Originally published as:

Franks, R. M., Klenert, D., Schultes, A., Lessmann, K., Edenhofer, O. (2018): Is capital back? The role of land ownership and savings behavior. - International Tax and Public Finance, 25, 5, 1252-1276.

DOI: https://doi.org/10.1007/s10797-018-9486-3

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

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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

*This is a post-peer-review, pre-copyedit version of an article published in *International Tax and Public Finance* available online at dx.doi.org/10.1007/s10797-018-9486-3

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1 Introduction

Recent empirical findings on wealth and its distribution can be summarized by the following 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 $\overline{r} = r(1 - \tau)$ and the growth rate of the economy g. A higher gap $\overline{r} - g$ implies more inequality, higher capital taxes τ imply less inequality. Piketty thus calls for a progressive capital tax.

However, most evidence shows that capital taxes discourage investment and reduce economic growth.[2] Moreover, in the common approach there is no

[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

distinction between capital and wealth (Homburg, 2015), which is inconsistent with empirical findings and leads to contradictory model results as Stiglitz (2016) points out. Stiglitz highlights the absence of land rents, 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, and determine how output is affected by these instruments. Further, we assess how different degrees of progressivity of the tax schemes affect output and the distribution of wealth. 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] We confirm the intuitive result

example of an incomplete set of fiscal instruments" as Chari, Nicolini, and Teles, point out in their manuscript *More on the taxation of capital*.

[3]In contrast to Stiglitz (2016), 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

that progressive tax schemes imply a more equal distribution. Quantitatively, this effect is relatively small for bequest taxes, but in agreement with Fernholz (2017), we find that progressive capital taxes have a relatively high potential to redistribute wealth. Moreover, a higher degree of progressivity also implies a slightly higher steady-state level of output for both bequest- and capital taxes. Finally, recycling revenues to the young generation instead of the old enhances output and reduces inequality.

To derive our results, we implement an overlapping generations model that includes the missing features listed above. In particular, due to the general equilibrium structure, asset prices are endogenous, which is crucial for the purpose of the present paper, since prices matter for a comprehensive policy instrument analysis. In Section 2 we describe this model in greater detail. We perform the policy instrument analysis in Section 3, which yields the main results of our paper. Sensitivity and robustness of our results are tested in Section 4, followed by a more general discussion of our approach in Section 5. Section 6 concludes.

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the portfolio effect by introducing a social welfare function as a normative benchmark for evaluating fiscal policy, in particular land rent taxes. The present paper, in contrast, takes a positive approach and focuses on the economic impacts of fiscal policy. Hence, we do 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 C).

2 An overlapping generations model with bequest heterogeneity and land

We begin by describing our model of overlapping generations. Then, in Section 2.2, we briefly explain our calibration.

2.1 Model description

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.

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. 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.[5] Further, we shall assume that one time step represents a period of 30 years (one generation). All variables are stated in per capita terms.

[5]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.

2.1.1 Households

The utility of households is given by an isoelastic function with elasticity parameter η. A household derives utility from consumption when young $c^y_{i,t}$, consumption when old $c^o_{i,t+1}$, and the "warm glow" (Andreoni, 1989) of leaving net-of-tax bequests to their children $b_{i,t+1}(1-\tau_B)$:

$$u\left(c^y_{i,t}, c^o_{i,t+1}, b_{i,t+1}\right) = \frac{(c^y_{i,t})^{1-\eta} + \mu(c^o_{i,t+1})^{1-\eta} + \beta_i\left(b_{i,t+1}(1-\tau_B)\right)^{1-\eta}}{1-\eta} \tag{1}$$

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

$$c^y_{i,t} + s_{i,t} = w_t + b_{i,t}(1-\tau_B) \tag{2}$$

$$s_{i,t} = k^s_{i,t+1} + p_t l_{i,t+1} \tag{3}$$

$$c^o_{i,t+1} + b_{i,t+1} = (1 + R_{t+1}(1-\tau_K))k^s_{i,t+1} + l_{i,t+1}(p_{t+1} + q_{t+1}(1-\tau_L)) \tag{4}$$

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 expressed in (4). 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, further numerical experiments showed that the results we obtain are independent of whether labor supply is fixed or endogenous (not shown). 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 (2) - (4) and

$$(c^o_{i,t+1})^\eta = \mu(1 + R_{t+1}(1 - \tau_K))(c^y_{i,t})^\eta \tag{5}$$

$$\beta_i(1 - \tau_B)^{1-\eta}(c^o_{i,t+1})^\eta = \mu b^\eta_{i,t+1} \tag{6}$$

$$\frac{p_{t+1} + q_{t+1}(1 - \tau_L)}{p_t} = 1 + R_{t+1}(1 - \tau_K). \tag{7}$$

To gain a better intuition for the model and in particular how land prices are determined, note that the no-arbitrage condition (7) could also be reformulated as the discounted sum of future rents (to see this, use induction):

$$p_t = \sum_{i=1}^{T-t} \frac{\widetilde{q}_{t+i}}{\prod_{j=1}^{i}(1 + \widetilde{R}_{t+j})}, \tag{8}$$

where $\widetilde{q}_t := q_t(1 - \tau_L)$ and $\widetilde{R}_t := R_t(1 - \tau_K)$. The no-arbitrage condition (7) 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.[6]

2.1.2 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 has constant elasticity of substitution. In intensive form it is defined as

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

where A_0 is total factor productivity, A_k is capital productivity, and $\sigma = \frac{\epsilon-1}{\epsilon}$ is determined by the elasticity of substitution ϵ. The total stock of capital k_t that the firm uses in production in period t equals the aggregate of capital $k^s_{i,t}$ that is supplied by households in period t and the stock of capital k_{t-1} that is left from the previous period net of depreciation δ_k. Thus, clearing of the factor markets is given by

$$k_t = \frac{1}{N}\sum_{i=1}^{N} k^s_{i,t} + \delta_k k_{t-1} \quad \text{and} \quad l = \frac{1}{N}\sum_{i=1}^{N} l_{i,t}.$$

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

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

[6] 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 $X_t = k^s_{i,t}/l_{i,t}$ 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 that have no bearing on any of our results.

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

2.1.3 Government

The government levies taxes on capital income τ_K, land rents τ_L, or bequests τ_B. Throughout Section 3.1, we assume that public revenues g_t are used for public consumption which has no effect on the economy. In Section 3.2 we relax this assumption and analyze alternative recycling schemes.

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

2.2 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.[7] Since we cannot obtain closed form 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 percentage 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

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

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, η) and production technology (α, γ, ϵ, A_0, A_k), and the initial endowments (k_0, l_0) are summarized in Table A.1 in Appendix A. A comparison of the data with the model output can be found in Table A.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.

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 4 summarizes our findings and presents a detailed analysis of those parameters that have a non-trivial effect on our results.

3 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 we found that the transition from the initial state to the steady state revealed no additional insights.

In Section 3.1, 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 3.2, in which we consider different ways of using the public funds generated by fiscal policy.[8] 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 are given to the old generation.

3.1 The revenue side of fiscal policy

We begin by characterizing the policy-option space associated with the three different tax instruments. Then, in Section 3.1.2, we demonstrate that there is a range of output-neutral tax reforms, consisting of different combinations of taxes on land rents and bequests. Finally, in Section 3.1.3, we briefly discuss

[8] Similar to Davies (1986), we can thus separate two different effects of taxation: We first analyze only the distorting effect of different taxes on households' investment behavior, and do not take into account the effect caused by the redistribution of the tax revenues to the households as transfers. Only in the second step we also consider the impact of the government's transfers. In contrast to Davies (1986), however, we always allow for general equilibrium effects.

the impact of implementing progressive tax schemes.

3.1.1 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 $\{v_i^*\}_{i=1,\ldots,5}$, 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 1.17 million US$ per time period (30 years) and the Gini coefficient of the wealth distribution has a value of about 0.74. This point is marked by the intersection of the two dashed lines.

As the tax rates are increased, respectively, we observe that all taxes reduce wealth inequality as measured by the Gini coefficient.[9] 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.

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 distribution of wealth will change accordingly. It turns out that the capital

[9]In Section 3.2, we will discuss conditions under which capital income and bequest taxes may *increase* inequality.

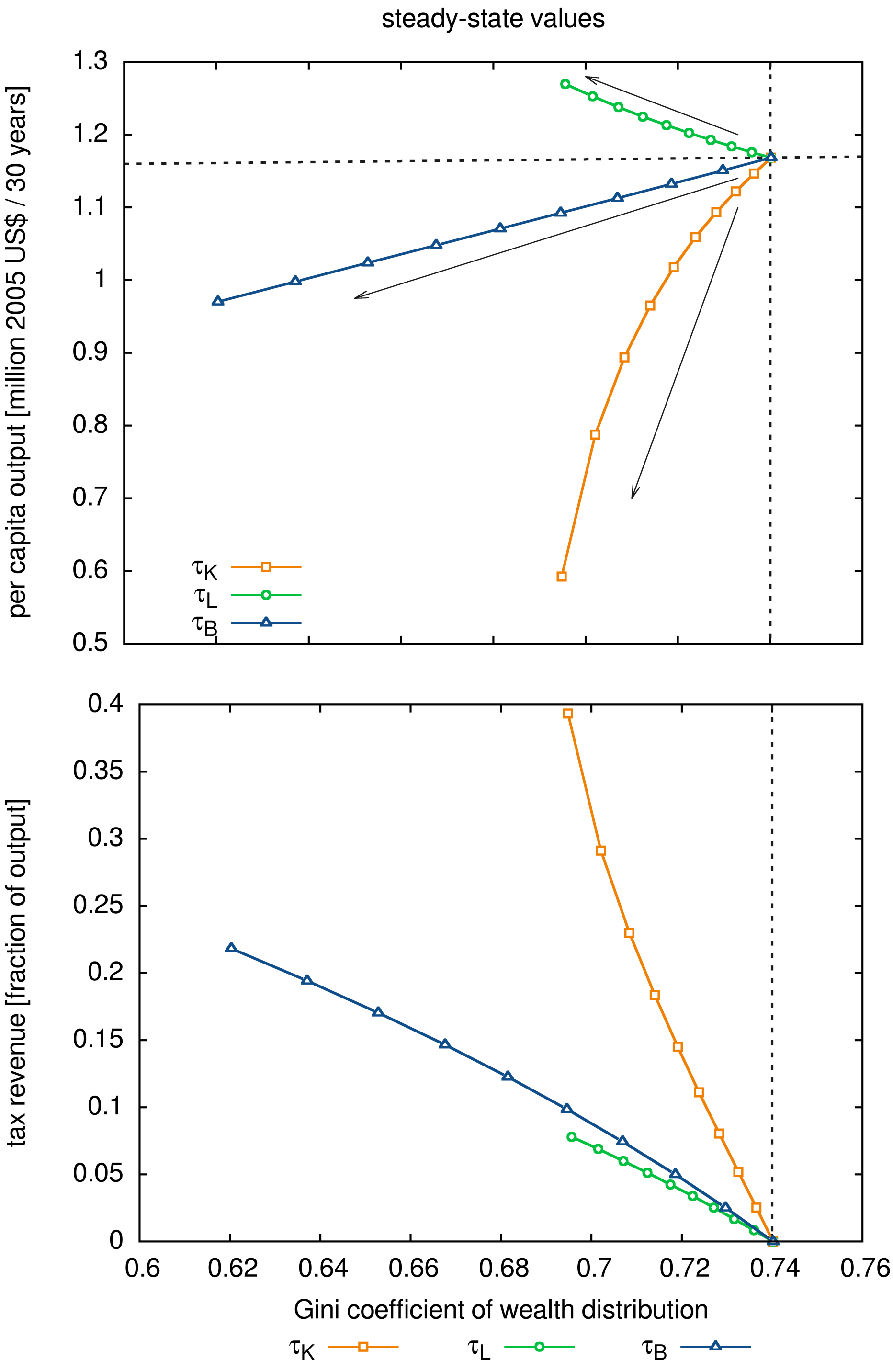

Figure 1: Depending on which tax instrument is used, the government may achieve different coordinates in the policy-option space of output, redistribution, and public revenue. Each curve represents the set of coordinates which are achievable with the use of one single tax instrument. The arrows in the 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 90%.

