Hypergeorgism: When rent taxation is socially optimal*

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Abstract

Imperfect altruism between generations may lead to insufficient capital accumulation. We study the welfare consequences of taxing the rent on a fixed production factor, such as land, in combination with age-dependent redistributions as a remedy. Taxing rent enhances welfare by increasing capital investment. This holds for any tax rate and recycling of the tax revenues except for combinations of high taxes and strongly redistributive recycling. We prove that specific forms of recycling the land rent tax - a transfer directed at fundless newborns or a capital subsidy - allow reproducing the social optimum under parameter restrictions valid for most economies.

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1 Introduction

Rent taxation may become a more important source of revenue in the future due to potentially low growth rates and increased inequality in wealth in many developed economies (Piketty and Zucman, 2014; Demailly et al., 2013), concerns about international tax competition (Wilson, 1986; Zodrow and Mieszkowski, 1986; Zodrow, 2010), and growing demand for natural resources (IEA, 2013). It may alleviate spending constraints for reducing high public debt (Bach et al., 2014) and public investment (Mattauch et al., 2013).

On a theoretical level, it is well-known that the taxation of rents from fixed factors such as land is non-neutral, and may enhance efficiency if there is capital underaccumulation (Feldstein, 1977; Fane, 1984; Petrucci, 2006). The reason for underaccumulation is typically assumed to be imperfect altruism between generations – that leads to an unequal distribution of assets across households. Nevertheless, the consequences of redistributional spending of tax proceeds have so far been ignored in the literature, despite great disparities in rent income in developed economies.

This paper fills this gap by providing a distributional argument for the desirability of taxation of rents that goes beyond the traditional case for rent taxation based on its efficiency. We show that reaching the socially optimal allocation *requires* both rent taxation and spending the revenue in a redistributive way. Among the redistribution patterns we analyse is a uniform transfer that increases capital accumulation and welfare, but can never be socially optimal. Giving instead a disproportionately high share of the tax revenue to the poor younger generations does allow to reproduce the social optimum by making the productivity loss vanish (but can lead to overaccumulation if the land rent tax is very high). These results are at odds with the common view that redistribution creates efficiency losses.

Our argument is based on two premises. First, fixed factors of production matter for the size of economic output (see Caselli and Feyrer (2007) for an analysis of the role of land and natural resources). Land scarcity is ubiquitous in explaining economic outcomes, from the real estate to the agricultural sector. Although land is the canonical example for a fixed production factor, it is not the only one. The stocks of old industries in which no further investment will be undertaken are best understood as fixed production factors and exogenously given availability of natural resources is another example.

Second, we explicitly make minimal assumptions about household heterogeneity: There are no bequests, so individuals are differentiated by age because they are born fundless and accumulate wealth over time. This assumption implies that capital accumulation is suboptimally low compared to the case of perfect altruism between all generations. To isolate the effect of imperfect altruism, no further structure such as a lifecycle of working and retirement or increasing death probabilities is imposed. With a more realistic demographic structure our results would not change qualitatively, whence we employ an age-invariant mortality rate for analytical simplicity.

The central tenet of Georgism (Heavey, 2003), going back to Henry George's proposal to abolish all taxes in favour of a single tax on land (George, 1920), is that taxing rents from such fixed production factors is a non-distortionary way of raising fiscal income. Feldstein (1977) argued that this is not the case if owners of land also provide other factors such as capital, if there is an alternative in saving decisions to invest in land or capital or if these assets have different risks. Previous work has not systematically analysed the welfare effects of rent taxation in this context: while we confirm that taxing fixed factors can increase aggregate capital and consumption (as pointed out by Petrucci, 2006), our contribution is that a tax on such rents, combined with age-dependent redistributions, can even be socially optimal. The underlying mechanism is composed of two effects: First, the tax shifts investment towards reproducible stocks, alleviating their undersupply and leading to higher output and aggregate consumption. Second, redistributing the tax revenue to those generations in the economy who benefit most from transfers additionally increases welfare. Extending and modifying the tenet of Georgism, we propose that this insight be called *Hypergeorgism*.[1]

Our argument is as follows: In Section 2, a continuous overlapping generations (OLG) model is introduced to study the relationship between household heterogeneity and the trade-off of investing in land or reproducible assets, which is captured by a no-arbitrage condition. Aggregate consumption growth depends *inter alia* on the land price and the type of redistribution of the tax revenue. As the benchmark for tax policy evaluation, we take social welfare to be the preference satisfaction of all heterogeneous individuals (Calvo and Obstfeld, 1988).

