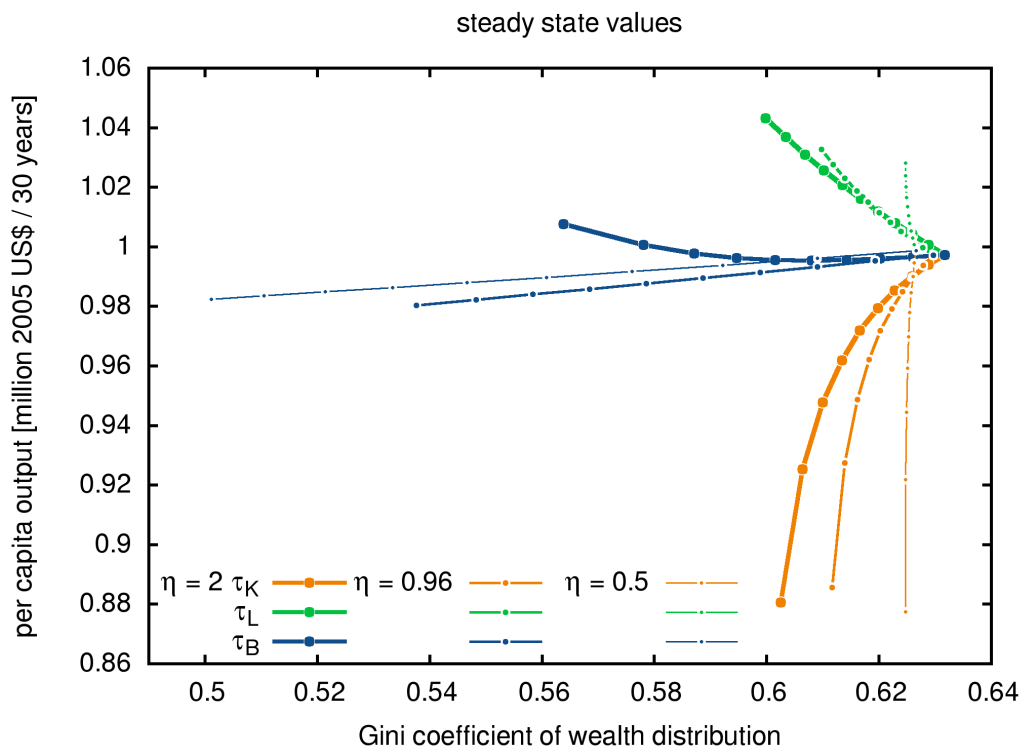
Figure E.9: Policy-option space under variation of preference parameter η and subsequent recalibration of all other parameters such that the case of $\tau_K = 0.2, \tau_L = \tau_B = 0$ remains invariant under the variation of η.

save more, which implies more capital, and thus a higher output level. For low η the opposite is the case.

Finally, in Figure E.10 we see that the potential to raise public revenues with the bequest tax τ_B strongly depends on the choice of the elasticity parameter η. The higher η is, the greater the revenue raising potential of the bequest tax becomes. In contrast, revenues from capital income and land rent taxation remains almost unchanged when η changes.

The mechanism that drives this behavior is again the interplay of the income effect and the substitution effect of bequest taxation. For a high elasticity parameter η, the substitution effect outweighs the income effect. In that case, increasing the bequest tax also increases the demand for leaving bequests, and thus increases the tax base. In analogy, for low values of η, the opposite is the case.

E.2.1.2 Production function

Figure E.11 shows that varying the substitution elasticity ϵ (and subsequently recalibrating all other parameters) has no greater qualitative impact. However, the graph shows clearly the intuitive result that varying the elasticity does change the results quantitatively. The higher the substitution elasticity is, the greater is the impact of bequest and capital income taxes on output and the wealth distribution. In contrast, the impact of land rent taxation on the wealth distribution is slightly reduced.