	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	0.944	1.019	0.96	0.682	1.09	0.83
	2	0.942	1.017	0.95	0.677	1.08	0.81
	3	0.938	1.012	0.94	0.663	1.05	0.76
	4	0.931	1.004	0.92	0.644	1.02	0.79
	5	0.897	0.964	0.83	0.557	0.88	0.48
Bequests b^*							
	1	0.907	0.975	1.061	0.566	0.894	1.26
	2	0.905	0.973	1.055	0.562	0.886	1.23
	3	0.901	0.968	1.041	0.550	0.867	1.15
	4	0.895	0.961	1.021	0.535	0.842	1.06
	5	0.863	0.922	0.923	0.462	0.723	0.73

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 fraction 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.

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 taxation*. Households whose income consists of a comparably high share of bequests are affected more strongly by the income effect of bequest taxation 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. If the rates of taxes on capital income and land rents are changed, the relative prices of assets change. Thus, households react to such changes by adjusting the composition of their asset portfolio – a *portfolio effect* takes place. A graphical exposition of this portfolio effect is given in Appendix B, Figure B.1. The portfolio effect induced by a tax on land rents consists of a shift of households' investments toward capital. The amount of land used in production never changes as it is a fixed factor. Hence, output actually increases under an increase of the land rent tax due to the increased investment in capital. Analogously, the portfolio effect induced by a capital tax leads to the opposite result – output decreases.

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 (5) and (6). We shall refer to this as the *substitution effect of bequest taxation*, since the bequest tax induces households to substitute bequests for consumption.

[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.

Table 1 reveals that for the richest households the income effect outweighs the substitution effect of bequest taxation, as their bequests drop under an increase of the bequest tax. For the other households, the opposite 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%. Households belonging to the lowest quintile, by contrast, *increase* their bequests by 6.1% in reaction to 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 4 and the supplementary material).

3.1.2 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

[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 circles marking the data points – with the coordinates in the policy-option space that

combinations of bequest and land rent tax rates that do not reduce the steady state level of output below the level of the benchmark case in which $\tau_K = 0.2$, 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 (OECD, 2017).

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 0.73 down to 0.6.[12] Public revenues increase from 5% to about 26% of output, as Table 2 shows.

3.1.3 Progressive taxation

For the main results presented so far we have made the assumption that all households face the same tax rate, independent of their position in the wealth distribution. Thus, we have been able to transparently illustrate the general impact of different taxes on the wealth distribution and on output, as well as the portfolio effect. However, one prominent aspect of the debate about the right policy response to rising inequality is progressive taxation of wealth. Piketty (2014), for example, calls for a progressive capital tax, which only recently has been assessed in a rigorous mathematical approach by Fernholz (2017). Fernholz finds that levying a small capital tax on the top 1% of the

can be reached with the bequest tax – the blue curve with triangles as data points. When implementing a mix of both taxes it is likely that the coordinates that can be thus reached lie between the green (circles) and the blue (triangles) curve.

[12]The difference of 0.13 is a little bit less than the difference between the wealth distributions of the USA (with 0.93, the highest inequality within the sample given by OECD, 2015), and France or Finnland (both 0.77). The difference of 0.13 corresponds to the difference between the Slovak Republic (with 0.52, the most equal country in the sample), and Greece (0.65). The Gini coefficients of all countries for which OECD (2015) reports wealth distributions are given in Table B.3 in Appendix B.

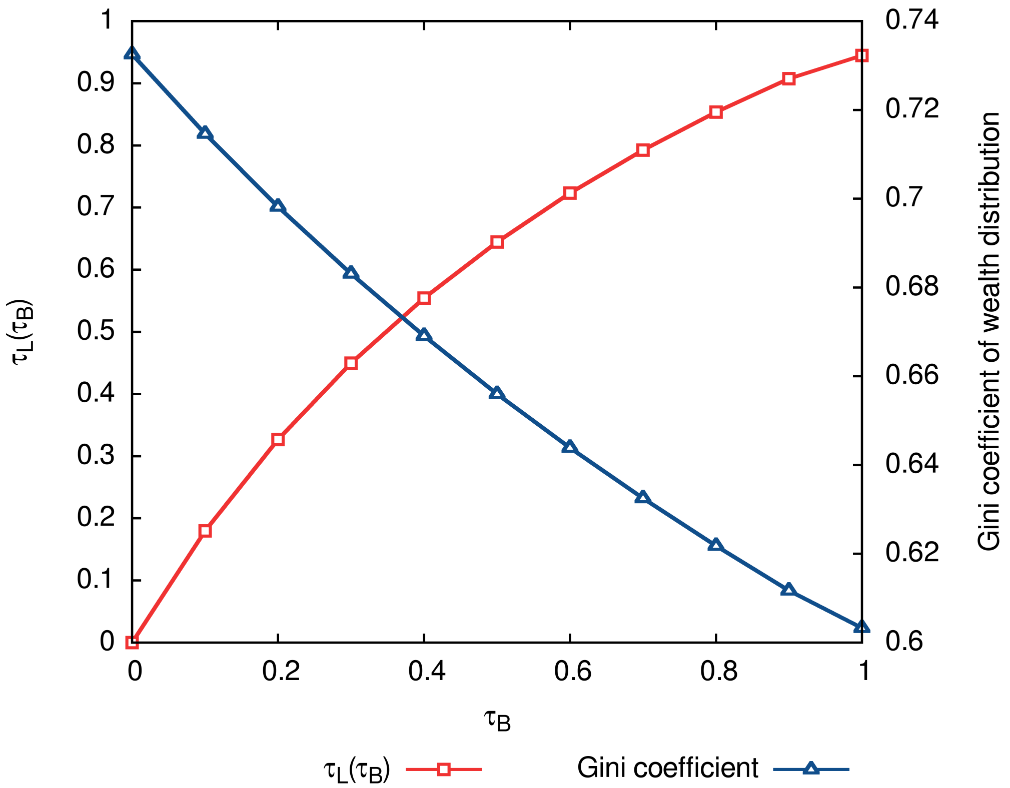

Figure 2: Combinations of bequest- and land rent taxes that imply the same steady-state level of output as in the benchmark case in which $\tau_K = 0.2, \tau_L = \tau_B = 0$. The plotted Gini coefficients represent inequality given the corresponding plotted combinations of land rent and bequest taxes

τ_B	τ_L	Gini	public revenue per capita [10^3 2005 US$/30 years]	[fraction of output]
0.00	0.00	0.73	58	5%
0.10	0.18	0.72	99	9%
0.20	0.33	0.70	133	12%
0.30	0.45	0.68	162	14%
0.40	0.55	0.67	187	17%
0.50	0.65	0.66	209	19%
0.60	0.72	0.64	229	20%
0.70	0.79	0.63	247	22%
0.80	0.85	0.62	264	23%
0.90	0.91	0.61	279	25%
0.99	0.95	0.60	292	26%

Table 2: Combinations of bequest and land rent taxes that imply the same steady-state level of output ($f^* = 1.12$ million 2005 US$ / 30 years) as in the benchmark case in which $\tau_K = 0.2, \tau_L = \tau_B = 0$.

wealth distribution substantially reduces inequality.

Given the structure of our model, we cannot explicitly take into accout the top 1% or 0.1%. However, our model still permits to analyze the impact of varying degrees of progressivity. Therefore, we assess how progressive bequest and capital taxes impact inequalty and output in our model. If only the top quintile is subject to bequest taxes, the steady state wealth distribution is more equal than if the tax is more comprehensive. The more classes are subject to taxation – the top 40%, the top 60%, the top 80%, or all households – the less potential the bequest tax has to redistribute wealth. This relationship is visualized in Figure 3. The result is plausible, since the top quintile owns by far the largest share of total wealth in the economy. Moreover, the less progressive the tax, the higher are the losses with respect to output. However, the effects of varying the progressivity are quantitatively rather small and do not alter the qualitative behavior of the economy in response to the bequest

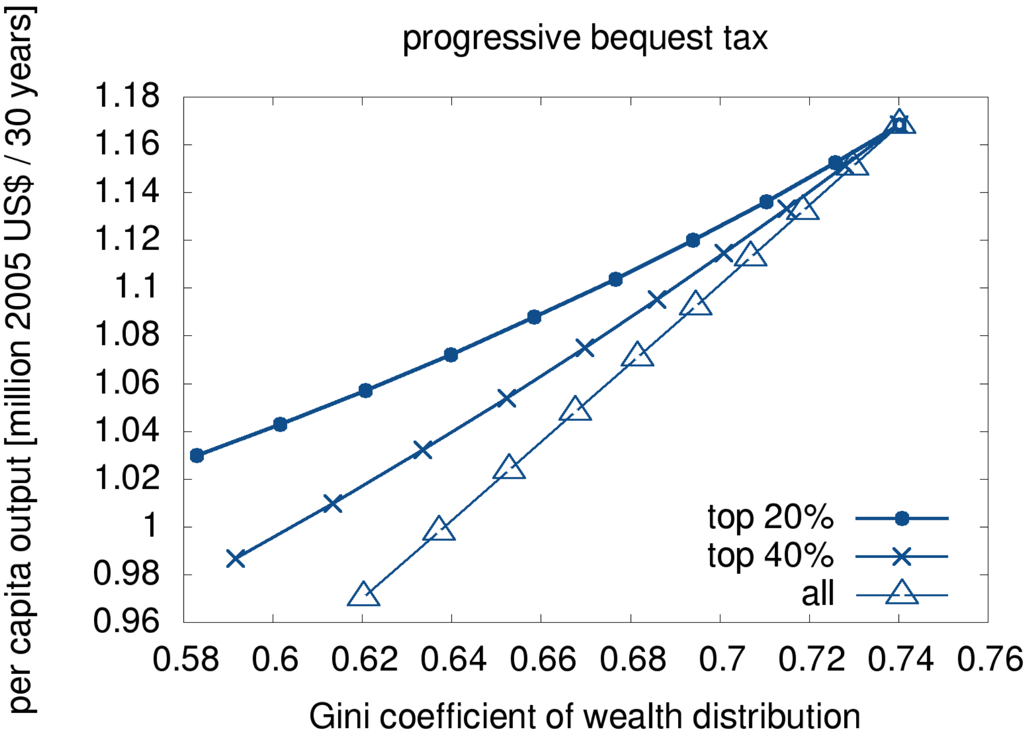

Figure 3: If only the top quintile is subject to bequest taxes, the wealth distribution is more equal than if the tax is more comprehensive. The more classes are subject to taxation – the top 40%, the top 60%, the top 80%, or all households – the less potential the bequest tax has to redistribute wealth. For expository reasons, we omit the curves for taxes on the top 60% and 80%.

tax (cf. the scale of the y-axis in Figure 3).