In Section 3, the main result is proved: Any redistribution of the revenue from land rent taxation that is stable in the long run and not too egalitarian stimulates capital accumulation and thus increases total consumption and welfare. If a disproportionate share of the revenue is given to the young generations, the social optimum can be achieved, but overaccumulation is possible if the tax rate is high.

For the fiscally realistic case of a uniform age- and wealth-independent redistribution, the social optimum is shown to be infeasible (Section 3.2.1) – but we derive conditions under which it can be socially optimal to redistribute the land tax revenue to the newborn generation only (Section 3.2.2) or exponentially with age (Section 3.2.3). Furthermore, a uniform redis-

[1] From a historical perspective, our result may be closer to Henry George's original thinking than Georgism or the neoclassical Henry George Theorems (Stiglitz, 1977): Henry George was chiefly concerned with poverty eradication (George, 1920). We show that taxing rent income and giving it to the poor young generations actually enhances economic efficiency.

tribution is shown to be more efficient than compensating land owners for reduced rent flows due to taxation (Section 3.2.4). Alternatively, the use of the revenue as a capital subsidy may establish the social optimum under a condition given in Section 3.3. The results about the different possible redistributions are summarised in Table 1.

In Section 4 the application of our formal result to fiscal policy is discussed: we find that the conditions for social optimality plausibly hold for the economies of a large and diverse set described in an econometric study by Caselli and Feyrer (2007). Furthermore we justify our choice of social optimum.

The present study builds on two strands of literature. The relationship between land price, land rent tax and interest rate has been discussed by Feldstein (1977), Calvo et al. (1979), Fane (1984), Burgstaller (1994) and Foley and Michl (1999), and the question of the tax incidence has been clarified. Chamley and Wright (1987) studied the dynamic effects of fiscal policy in this context.

On the other hand, in the continuous overlapping generations model of Blanchard (1985), land has been introduced as a production factor to study when in such a model Ricardian equivalence holds (Buiter, 1988, 1989; Weil, 1989). Buiter was to the best of our knowledge the first to consider the impact of land as a fixed production factor in the continuous OLG model. He proved that with land, Ricardian equivalence holds despite the arrival of newborn generations (Buiter, 1989), but did not take into account capital accumulation. Fried and Howitt (1988) considered the interaction of debt with land for the case of an open economy. Engel and Kletzer (1990) studied the impact of age-dependent redistributions in an open economy model with tariffs, but did not provide a normative analysis. Calvo and Obstfeld (1988) determined the socially optimal allocation in a continuous OLG model.

The studies closest to ours are Petrucci (2006), which uses a model similar to that presented below to discuss the impact of an endogenous labour-leisure choice on the incidence of a land rent tax and Koethenbuerger and Poutvaara (2009), which analyses the impact on transition generations of a shift from labour taxation to land rent taxation. Petrucci as well as Koethenbuerger and Poutvaara state that a land rent tax leads to higher capital and consumption for the case originally considered by Feldstein, but model a small open economy with a fixed interest rate for their own analysis and do not consider the welfare effects and the redistribution possibilities of the land tax revenue. Hashimoto and Sakuragawa (1998) study a land rent tax in a discrete OLG model with endogenous technological change. They also find that it is preferable to redirect the revenue to the young generation as this increases the economic growth rate, but a Pareto improvement cannot be reached in their model, and social optimality is not analysed.

2 Model

We extend a continuous overlapping generations (OLG) model (Yaari, 1965; Blanchard, 1985) to include a fixed factor of production, which we label land (Buiter, 1989). The model describes an economy with one final good of unit price and three other flow markets for labour, capital and land rental as production inputs as well as two stock markets for capital and land ownership[2]. We first detail the decentralised model, while the second subsection provides the social planner solution. The third subsection then discusses essential properties of the steady-state.