Varying ϵ changes the elasticity of capital supply with respect to capital income and bequest taxes. Hence, we observe a relatively strong increase in the impact of the two instruments if ϵ is increased. Since land is a fixed
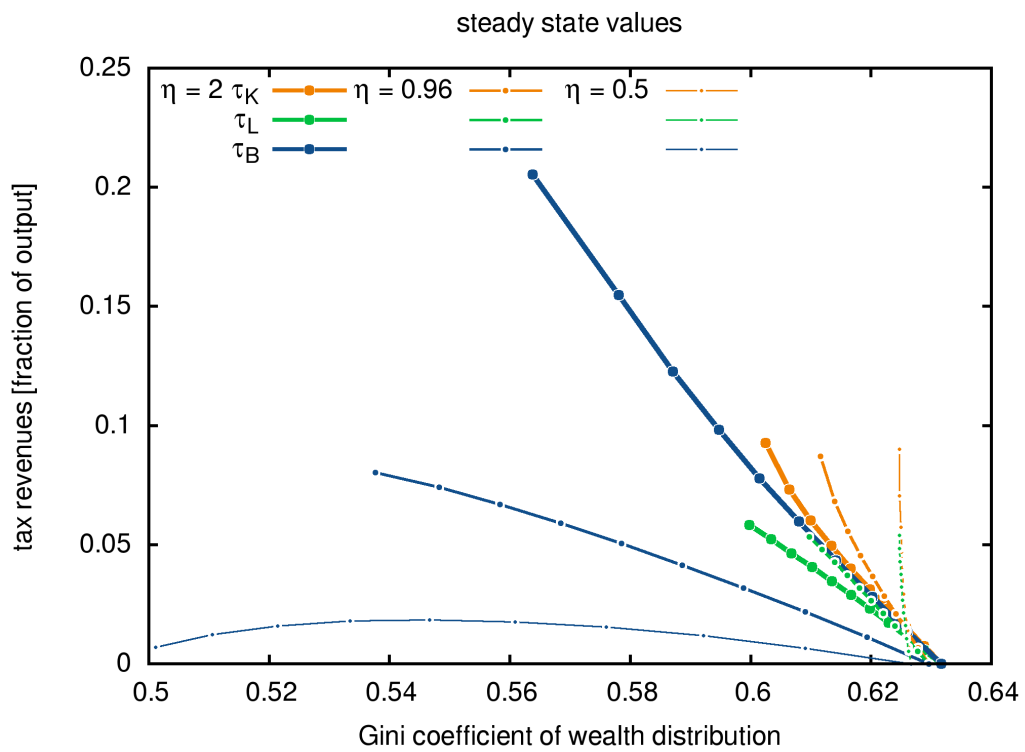
Figure E.10: Tax revenues and Gini coefficient under variation of preference parameter η and subsequent recalibration of all other parameters such that the case of $\tau_K = 0.2, \tau_L = \tau_B = 0$ remains invariant under the variation of η.
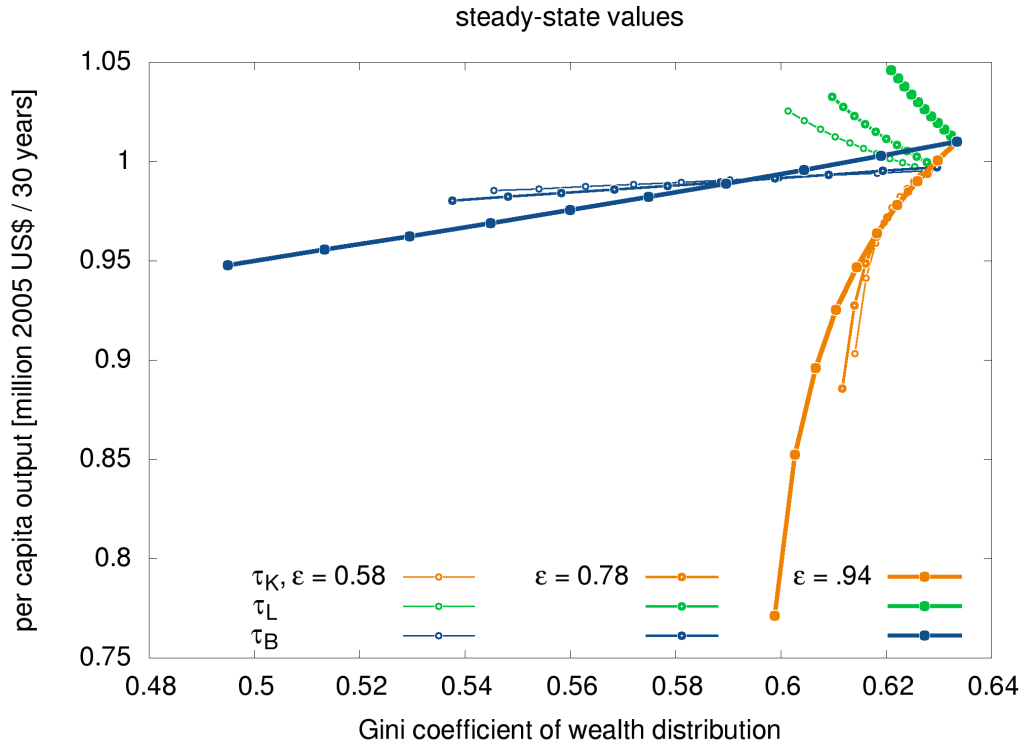
Figure E.11: Policy-option space under variation of substitution elasticity ϵ and subsequent recalibration of all other parameters such that the case of $\tau_K = 0.2, \tau_L = \tau_B = 0$ remains invariant under the variation of ϵ. Benchmark case: $\epsilon = 0.78$.