The analogous experiment for the capital tax confirms the result of Fernholz (2017) to a certain extent: If only the top quintile is taxed, the capital tax has a relatively high potential to redistribute wealth (see Figure B.4). However, due to the structure of our model, we have conducted the variation of the progressivity of the capital tax in a simplifyed model version without land. Since the presence of land implies that the no-arbitrage condition (7) has to be fulfilled, introducing different capital tax rate for different households

$i \in \{1, ..., 5\}$ is only possible, if land is taxed at 100%. Consequently, we have also omitted the case of progressive land taxes, as then a 100% capital income tax would be required to fulfill the no-arbitrage condition (7). When all households face the same tax rate, the bequest tax in the simplified version of the model performs almost identical to the capital tax since no land is available, and, thus, all wealth that can be bequeathed consists of capital. The bequest tax, however, is less sensitive to the degree of progessivity than the capital tax. In particular, a capital tax that is only levied on the top quintile has a higher potential for redistribution and a less negative impact on output than a bequest tax on the top 20%.

3.2 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 the supplementary material, we also consider the alternative case of productivity enhancing public spending, for example through infrastructure investments.

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 old households living in period t are given by

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

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

As Figure 4 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[13]. 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. In particular, the more the government directs transfers to the old, the more capital income and bequest taxation will have the tendency to *increase* wealth inequality.

[13]Here, we use $\delta = \frac{1}{2}$. In general, of course, any $0 < \delta < 1$ implies transfers to both.

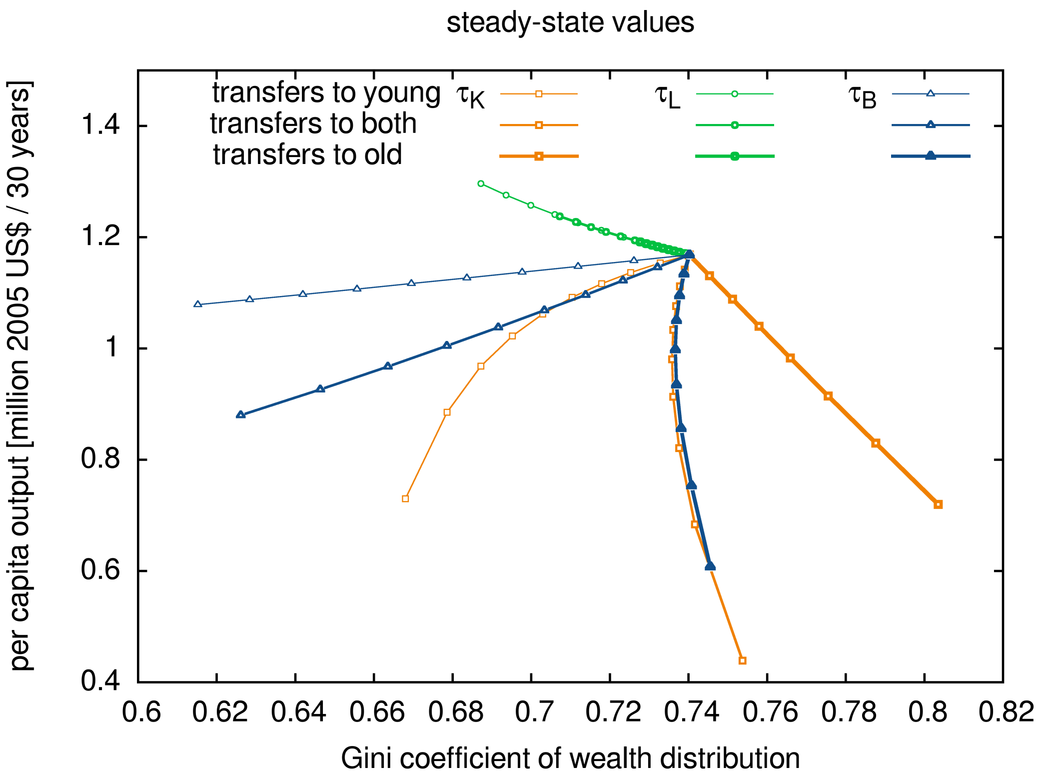

Figure 4: Impact of different recycling schemes (variations of δ) on output and the distribution of wealth.

If a transfer increases a young household's income, it directly increases consumption as well as savings – a *direct income effect*. This leads to increased capital supply and thus more output. By contrast, a transfer to an old household has only an indirect positive effect on the capital supply through increased bequest. That indirect positive effect, however, 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, thus, for savings). Hence, when transfers are directed only to the old generation, all households' savings decrease – and the poorer the household, the greater is that decrease in savings. Thus, the Gini coefficient increases and the output level decreases with δ. In particular, capital income and bequest taxes may even become regressive when transfers are directed only to the old generation.

It is worth mentioning that there is a relatively low threshold for the percentage of transfers that 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 B, Figure B.3).

For the bequest tax, public revenues are lowest under recycling scheme $\delta = 0$ and highest when $\delta = 1$. Revenues from land rent taxes and capital income taxes show no substantial change under variation of δ.[14] For the bequest tax, this dependence on the type of recyling scheme is due to the fact that the choice of the redistribution parameter δ directly changes the tax base of the bequest tax: More transfers to households belonging to the old generation implies more disposable income for consumption when old and for leaving bequests.

4 Robustness checks and sensitivity analysis

This section explores 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

[14]See Appendix B, Figure B.2 for a graphical exposition of this fact.

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
Preference heterogeneity	If $\beta_i = \beta \, \forall i, j$ and the μ_i are heterogeneous, no wealth redistribution is possible with any tax instrument; β is very small, thus there are no bequests and the bequest tax has virtually no impact on the economy.

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

summarizes our findings of the robustness checks. A more detailed account of the sensitivity analysis is given in the supplementary material (see Section D).

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 (5) and (6). Nevertheless, the main differences between the three tax instruments remain the same under the variation of η.

Further, 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. Therefore, we endogenized total factor productivity in our model following Barro (1990), Baxter and King (1993), and Turnovsky (1997). In particular, we have analyzed 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 for certain values of the ψ_i, capital income and bequest taxation can lead to an inverted U-shape in the policy option space when for low tax rates the marginal benefits of additional infrastructure exceed their costs (and for high rates vice versa).

Finally, we have tested how the policy option space changes, if we assume that households have heterogeneous preferences with respect to consumption in old age, instead of heterogeneous preferences for leaving bequests. We find that it is theoretically also possible to reproduce the observed wealth distribution using an alternative parametrization with heterogeneity only in the μ_i and with $\beta_i = \beta_j$ for all $i, j \in \{1, \ldots, 5\}$. Such a parametrization, however, would not be consistent with the empirical evidence that bequests are a key determinant of the distribution of wealth (Cagetti and De Nardi, 2008). A linear variation between our standard and the alternative parametrization reveals that if preferences are only heterogeneous with respect to the μ_i, (a) β_i is very small for all households, which implies that bequest taxation has virtually no impact on the economy, and (b) the potential to redistribute wealth with any kind of taxation is eliminated. The latter effect is due to the fact that with more equal preferences for bequests, the income composition of all households is also more equal under taxation. Then, a tax increase changes the young households' respective shares of wages and received bequests in income to a lesser degree.[15]

5 Discussion

Before concluding, we briefly discuss our assumptions, in particular on the driving force behind the wealth distribution, limitations of our approach, and the available empirical evidence that supports our results.

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

[15]As discussed in Section 3.1.1, the main channel through which tax reforms change the wealth distribution in our model is the difference in income composition, i.e. the ratio of bequests to wages in total income.

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.

By chosing to calibrate our model to OECD data on wealth quintiles, we are not able to fully reflect the wealth distribution at the top, e.g. the top 1% or 0.1%. However, by varying the degree of progressivity of bequest and capital income taxation, we have obtained the intuitive result that more progressive schemes lead to a higher potential for redistribution and a higher steady state level of output (see Section 3.1.3). Within our model, the variation is possible in steps of quintiles and hence the most progressive tax is one that is payed only by the top 20%. Guided by the results obtained by Fernholz (2017), we conjecture that a further increase of the degree of progressivity beyond that which is possible within our model framework can be approximated by an extrapolation of the trend we have identified. For a rigorous assessment of progressivity of taxes on capital income and land rents our model is less well equipped: If different types of households face different tax rates on the income generated by one of the two factors, the no-arbitrage condition (7) can only be fulfilled, if the income of the other factor is taxed at 100%.

Moreover, the literature has also identified circumstances in which bequests have an equalizing effect on incomes. Such an equalizing effect can arise when labor efficiency is distributed stochastically (see, e.g., Becker and Tomes, 1979 and Davies, 1986). Then, bequests cause an averaging of labor efficiency luck. Taxing bequest would result in an increase in income inequality. Two recent papers analyze the specific assumptions that lead to the equalizing effect of bequest taxes. Zhu (2018), for example, suggests that if in a model of stochastic labor efficiency bequests are motivated by the “warm glow” instead of the altruistic motive assumed by Becker and Tomes (1979) and Davies (1986), then bequest taxes have a progressive distributional effect. Further, also the assumption of stochasticity in capital income restores the regressive effect of bequests, and, hence, the progressivity of bequest taxes (Wan and Zhu, 2017).