2.1 Decentralised model

We first describe individual behaviour and the role of the government and then proceed to the aggregation of demand-side quantities before specifying the model's simple production structure.

Assume a constant birth rate ϕ, equal to each individual's instantaneous probability of death and thus to the death rate in a large population. Therefore population size is constant – henceforth normalised to 1 – and individuals' lifetimes are exponentially distributed. The size at time τ of a cohort born at time ν is $\phi e^{-\phi(\tau-\nu)}$.

For an individual born at time ν with a rate of pure time preference ρ and instantaneous utility $\ln c(\nu,t)$, expected lifetime utility $u(\nu,t)$ at time $t \geq \nu$ is given by

$$u(\nu,t) = \int_t^\infty \ln c(\nu,\tau) e^{-(\phi+\rho)(\tau-t)} \mathrm{d}\tau \tag{1}$$

with $c(\nu,\tau)$ describing the path of consumption. Individuals have the following budget identity for all $\tau \in [t,\infty)$:

$$\begin{aligned}\dot{k}(\nu,\tau) + p(\tau)\dot{s}(\nu,\tau) = w(\tau) + [r(\tau)+\phi]k(\nu,\tau) + \\ + [(1-T)l(\tau) + p(\tau)\phi]s(\nu,\tau) + z(\nu,\tau) - c(\nu,\tau)\end{aligned} \tag{2}$$

where $\dot{k}(\nu,\tau) = \mathrm{d}k(\nu,\tau)/\mathrm{d}\tau$, etc.[3] Newborns do not inherit wealth, so $k(\nu,\nu) = s(\nu,\nu) = 0$. Individuals own capital k and a share s of total land S, which can be bought and sold at a price p. Each individual supplies one unit of labour and receives an age-independent wage w, rents out capital and land to firms at market rates r and l, respectively, with a tax

[2] Our model is hence a closed-economy version of the one employed by Petrucci (2006), but with inelastic labour supply and age-dependent transfer schemes.

[3] Frequently, a different notation in terms of nonhuman assets $a \equiv k + ps$ is used in the literature: we deviate from it to make more transparent the relation of the no-arbitrage condition (8) below to the individual optimisation problem and the role of the land price, which are crucial for our results. To obtain the more conventional form of the budget identity, use (8) in (2) to obtain $\dot{a} = (r+\phi)a + w + z - c$.

T on land rents, and obtains potentially age-dependent transfers z from the government. There are no bequest motives. Instead, to close the model, a competitive, no-cost life insurance sector pays an annuity ϕk in return for obtaining the individual's financial assets in case of death (thus, all financial wealth of those who died is redistributed to the living in proportion to their capital). Similarly, the insurance sector distributes land to individuals in proportion to their land ownership (ϕs), in return for receiving their land in case of death. Thus, while total land is constant and all land is owned by somebody,

$$\int_{-\infty}^{\tau} s(\nu,\tau)\phi e^{-\phi(\tau-\nu)}\mathrm{d}\nu = S(\tau) = S \quad \text{const. }, \tag{3}$$

the changes in land ownership of all *living* generations do not sum to zero:

$$\int_{-\infty}^{\tau} \dot{s}(\nu,\tau)\phi e^{-\phi(\tau-\nu)}\mathrm{d}\nu = \phi S. \tag{4}$$

The individual also respects a solvency condition which prevents her from playing a Ponzi game against the life-insurance companies[4]:

$$\lim_{\tau\to\infty}[k(\nu,\tau)+p(\tau)s(\nu,\tau)]e^{-R(t,\tau)} = 0 \tag{5}$$
$$\text{with} \quad R(t,\tau) \equiv \int_t^{\tau}(r(\tilde{t})+\phi)\mathrm{d}\tilde{t}.$$

The government collects a tax T on land rents and instantaneously redistributes the entire revenues by choosing a redistribution scheme that consists of transfers z to individuals. The scheme must satisfy the following condition:

Definition 1. *A redistribution scheme $z(\nu,\tau)$ is called* permissible *if it is non-negative for all ν and τ and satisfies the government budget equation at all times:*

$$\int_{-\infty}^{\tau} z(\nu,\tau)\phi e^{-\phi(\tau-\nu)}\mathrm{d}\nu = Tl(\tau)S \quad \textit{for all } \tau. \tag{6}$$

This definition implies that the government budget is balanced at all times: we abstract from government debt for simplicity.