factor, changes in the effects of land rent taxation are much less pronounced when ϵ is varied.[15]

The elasticity of substitution determines the potential to raise public revenues in a similar way (see Figure E.12 and Table C.3 in Appendix C). Thus, the potential of the land rent tax remains invariant. Under relatively high values of ϵ, the bequest tax has a higher tendency to erode its tax base. Consequently, increasing ϵ reduces the tax revenues collected with the

---

[15]For a mathematical derivation of the demand functions for factor inputs, see for example Allen (1938), p. 369 ff.
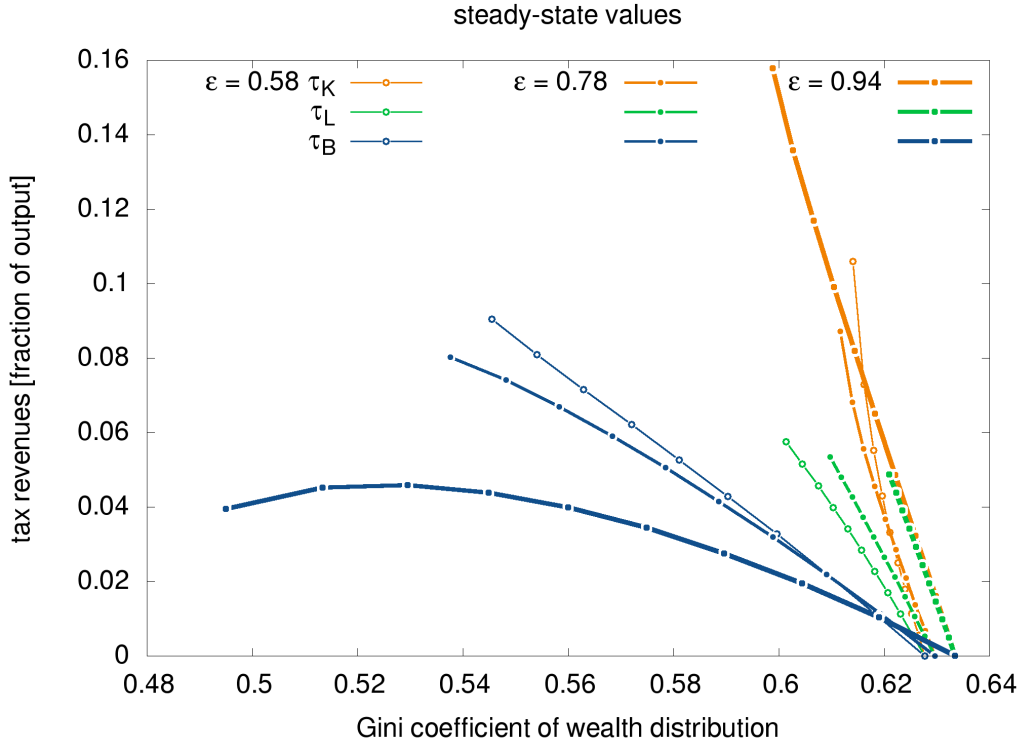
Figure E.12: Tax revenues and Gini coefficient of wealth distribution under variation of substitution elasticity ϵ and subsequent recalibration of all other parameters such that the case of $\tau_K = 0.2, \tau_L = \tau_B = 0$ remains invariant under the variation of ϵ. Benchmark case: $\epsilon = 0.78$.

bequest tax. Finally, the capital tax also erodes its tax base more strongly under higher values of ϵ. However, the decrease of the capital stock k^* is less than the increase of the interest rate $R^* = f_k(k^*)$. Therefore, capital income tax revenues $k^* R^* \tau_K$ increase if the elasticity of substitution ϵ increases.

E.2.2. Alternative spending option: Infrastructure investments

In Section 4.2 we considered different ways of recycling tax revenues as lump-sum transfers to the households. Here, we briefly show how results change under the alternative assumption that the government spends tax revenues to

enhance firms' productivity, for example through infrastructure investments. In line with the literature on economic growth, we assume the following relationship between public revenues and total factor productivity A:

$$A_t = A_0 \psi_1 (g_t + \psi_2)^{\psi_3}$$

We choose the baseline values of the parameters ψ_i, $i = 1, 2, 3$ to roughly reproduce the base case without public spending. Then, varying the parameters ψ_i, $i = 1, 2, 3$ one at a time does not reveal any unexpected or unintuitive effects. Increasing the effectivity of infrastructure investments, i.e. increasing ψ_i for any i raises output, reducing the effectivity also reduces output. All tax instruments remain progressive in their impact on the distribution of wealth. The land rent tax unambiguously increases output due to the portfolio effect discussed above. The other taxes are never able to raise output levels above the levels that can be achieved with the land rent tax. Under certain parameter choices for ψ_i, $i = 1, 2, 3$, the bequest tax and the capital tax reveal an inverted U-shape. That shape is due to the fact that for low tax rates, the marginal benefit of additional infrastructure investments is higher than the marginal costs and vice versa for relatively high rates.