The asset portfolio effect discussed in Section 3.1.1 constitutes a key mechanism that underlies our main result that combinations of land rent and bequest taxes can reduce inequality without changing the steady-state level of output. The empirical literature on the relevance of theoretical growth effects of land taxes, however, is rather scant due to the lack of data (Kalkuhl et al., 2017). Since such an analysis would require a large variability of land tax schemes over time and space, analyses of property and split-rate taxes are more common. In one of the few empirical studies, Arnold (2008) demonstrates that taxes on immovable property have the least growth-reducing effect compared to all other taxes (including consumption taxes). This suggests that a portfolio effect from land taxation might be relevant to some extent, even though taxes on immovable property are not equivalent to land taxes. However, more empirical research is needed to adequately assess the role of portfolio effects.

Finally, 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.

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). They recommend taxing capital to counter the increase of inequality. Recent literature, however, suggests that land ownership and bequest heterogeneity play a more important role in the process of wealth concentration (Homburg, 2015; Kopczuk, 2013; Stiglitz, 2015, 2016). 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. Our findings support his line of reasoning as financing such a transfer indeed reduces inequality in our framework. We find that the more the transfers are directed to the young and the less they are directed to the old, the higher output in the steady state is and the more equal the wealth distribution becomes. In this case, reducing inequality goes hand in hand with enhancing output.

Acknowledgements

We would like to thank Mireille Chiroleu-Assouline, Marc Fleurbaey, Robert C. Franks, Beatriz Gaitan, Etienne Lehmann, Linus Mattauch, Christina Roolfs, Marco Runkel, Gregor Schwerhoff, and two anonymous referees, as well as seminar participants at PIK's RD3 PhD seminar, the PRSE seminar at Universität Potsdam, the OLG days 2016 in Luxembourg, the Journées Louis-André Gérard-Varet 2017, and PET 2017 in Paris for helpful comments and discussions.

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A Model parameters and calibration

Preferences	Elasticity parameter	η	1.004
	Preferences for consumption when old	μ_1	0.005
	Preferences for leaving bequests	β_1	0.0001
		β_2	0.011
		β_3	0.035
		β_4	0.065
		β_5	0.156
Production	Share parameter of capital	α	0.27
	Share parameter of land	γ	0.09
	Elasticity of substitution	ϵ	0.7
	Total factor productivity	A_0	1060
	Capital productivity	A_K	0.015
	Depreciation rate	δ_k	0.5
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	124,000 US$ per capita
	Initial land	l_0	1.3 land units per capita

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

	Average OECD data	Model output
GDP per capita	1,121,631 US$ per generation	1,112,778 US$ per generation
Gini coefficient	0.75	0.73
Capital	75,462 US$	76,000 US$
Capital-land ratio	2.53	2.53
Wealth holdings of the five quintiles		
Q1	(2,356) US$	15,082 US$
Q2	48,790 US$	49,006 US$
Q3	136,132 US$	136,048 US$
Q4	262,057 US$	262,180 US$
Q5	922,703 US$	925,231 US$

Table A.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, parentheses for Q1 indicate debt.

B Additional figures and data

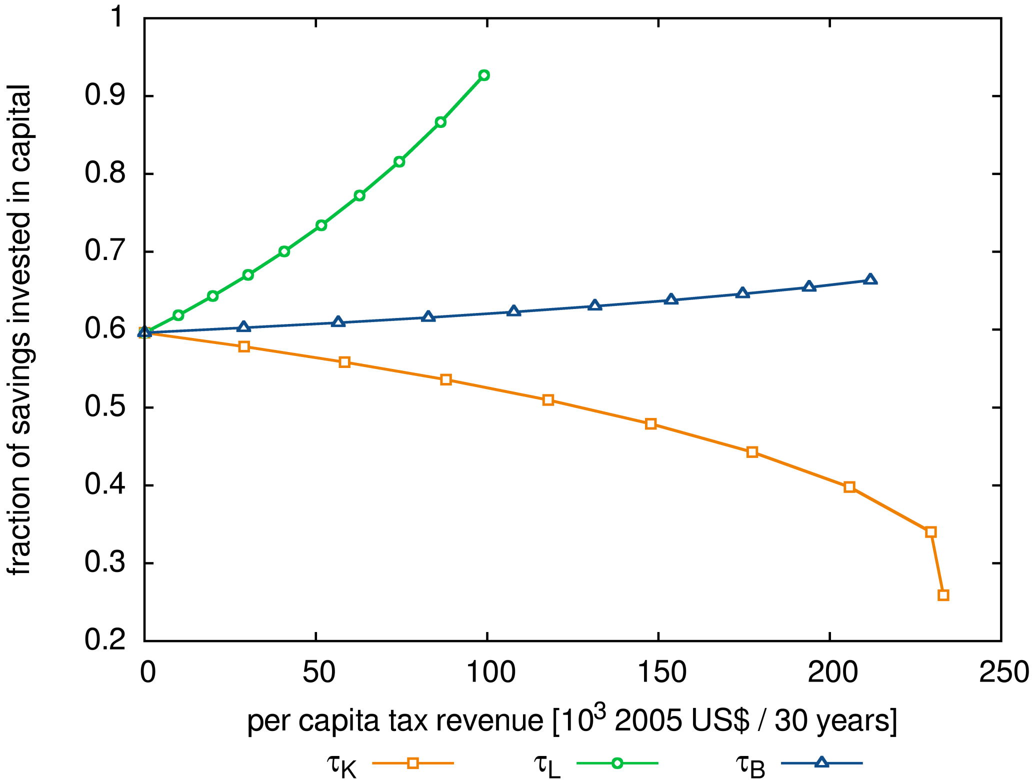

Figure B.1: Aggregate composition of assets (cf. Section 3.1) under variation of fiscal policy. Fiscal policy that stimulates (hampers) investment in capital will unambiguously increase (decrease) output. While a bequest tax only indirectly affects asset prices, taxes on capital income and land rents have a relatively strong impact on asset prices. As the relative prices of assets change, households react by changing the composition of their portfolio – a *portfolio effect* takes place. The tax on land rents shifts investment toward capital. The capital stock increases, but the other two inputs, labor and land, do not change, as we assume that they are in fixed supply. Hence the land rent tax increases output. Raising a capital income tax has the opposite effect. It discourages investments in capital and, thus, leads to output reductions.

Country	Gini coefficient of wealth distribution
Slovak Republic	0.52
Greece	0.65
Spain	0.66
Italy	0.69
Australia	0.69
Belgium	0.70
Korea	0.70
United Kingdom	0.71
Luxembourg	0.74
Portugal	0.75
Canada	0.76
Finland	0.77
France	0.77
Austria	0.85
Norway	0.86
Netherlands	0.91
Germany	0.92
United States	0.93

Table B.3: Gini coefficients of the wealth distributions of those countries for which OECD (2015) reports data on their respective wealth distribution.

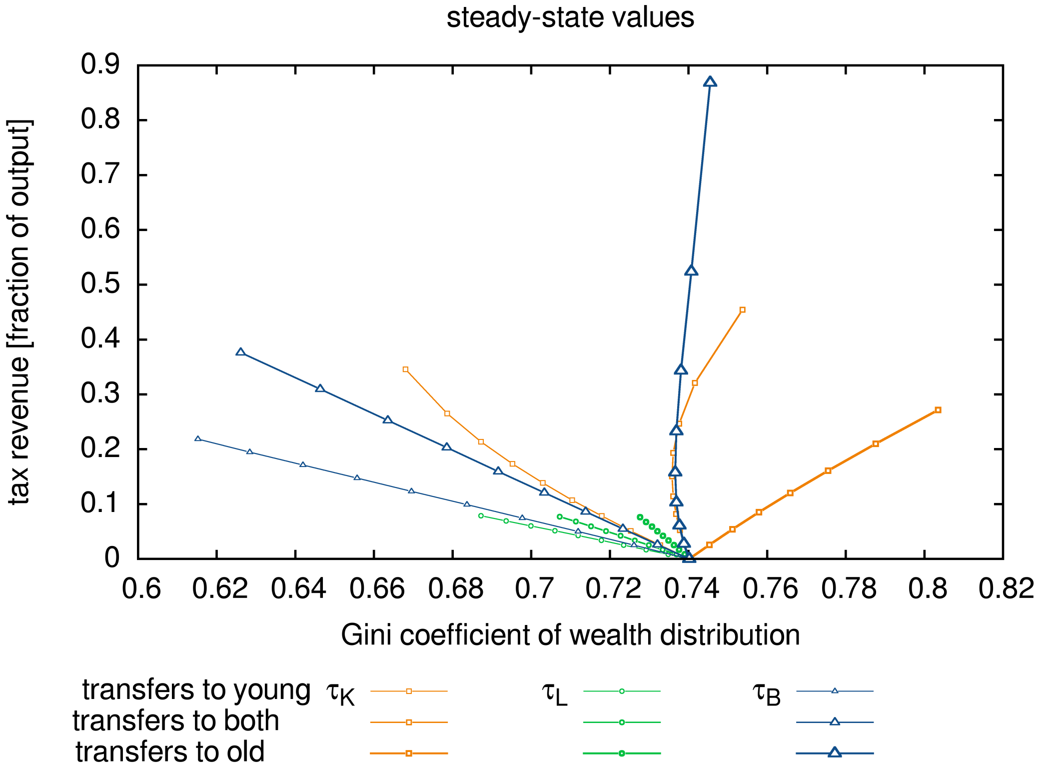

Figure B.2: The revenue raising potential of fiscal policy depends on the recycling scheme used. For the bequest tax, public revenues are higher the higher the share of transfers to the old. The capital income and the land rent tax are much less sensitive to the transfer scheme used. Note that if all tax revenues are transferred to the old generation ($\delta = 1$), the capital income tax is only feasible up to a rate of 70%. Figure 4 shows how the choice of the transfer scheme affects output.