Individuals maximise utility (1) by choosing paths for c, k and s, subject to budget identity (2) and transversality condition (5). From the first-order conditions of this optimisation problem, one obtains the usual Keynes-Ramsey rule for the dynamics of individual consumption

$$\frac{\dot{c}(\nu,\tau)}{c(\nu,\tau)} = r(\tau) - \rho \tag{7}$$

[4]Although the individual can take up debt ($k < 0$), the limit of the present value of her total financial and land wealth at infinity has to be zero. Note that there can be no debt in terms of land, so land appears as collateral for capital debt in the transversality condition.

and a no-arbitrage condition (Burgstaller, 1994; Foley and Michl, 1999) between land and capital (see Appendix A.1):

$$\frac{(1-T)l(\tau)}{p(\tau)} + \frac{\dot{p}(\tau)}{p(\tau)} = r(\tau). \tag{8}$$

The arbitrage condition is crucial for the main result below since it links the stock and flow markets for land by relating the unit value of land as an investment p to its after-tax rent, $(1-T)l$.

Using the instantaneous budget identity (2), transversality condition (5) and arbitrage condition (8), the lifetime budget constraint can be derived[5]:

$$\int_t^\infty c(\nu,\tau)e^{-R(t,\tau)}\mathrm{d}\tau = k(\nu,t) + p(t)s(\nu,t) + \bar{w}(t) + \bar{z}(\nu,t) \tag{9}$$

$$\text{where} \quad \bar{w}(t) \equiv \int_t^\infty w(\tau)e^{-R(t,\tau)}\mathrm{d}\tau$$

$$\text{and} \quad \bar{z}(\nu,t) \equiv \int_t^\infty z(\nu,\tau)e^{-R(t,\tau)}\mathrm{d}\tau.$$

This means that the present value of the consumption plan at time t of individuals born at ν equals their total wealth consisting of capital, land and the present values of lifetime labour income $\bar{w}$ and transfers $\bar{z}$.

Solving the Keynes-Ramsey rule (7) for c and using the result in Equation (9) shows that all individuals consume the same fixed fraction of their total wealth consisting of capital, land and the present value of lifetime labour income and transfers (see Appendix A.2):

$$c(\nu,t) = (\rho+\phi)[k(\nu,t) + p(t)s(\nu,t) + \bar{w}(t) + \bar{z}(\nu,t)]. \tag{10}$$

We proceed by detailing the aggregation of demand-side quantities: the aggregate of any individual variable x for the total population X is

$$X(t) = \int_{-\infty}^t x(\nu,t)\phi e^{-\phi(t-\nu)}\mathrm{d}\nu.$$

Using Equation (3) for total land, aggregation of Equation (10) yields:

$$C(t) = (\rho+\phi)[K(t) + p(t)S + \bar{W}(t) + \bar{Z}(t)], \tag{11}$$

$$\text{with} \quad \bar{W}(t) \equiv \int_{-\infty}^t \bar{w}(t)\phi e^{-\phi(t-\nu)}\mathrm{d}\nu = \bar{w}(t)$$

$$\text{and} \quad \bar{Z}(t) \equiv \int_{-\infty}^t \bar{z}(\nu,t)\phi e^{-\phi(t-\nu)}\mathrm{d}\nu,$$

[5]See Appendix A.2. Conventionally, human wealth is defined to include wage and government transfers, $h(\nu,t) \equiv \bar{w}(t) + \bar{z}(\nu,t)$. We separate these terms here since our analysis focusses on z.

where C and K denote total consumption and capital, and $\bar{W}$ and $\bar{Z}$ the total present values of labour income and transfers from the government to individuals. Therefore aggregate consumption is the same constant fraction of total wealth as for each individual.

For the dynamics of the total capital stock, apply the definition of K, Leibniz' rule and the individual budget constraint (2) to get (Appendix A.3):

$$\dot{K}(t) = r(t)K(t) + l(t)S + w(t) - C(t). \tag{12}$$

Taxes and transfers do not appear in this expression, as the aggregate tax payments and transfers from the individuals' budget constraint are equated via the government's budget constraint.