The impact of varying the parameters ψ_i on output and the distribution of wealth are summarized in Figures E.13. The specific values in the variation are listed in Table E.5.
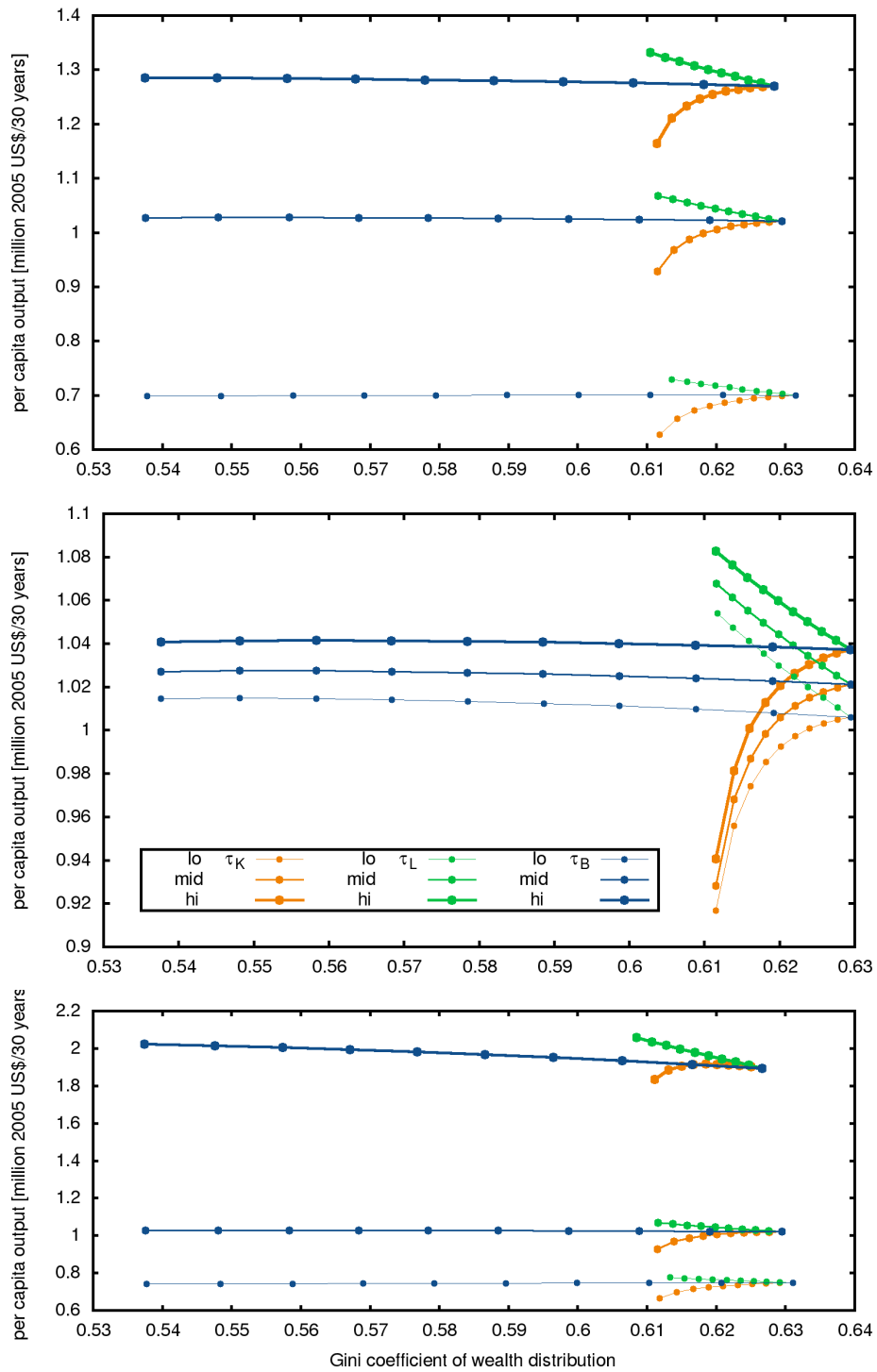
Figure E.13: Impact of different degrees of effectivity of infrastructure on output and the wealth distribution (low, middle and high values of ψ_1 in upper panel, of ψ_2 in middle panel, and of ψ_3 in lower panel).

	lo	mid	hi
ψ_1	0.4	0.57	0.7
ψ_2	300	345	400
ψ_3	0.05	0.1	0.2

Table E.5: Values used in sensitivity analysis of infrastructure.