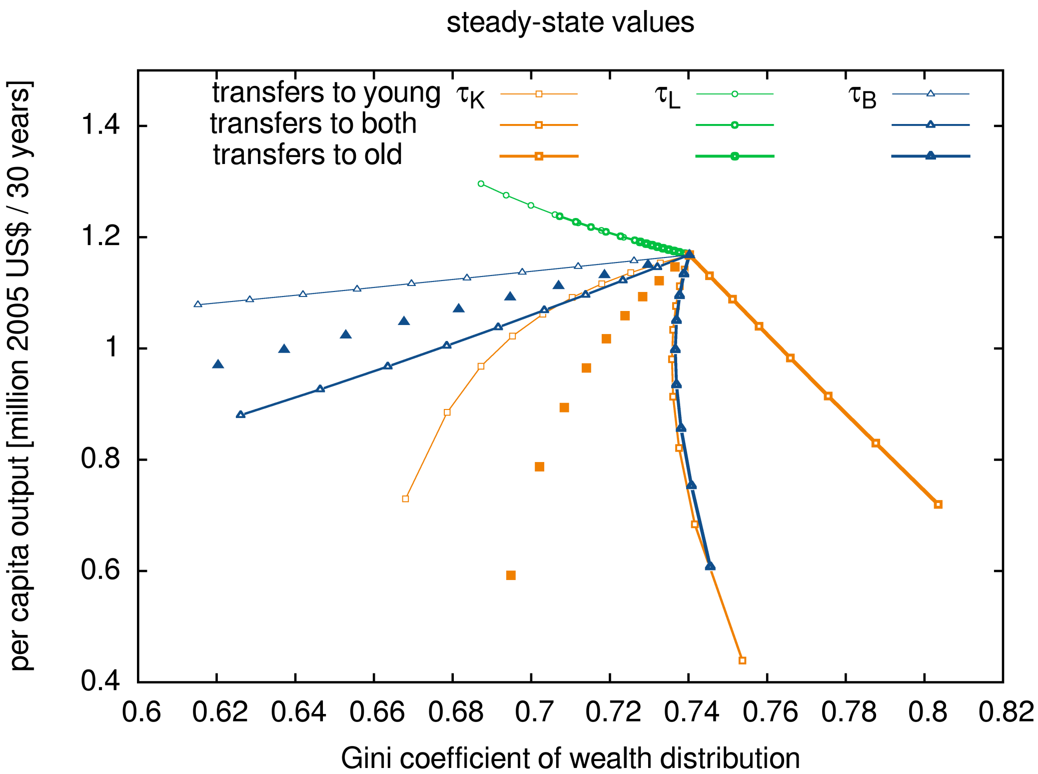

Figure B.3: Impact of different recycling schemes on output and on the wealth distribution (cf. Figure 4). The filled points mark the option space for the case in which public revenues are not redistributed (the capital income tax is marked by boxes, the bequest tax by triangles). Thus, transferring all tax revenues to the old generation, for example, would result in a lower steady-state level of output and higher wealth inequality, than if the tax revenues were not recycled to the modeled economy at all.

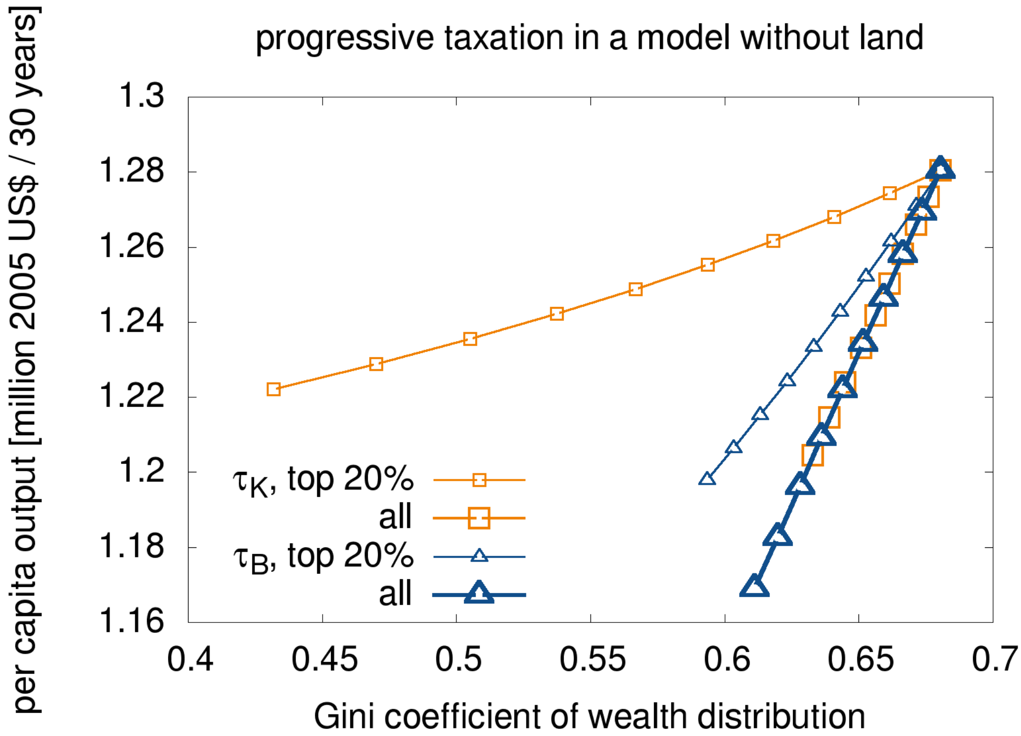

Figure B.4: Impact of varying the progressivity of the capital and the bequest tax in a model without land (cf. Section 3.1.3). If only the top quintile is taxed, both tax instruments have a higher potential to reduce wealth inequality compared to scenarios in which a greater fraction, or all households are taxed. A capital tax on the top quintile has a higher potential to reduce inequality and a less negative impact on output than a bequest tax on the top 20%.

C 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 with such a transfer scheme. 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 Figures C.5 and C.6. Absent any additional transfer mechanism between winners and losers, generations belonging to the top wealth quintile $i = 5$ and possibly all households belonging to the first old generation suffer under the tax. Whether the first old generation suffers under the tax depends on the assumption made about its exogenously fixed level of consumption when young.

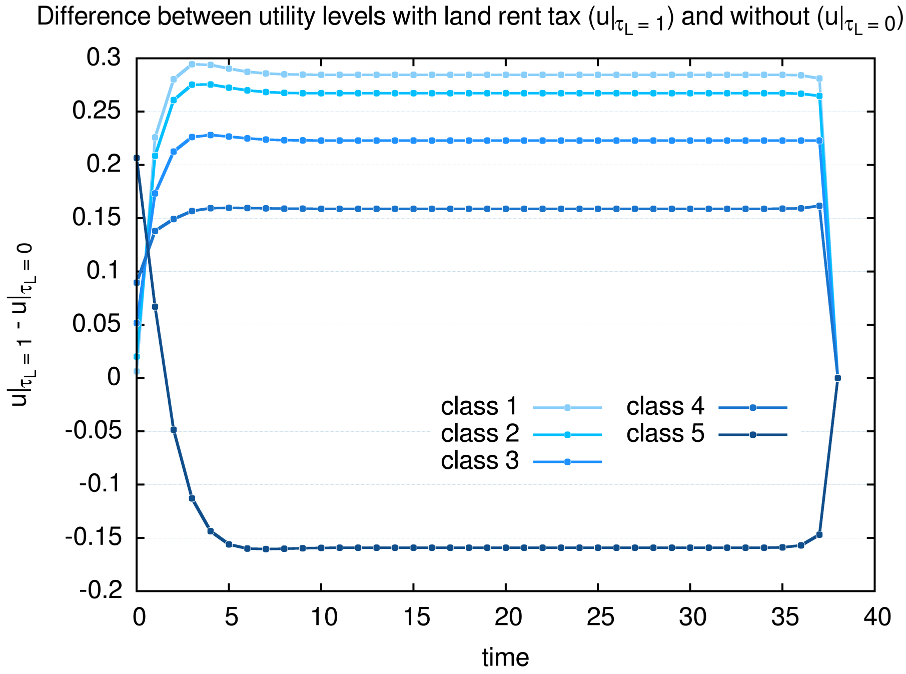

Figure C.5: When land rents are taxed at 100% and recycled as lump-sum transfers to the young, the richest households bear the burden. Their utility under taxation is less than without taxation, i.e., $u|_{\tau_L=1} - u|_{\tau_L=0} < 0$. All other households benefit from the policy.

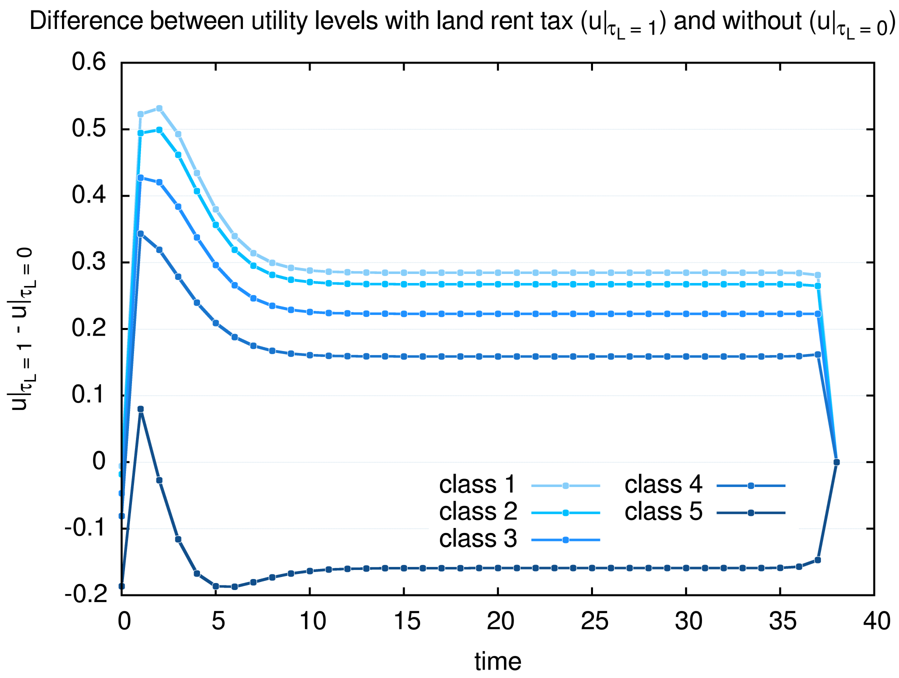

Figure C.6: For certain parameters, not only the rich households, but also the households belonging to the first old generation bear the burden of the tax reform.

Now, we introduce a mechanism that 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

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

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

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 $\{X_{i,t}^y, X_{i,t}^o\}_{i=1,\dots,N,\ t=1,\dots,T}$ such that the winners of the 100% land rent tax can compensate the losers, i.e., that

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

D 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.

D.1 Basic dynamic model properties

We observe that the model described in Section 2.1 converges to a steady state. Figure D.7 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 D.8). The land price may be formulated as a sum of future rents – recall equation (8). 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.