Finally, derivation of the dynamics of aggregate consumption uses the definition of C, Leibniz' rule and Equations (7) and (10)[6]:

$$\frac{\dot{C}(t)}{C(t)} = r(t) - \rho - \phi(\rho + \phi)\frac{K(t) + p(t)S + \bar{Z}(t) - \bar{z}(t,t)}{C(t)}. \tag{13}$$

The last term reflects the "generation replacement effect": A fraction ϕ of the total population, owning aggregate capital K and land wealth pS as well as expecting lifetime transfers of $\bar{Z}$, dies and is replaced by newborns, whose only "non-human wealth" are expected lifetime transfers $\bar{z}(t,t)$. Since individuals consume a fixed fraction $(\rho + \phi)$ of their wealth, this continuous turnover affects aggregate consumption growth. Growth is diminished by the newborns' missing capital and land but also impacted (positively or negatively) by future transfer payments, depending on how these redistribute wealth between generations. We will come back to this mechanism in Section 3.1.

On the supply side, assume a single final good is produced from inputs K, S and aggregate labour L ($L = 1$ as individuals constantly supply one unit of labour). The production function features constant returns to scale, diminishing marginal productivity in individual inputs and satisfies the Inada conditions in all arguments. The representative firm's problem is

$$\max_{K(t),L(t),S(t)} F(K(t), L(t), S(t)) - [r(t) + \delta]K(t) - w(t)L(t) - l(t)S(t) \tag{14}$$

[6]See Appendix A.3. Alternatively, directly differentiate Equation (11) and use that, by Leibniz' rule, $d\bar{W}/dt = (r + \phi)\bar{W} - w$ and $d\bar{Z}/dt = (r + \phi)\bar{Z} - Z - \phi(\bar{Z} - \bar{z}^N)$, where $\bar{z}^N = \bar{z}(t,t)$. This implies that the general result for the dynamics of human wealth in conventional notation is $\dot{H} = (r + \phi)H - w - Z - \phi(\bar{Z} - \bar{z}^N)$. The last term disappears *if and only if* transfers are age-independent ("lump sum", see Section 3.2.1), so $\bar{Z} = \bar{z}^N$. Thus, the expression $\dot{H} = (r + \phi)H - w - Z$, often considered a standard result in the literature, is in fact a special case (see also the proof of Lemma 1 for an intuition). In particular, in work related to this paper and unnoticed by the respective authors, Equation (4c) in Petrucci (2006) and Equation (11) in Marini and van der Ploeg (1988) require the assumption of uniform transfers.

yielding the standard first-order conditions

$$r(t) + \delta = F_K(K(t), L(t), S(t)), \tag{15}$$
$$w(t) = F_L(K(t), L(t), S(t)), \tag{16}$$
$$l(t) = F_S(K(t), L(t), S(t)). \tag{17}$$

where δ is the depreciation rate of private capital.

2.2 Social planner

The social planner solution is chosen as a normative benchmark to evaluate the tax policies examined below. We assume that social welfare consists of the preference satisfaction of all heterogeneous individuals weighted by a utilitarian social welfare function. For simplicity, we assume that the socially optimal rate of pure time preference equals the private rate of pure time preference.[7]

Social welfare V at time t is defined as follows:

$$\begin{aligned} V(t) = & \int_{-\infty}^{t} \left\{ \int_{t}^{\infty} \ln c(\nu,\tau) e^{-\rho\tau} \phi e^{-\phi(\tau-\nu)} \mathrm{d}\tau \right\} \mathrm{d}\nu \\ & + \int_{t}^{\infty} \left\{ \int_{\nu}^{\infty} \ln c(\nu,\tau) e^{-\rho\tau} \phi e^{-\phi(\tau-\nu)} \mathrm{d}\tau \right\} \mathrm{d}\nu. \end{aligned}$$

This is equivalent to the social welfare function considered by Calvo and Obstfeld (1988) when the private and social rates of pure time preference are equal.

We now use the two-step procedure of Calvo and Obstfeld (1988) for evaluating social welfare in economies with overlapping generations to determine the socially optimal level of aggregate capital and consumption: (i) the optimal static distribution at any point in time is chosen, (ii) the intertemporally optimal solution is chosen independently.

(i) Define $U(C(t))$ as the optimal solution to the *static maximisation problem*:

$$U(C(t)) = \max_{\{c(\nu,t)\}_{\nu=-\infty}^{t}} \int_{-\infty}^{t} \ln c(\nu,t) \phi e^{-\phi(t-\nu)} \mathrm{d}\nu$$
$$\text{subject to:} \quad C(t) = \int_{-\infty}^{t} c(\nu,t) \phi e^{-\phi(t-\nu)} \mathrm{d}\nu.$$

[7] It is sometimes considered normatively more justified to assume that the social discount rate is lower than the private rate of pure time preference. Adopting this viewpoint would introduce a further cause of underaccumulation in the present model. The effect of policy instruments introduced below would not change, while the social optimum would be harder to achieve than for the case considered in this paper.

Solving the static optimal control problem with an integral constraint (see Appendix A.4), it can be found that

$$U(C(t)) = \ln(C(t)).$$

This result can be obtained because all agents have the same utility function. Distributing the fixed amount $C(t)$ among all living agents at time t thus makes giving an equal share to each of them optimal. As population is normalised to 1, the share given to the individual equals the total amount of consumption, $C(t)$, so that total utility is $\ln(C(t))$. (For a proof see Appendix A.4).

(ii) The *intertemporal maximisation problem* of the social planner is hence the following optimal growth problem:

$$\max_{C(t)} \int_{t=0}^{\infty} U(C(t))e^{-\rho t}dt \tag{18}$$
$$\text{with} \quad U(C) = \ln(C)$$
$$\text{s.t.} \quad \dot{K}(t) = F(K(t), L(t), S(t)) - C(t) - \delta K(t).$$

The corresponding rule for socially optimal aggregate consumption growth is thus the Keynes-Ramsey rule

$$\frac{\dot{C}(t)}{C(t)} = F_K(K(t), L(t), S(t)) - \delta - \rho. \tag{19}$$

We therefore take the Keynes-Ramsey level of consumption and capital as the reference point for social optimality in the following. Implications of adopting the normative viewpoint just outlined are further discussed in Section 4.2.

2.3 Properties of the steady state

Since L and S are fixed, we drop them as arguments from the production function in the following. The social planner's system is in a steady state if the capital stock and consumption level satisfy

$$\begin{aligned} \dot{K} = 0 \rightarrow \quad & C^{kr} = F(K^{kr}) - \delta K^{kr} \\ \dot{C} = 0 \rightarrow \quad & 0 = F_K(K^{kr}) - \delta - \rho \end{aligned} \tag{20}$$

This characterises the optimal Keynes-Ramsey levels, denoted by superscripts ^{kr}, to which we compare the decentralised outcome: coupled differential equations for the aggregate capital stock (12), aggregate consumption (13) and the land price (8) govern the dynamics of the decentralised system[8]. Inserting the conditions on prices (15–17), we obtain the steady-state conditions:

$$\dot{K} = 0 \rightarrow \quad C_P(K) = F(K) - \delta K \tag{21}$$

$$\dot{C} = 0 \rightarrow \quad C_H(K) = \phi(\rho + \phi)\frac{K + p(K)S + \bar{Z}(K) - \bar{z}^N(K)}{r(K) - \rho} \tag{22}$$

$$\dot{p} = 0 \rightarrow \quad p(K) = \frac{(1-T)l(K)}{r(K)}. \tag{23}$$

The subscripts $_P$ and $_H$ highlight that the first equation defines a curve in the C-K-plane shaped like a parabola and the second a hyperbola (compare Heijdra, 2009, p.572f and Figure 1; exceptions are discussed below). The present value of current and future transfers to the newborn is denoted by $\bar{z}^N(K) = \bar{z}(t,t)$.