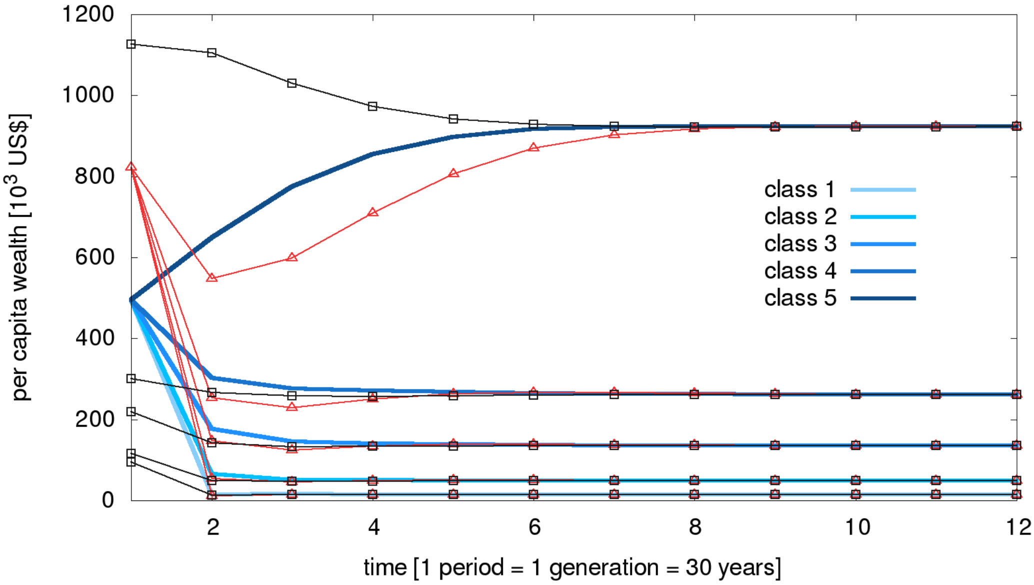

Figure D.7: Transition of wealth distribution to steady state. The steady state wealth levels are independent of the initial wealth endowment.

Moreover, we also observe that the steady state is independent of the initial values of the households' wealth, as Figure D.7 demonstrates. 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 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 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

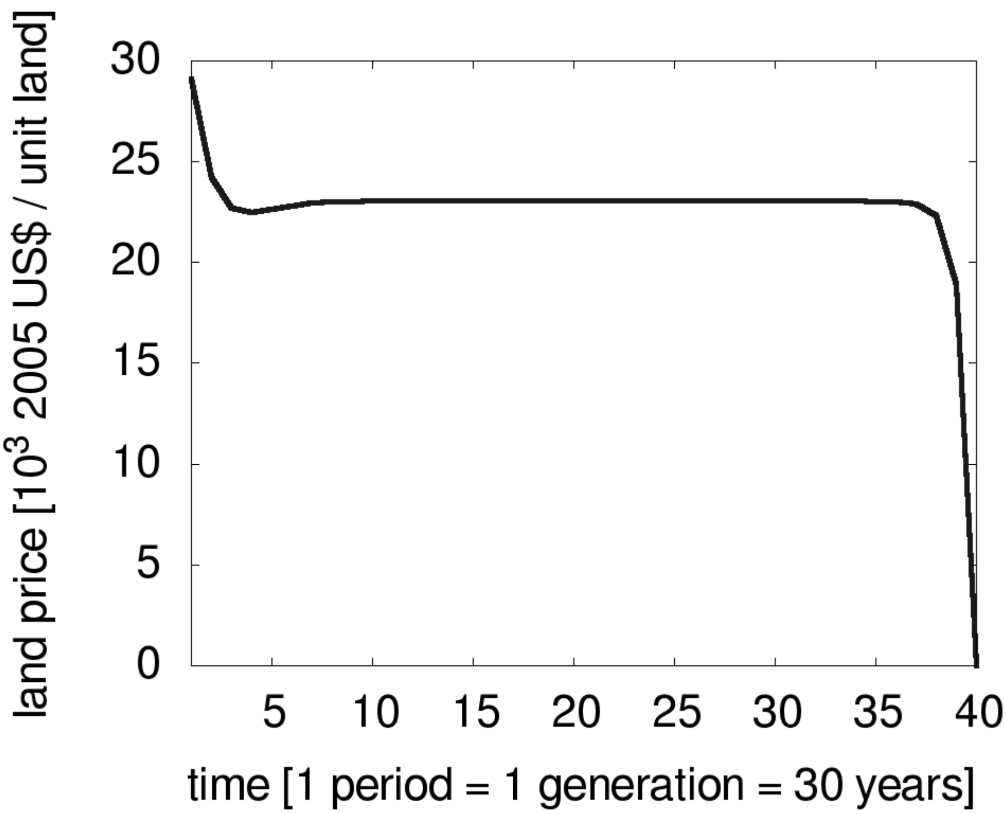

Figure D.8: Analogous to all other variables, for example household wealth (see Figure D.7), also the land price converges to a steady state.

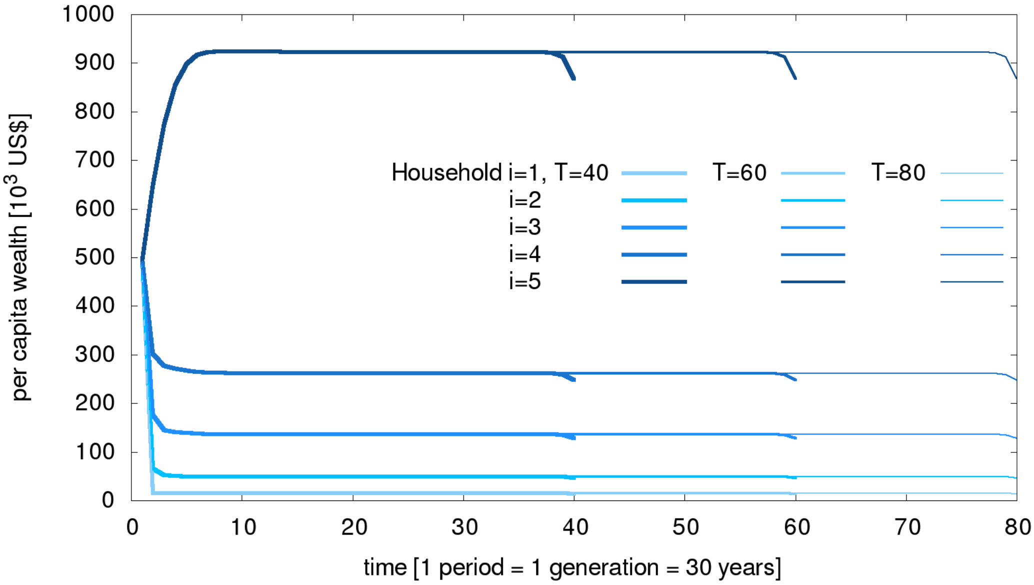

Figure D.9: The steady state is independent of the exact number of periods.

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 D.9 shows.

D.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 D.2.1, we describe how the policy option space (cf. Figure 1) changes under different parameter choices. Then, in Section D.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.

D.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 as well as possible.

For most tested parameters, we find that a variation has no significant qualitative nor quantitative effect on our results. However, a few parameters reveal a non-trivial relationship between parameter choice and model results: the elasticity parameters of the utility function η and of the production function ϵ, and the choice whether preferences for bequests or preferences for consumption when old are heterogeneous. Thus, in the following we only present the results of shifting the preference heterogeneity from the warm glow of bequests to preferences for consumption when old, and 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.

Utility function We analyze how our results depend on both the intertemporal elasticity η as well as the preference parameters μ_i and β_i. We begin with the sensitivity analysis of η and then discuss the preference parameters μ_i and β_i.

The elasticity parameter of the utility function η has a significant impact on the distribution of wealth and, moreover, on output, even when taxes are not taken into account. Ceteris paribus (i.e. without recalibration of all other parameter), the steady state level of output increases with η, while the Gini coefficient decreases (see Figure D.10). The reason is that households' substitution behavior depends on η. The first-order conditions (5) and (6) determine the relative demand for consumption and bequests. Consequently, higher values of η induce poorer households to save more, while it does not induce rich households to reduce bequests substantially (Table D.4 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 parameters. Figure D.11 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 increas-

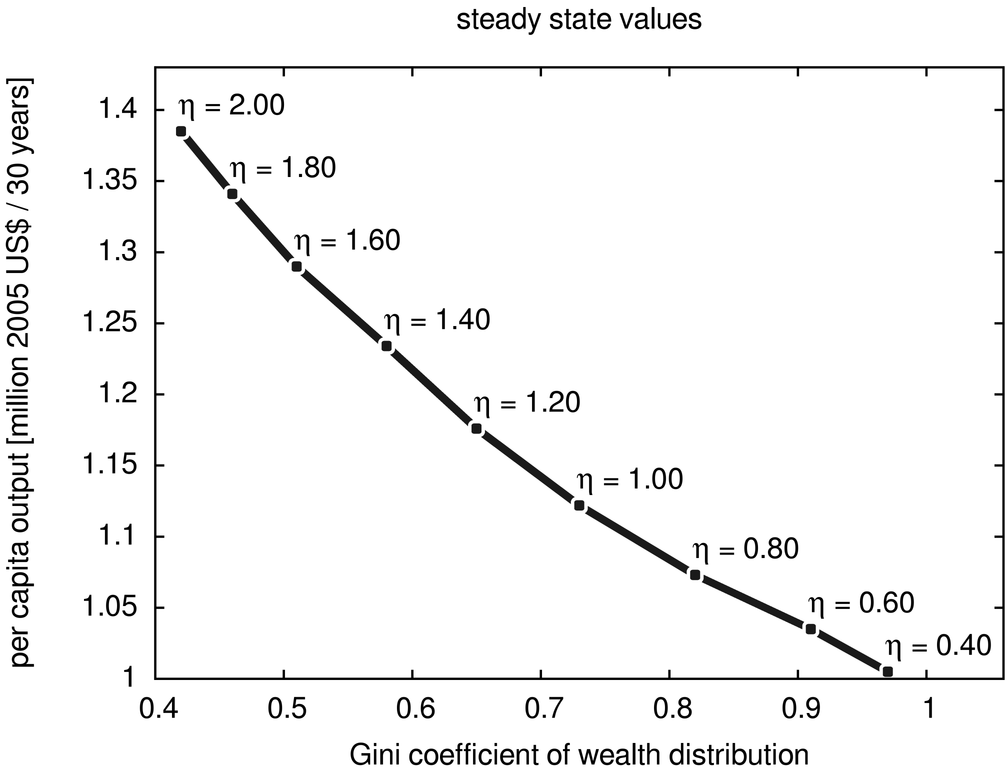

Figure D.10: Variation of preference parameter η without recalibration to observed data. Benchmark case: $\eta = 1.004$.

	Household i	$\eta = 0.4$	$\eta = 2$	Change induced by an increase of η
Consumption				
when young $(c^y)^*$	1	630.44	957.52	52%
	2	630.92	1027.15	63%
	3	639.77	1098.71	72%
	4	675.38	1162.98	72%
	5	1560.58	1325.98	-15%
Consumption				
when old $(c^o)^*$	1	0.08	96.18	124105%
	2	0.08	103.18	133034%
	3	0.08	110.37	140334%
	4	0.08	116.82	140719%
	5	0.19	133.20	69382%
Bequests b^*				
	1	0.00	13.82	very high
	2	0.58	154.13	26638%
	3	11.34	298.31	2531%
	4	54.64	427.81	683%
	5	1130.91	756.24	-33%

Table D.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 0.4 to a high value of 2. The benchmark value of η is 1.004.

ing 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.[16] 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 D.11 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 D.11 shows us how η determines the relative size of income and substitution effects of the bequest tax (see also the discussion in Section 3.1.1). 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 save more, which implies more capital, and thus a higher output level. For low η the opposite is the case.