A unique (non-trivial) steady state solution exists and the steady state is saddle-point stable. In the following the system is reduced to two dimensions by setting $\dot{p} = 0$. This projection captures all relevant dynamics.[9] We denote variables at the steady state (where all three of Equations (21–23) hold) by an asterisk *. In particular,

$$\begin{aligned} p^* &= p(K^*) = \frac{(1-T)l(K^*)}{r(K^*)} \\ r^* &= r(K^*) = F_K(K^*) - \delta \\ l^* &= l(K^*) = F_S(K^*). \end{aligned} \tag{24}$$

Note that not every redistribution scheme yields a steady state: intuitively, the scheme must not introduce any asymmetry between individuals of the same age, but born at different times. An example for a redistribution that is permissible according to Equation (6), but not consistent with a steady state, is a scheme where only generations born before a certain fixed date receive transfers. Formally, the aggregated present values of transfers $\bar{Z}^*$ (depending also directly on T, see Definition 1) must fulfill the following condition:

Lemma 1. *In a steady state, permissible redistribution schemes satisfy*

$$\phi \bar{z}^{N*} + r^* \bar{Z}^* = T l^* S. \tag{25}$$

[8] Any specific redistribution $z(\nu, t)$ is expressed in terms of K,C and p and their time derivatives, so Z and z are not independent dynamic variables themselves.

[9] This can be shown in the three-dimensional system: Linearizing around the steady state shows that it is a saddle point with one stable arm. Since C is a jump variable which instantaneously adjusts such that the optimality and transversality conditions are observed, the system is on the stable path (see Appendices of Petrucci (2006)).

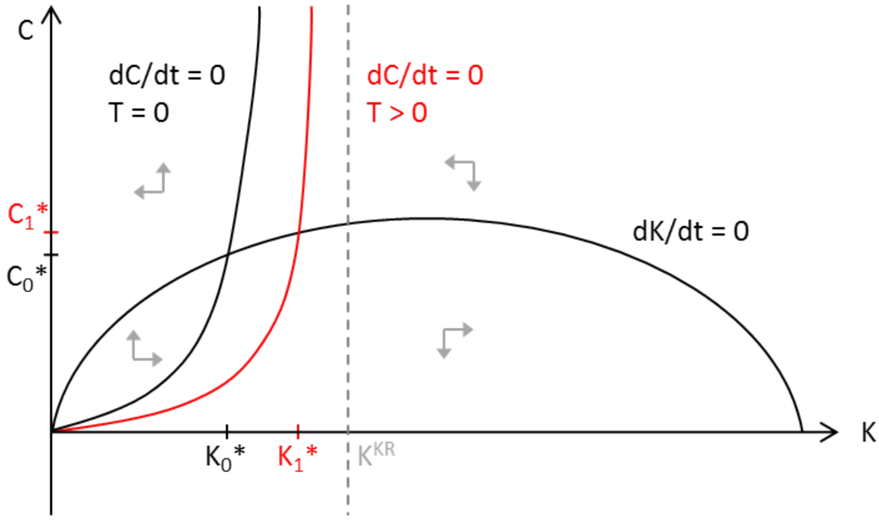

Figure 1: Phase diagram for redistributions with $\bar{Z}^{\dagger}(K) - \bar{z}^{N\dagger}(K) \geq 0$ for all $K \in [0, K^{kr}]$ and all $T \in [0; 1]$

Moreover, the aggregate of individual present values of future transfers in the steady state *for a permissible redistribution scheme satisfies*

$$\bar{Z}^* < \frac{Tl^*S}{r^*}. \tag{26}$$

Proof. We require $d\bar{Z}^*(t)/dt = 0$ in the steady state[10]. Applying Leibniz' rule yields:

$$\frac{d\bar{Z}(t)}{dt} = \phi \bar{z}^N(t) + r^* \bar{Z}(t) - Z(t).$$

This equation means that the change in the aggregate present-value of all future transfers is the sum of three components: Future transfers to newly born generations and interest on existing aggregate future transfers minus presently paid out aggregate transfers. These three terms cancel for a uniform ("lump-sum") redistribution scheme, but not for other redistributions. Setting to 0 and inserting the government budget equation (6) leads to the first result. Furthermore, for a permissible redistribution scheme, we have $\bar{z}^{N*} > 0$. The second result then follows directly from Equation (25). $\square$

Finally, in the steady state the growth factor $R(t, \tau)$ simplifies to

$$R(t, \tau) = \int_t^\tau (r(\tilde{t}) + \phi) \mathrm{d}\tilde{t} = (r^* + \phi)(\tau - t).$$

This simplification will be used for the rest of the article wherever steady-state properties are discussed.