In Figure D.12 we see that the potential to raise public revenues depends on the choice of the elasticity parameter η. The higher η is, the greater the

[16] As explained in Section 3.1.1, 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.

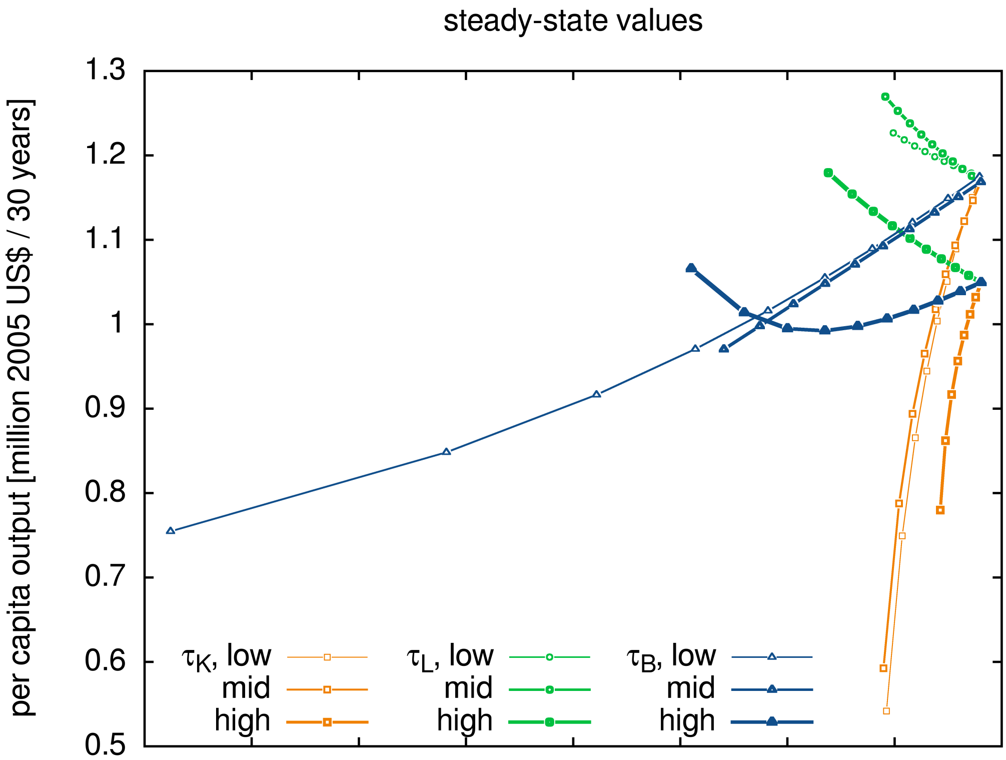

Figure D.11: Policy-option space under variation of preference parameter η (low = 0.5, mid = 1.004, high = 1.5) and subsequent recalibration of all other parameters such that the case of $\tau_K = 0.2, \tau_L = \tau_B = 0$ yields model output as close as possible to the data. Note, that for transfers that are directed only at the old generation, capital incom tax rates above 70% did not permit feasible solutions of the model.

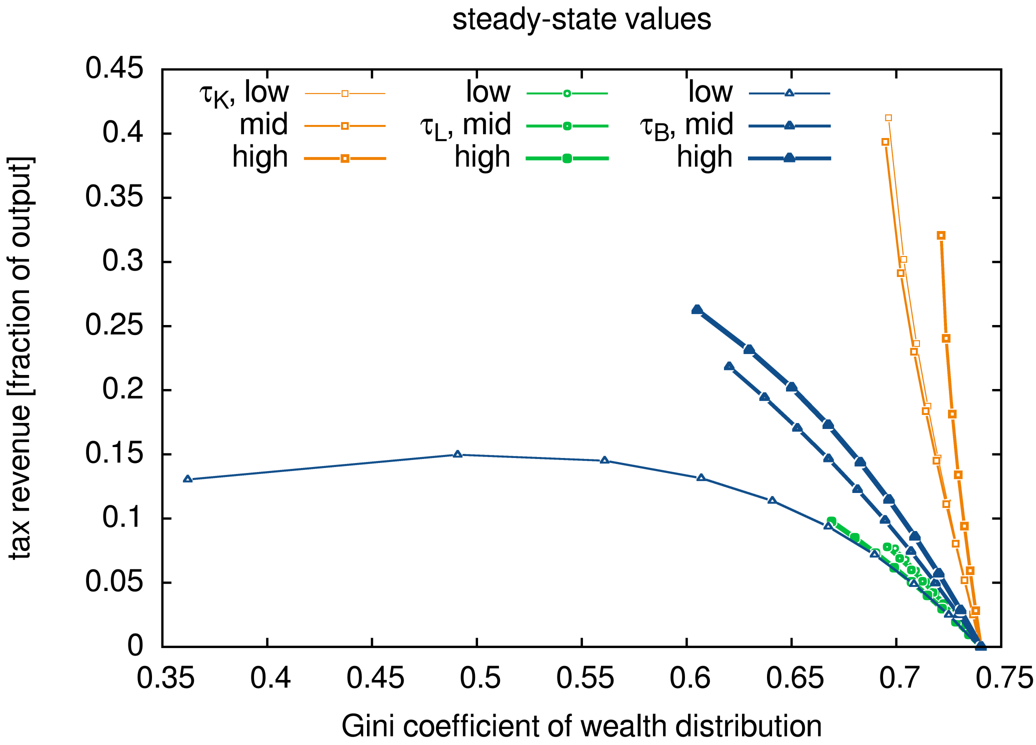

Figure D.12: Tax revenues and Gini coefficient under variation of preference parameter η (low = 0.5, mid = 1.004, high = 1.5) and subsequent recalibration of all other parameters such that the case of $\tau_K = 0.2, \tau_L = \tau_B = 0$ remains invariant under the variation of η. Note, that for transfers that are directed only at the old generation, capital incom tax rates above 70% did not permit feasible solutions of the model.

revenue raising potential of all taxes becomes. For a high elasticity parameter η, households' intertemporal substitution elasticity is low. Hence households have a stronger preference to smooth consumption; thus, aggregate savings tend to increase with an increase of η, which in turn tends to increase the tax base of each of the three tax instruments.

Finally, we vary the preference parameters μ_i and β_i for $i = 1, ..., 5$. In particular, we relax the assumption that households are heterogeneous only with respect to their preferences for leaving bequests. Therefore, we compare the standard parametrization with an alternative parametrization that is characterized by the fact that $\mu_i \leq \mu_{i+1}$ and $\beta_i = \beta_j$ for all i, j. Figure D.13 shows a linear variation between the two parametrizations including an intermediate case, in which both the μ_i and the β_i are heterogeneous. We observe that the more the parametrization approaches the alternative case with heterogeneity in the μ_i, the more the potential to redistribute wealth with any kind of taxation is eliminated. Moreover, β_i is reduced and becomes small for all households, which implies that the impact of bequest taxation on the economy is reduced.

The reason for the reduction of the potential to redistribute wealth with any of the tax instruments is the fact that with more equal preferences for bequests, the income composition of all households is also more equal under taxation. Then, a tax increase does not change the young generation's respective shares of wages and received bequests in income.

Production function Figures D.14 and D.15 show that varying the substitution elasticity ϵ (and subsequently recalibrating all other parameters) has no greater qualitative impact. However, the graphs show clearly the intuitive result that varying the elasticity does change the results quantitatively. While the coordinates in the Gini-output-space (Figure D.14) that can be achieved with the bequest tax do not change very much, variations in ϵ do shift the curves associated with taxes on the input factors capital and land: Smaller values of the substitution elasticity tend to exacerbate distortions on the factor markets caused by taxes on input factors. Hence, lower degrees of substitutability tend to reduce output under capital income and land rent taxation. Moreover, we also observe the intuitive result that lower degrees of

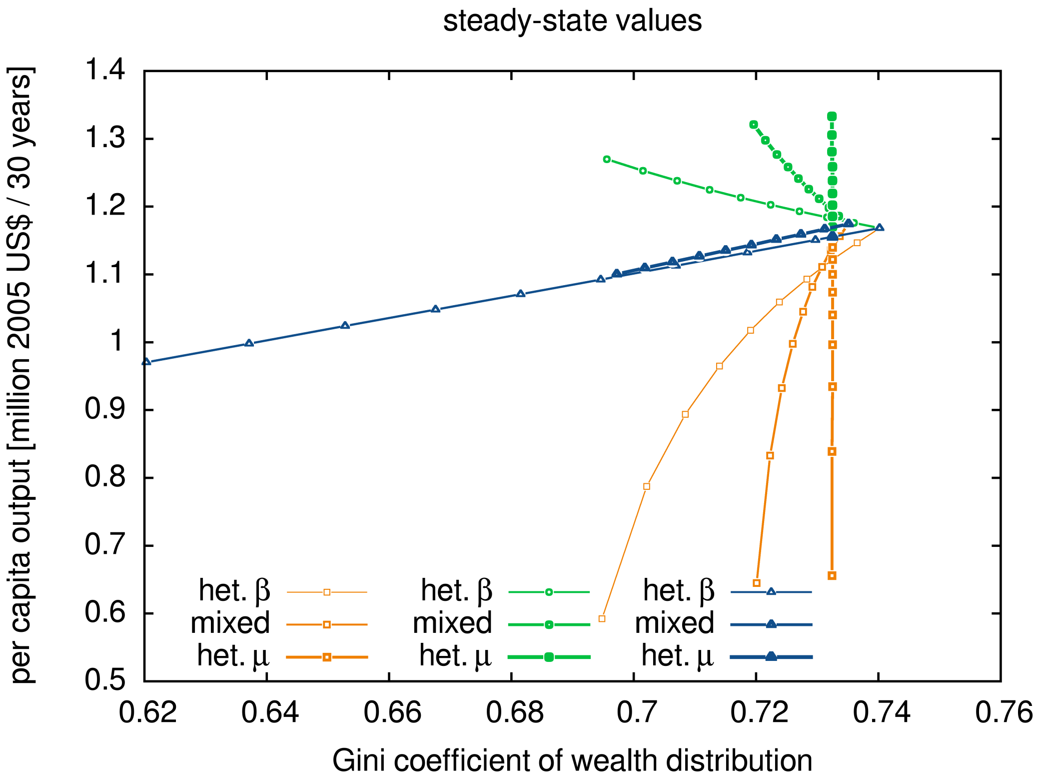

Figure D.13: Policy option space under linear variation between two differente parametrizations: a) our standard parametrization with heterogeneous β and b) a parametrization with $\beta_i = \beta_j$ for all i, j and heterogeneous μ. Note that in the latter case, the bequest tax has no impact at all on the economy: the curve collapses to a single point in the policy option space.

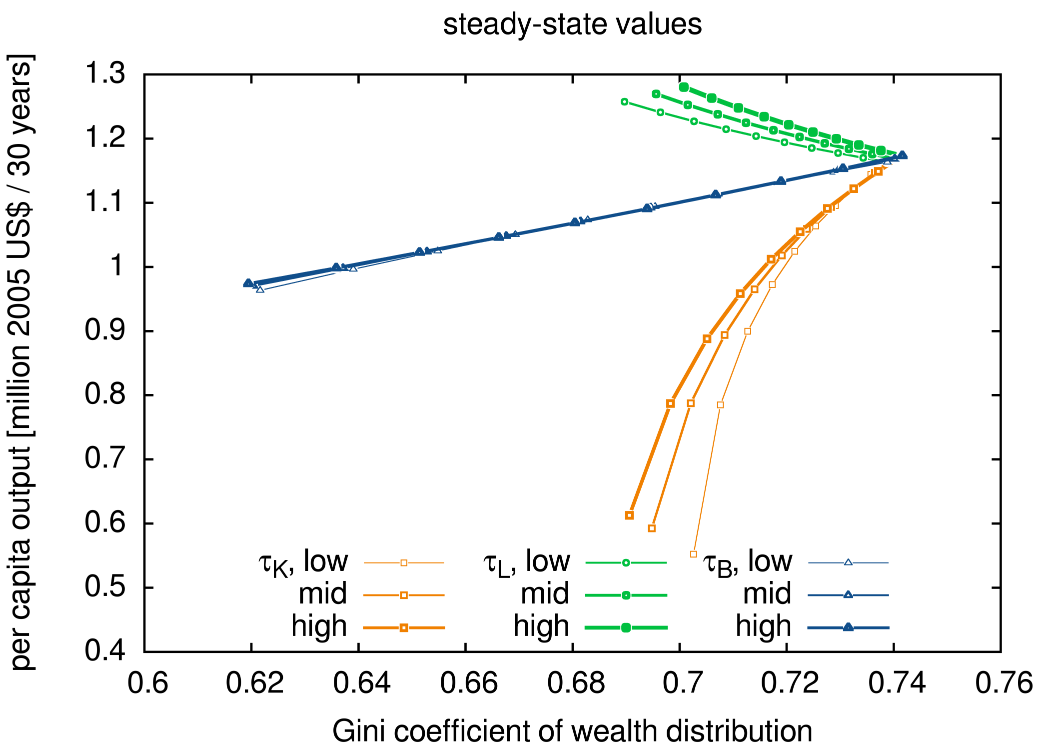

Figure D.14: Policy-option space for the Gini coefficient and output under variation of substitution elasticity ϵ (low = 0.6, mid = 0.7, high = 0.8) and subsequent recalibration of all other parameters such that the case of $\tau_K = 0.2, \tau_L = \tau_B = 0$ remains invariant under the variation of ϵ.

substitutability lead to an increase in tax revenues (Figure D.15 and Table D.5).

D.2.2 Alternative spending option: Infrastructure investments

In Section 3.2 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 rela-

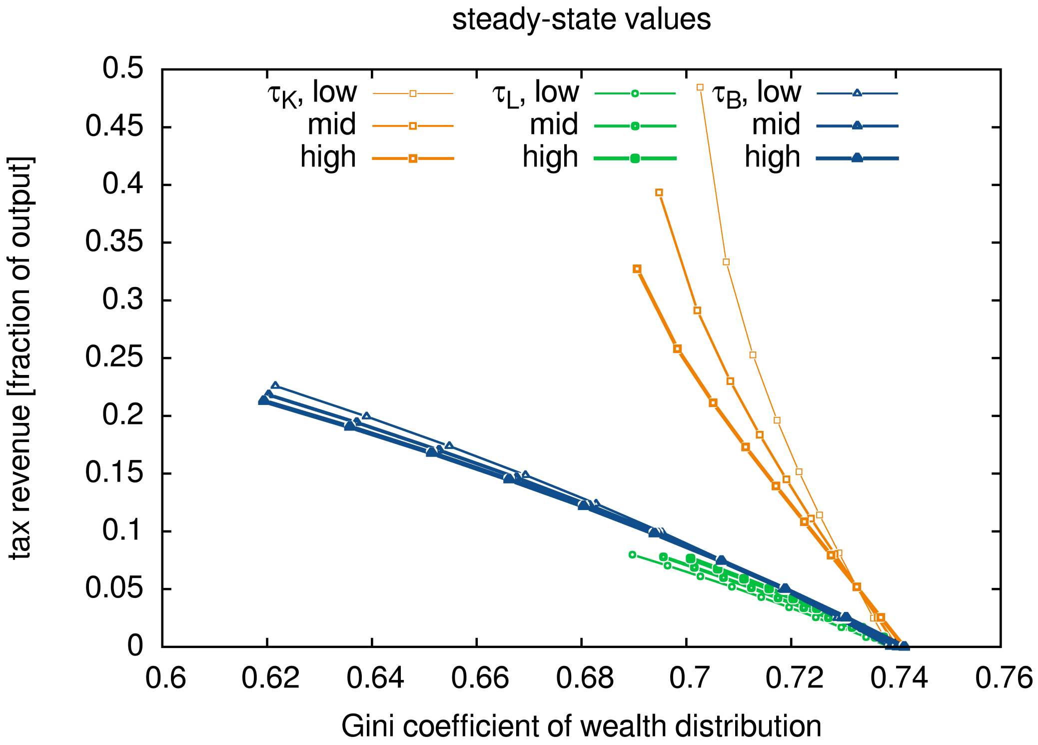

Figure D.15: Policy-option space for the Gini coefficient and tax revenues under variation of substitution elasticity ϵ (low = 0.6, mid = 0.7, high = 0.8) and subsequent recalibration of all other parameters such that the case of $\tau_K = 0.2, \tau_L = \tau_B = 0$ remains invariant under the variation of ϵ.

	tax rate	tax revenue			output		
		τ_K	τ_L	τ_B	τ_K	τ_L	τ_B
$\epsilon = 0.6$	0.2	58	20	56	1122	1177	1131
	0.5	156	52	133	1025	1204	1074
	0.7	228	75	178	900	1227	1025
$\epsilon = 0.8$	0.2	58	20	57	1122	1190	1133
	0.5	141	51	130	1012	1222	1069
	0.7	188	74	172	888	1248	1023

Table D.5: 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.

tionship 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, and to yield an infrastructure elasticity of output of approximately 0.1, the value estimated by Bom and Ligthart (2014) in their recent meta study. 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 D.16. The specific values in the variation are listed in Table D.6.

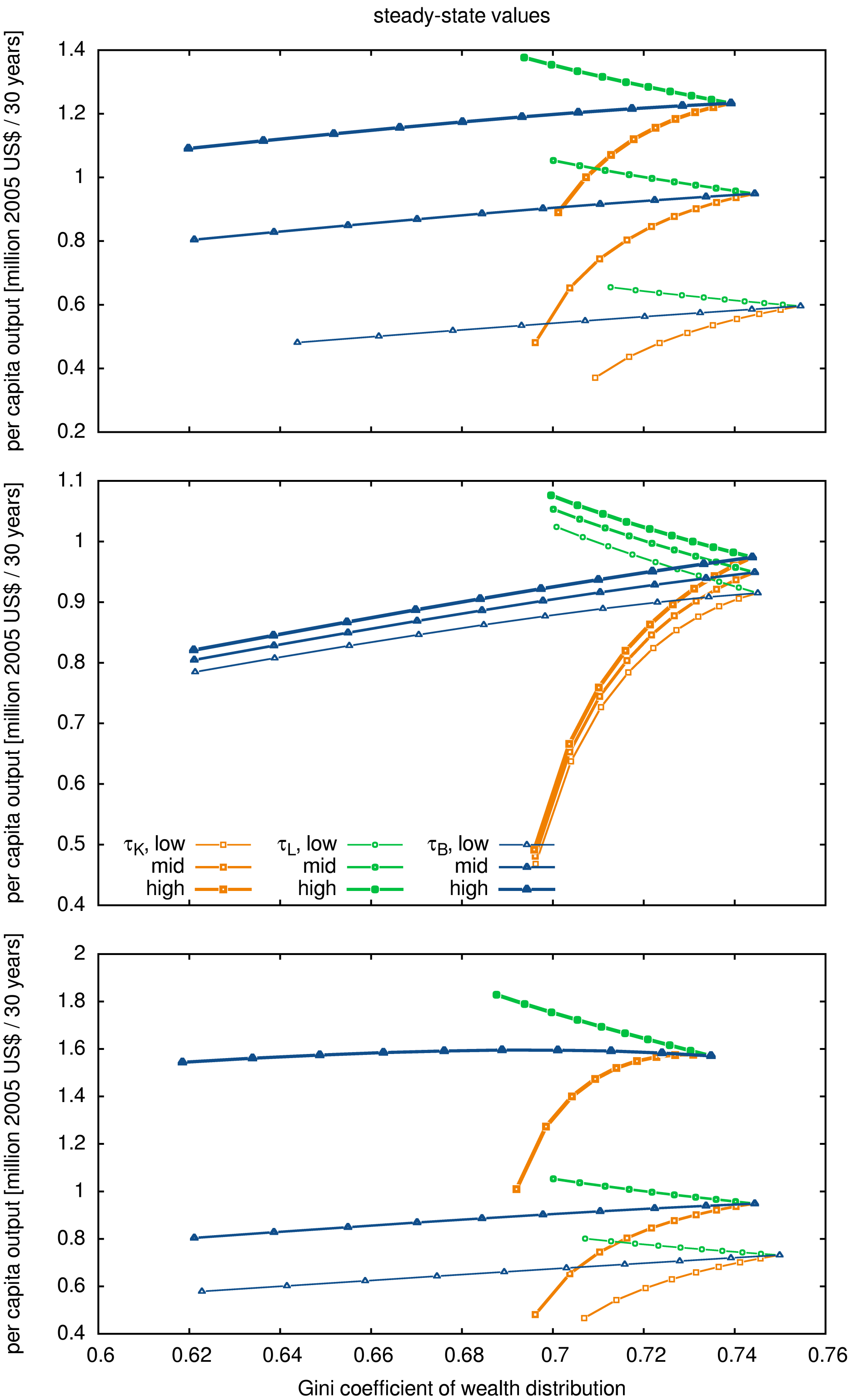

Figure D.16: Impact of different degrees of effectivity of infrastructure on output and the wealth distribution (low, middle and high values of ψ_1 in upper panel, of ψ_2 in middle panel, and of ψ_3 in lower panel).

	lo	mid	hi
ψ_1	0.4	0.57	0.7
ψ_2	200	300	400
ψ_3	0.035	0.07	0.14

Table D.6: Values used in sensitivity analysis of infrastructure.