[10]We are indebted to Dankrad Feist for suggesting this derivation.

3 Results

We develop an intuition first for the fact that underaccumulation of capital due to the generation replacement effect can be mitigated by land rent taxation, which directs investment towards capital, and by redistribution favouring the fundless newborns. Second, we sketch why achieving the social optimum requires giving a high share of tax revenue to the newborn generations. Then, these intuitions are formalised: A theorem on the beneficial welfare effects of land rent taxation for arbitrary steady-state compatible redistributions is formulated and proved (Section 3.1), followed by an analysis of the feasibility of the social optimum and the details of specific redistribution schemes (Section 3.2). Finally, we consider a capital subsidy as an alternative to redistribution (Section 3.3). Table 1 at the end of this section summarises the welfare properties of the different possibilities for spending the land tax revenue.

Equation (22) is essential for analyzing the welfare effects of policies. Solving for the steady state interest rate yields

$$r^* = \rho + \phi(\rho + \phi)\frac{K^* + p(K^*, T)S + \bar{Z}^* - \bar{z}^{N*}}{C^*}. \tag{27}$$

Consider two cases: First, without taxes and transfers ($T = z = 0$), there is suboptimal underaccumulation in the decentralised equilibrium: using Equation (24), the numerator of the second term simplifies to $K^* + l^*S/r^*$ which is always positive. Thus, the interest rate of the decentralised case is higher than the implied price of capital in the social planner's steady state (compare Equation 20). It then follows from $F_{KK} < 0$ and Equation (15) that capital accumulation is lower, $K^* < K^{kr}$. As K^{kr} is to the left of the maximum of the parabola described by Equation (21), a lower capital stock implies suboptimal consumption, $C(K^*) < C(K^{kr})$.

Second, with positive taxes and transfers, there are two competing effects entering Equation (27): the land price effect given by $p(K^*, T)S$, and the overall redistribution effect given by $\bar{Z}^* - \bar{z}^{N*}$.

The price effect always reduces underaccumulation compared to the no-policy case, since the tax lowers pS, so *ceteris paribus* the second term in Equation (27) is smaller. Intuitively, this is because a land rent tax makes investment in land less attractive relative to investment in capital, as reflected in the no-arbitrage condition (8). Also, a lower land price implies that land wealth contributes less to the generation replacement effect. (These effects cannot, of course, be treated in isolation as the model describes a general equilibrium. Hence a formal derivation that accounts for all effects is needed and provided in Section 3.1.)

For the redistribution effect, the sign and relative size depends on the specific transfer scheme. There are two classes of redistributions:

As long as the newborns do not receive higher transfers than the average (Figure 1), the redistribution effect is positive or zero in Equation (27), but the contribution of the price effect dominates (according to Lemma 1, $\bar{Z}^* < Tl^* S/r^*$), so welfare is still increased. Since the price effect is on land wealth only, the generation replacement effect does not fully disappear and the social optimum cannot be achieved. This class of redistribution schemes includes important cases such as a uniform transfer to every individual, independent of age, and a regime where land owners are compensated for the flow of tax payments (Sections 3.2.1 and 3.2.4).

If the distribution is tilted towards the young (Figure 2), the redistribution effect is also negative in Equation (27). It shifts the aggregate steady state capital stock and consumption to higher values, and even to the social optimum. However, if the tax is high at the same time, both effects together may result in overaccumulation (Figure 3). From this second class, we analyse schemes where only the newborn receive transfers, or where transfers decline exponentially with age (see Sections 3.2.2 and 3.2.3).

We now capture and prove these heuristic explanations in three formal results: one on the potential positive welfare effects of land rent taxation depending on arbitrary redistributions (Section 3.1), one on the general infeasibility of the social optimum under uniform redistribution (Section 3.2.1) and the third stating a feasibility condition for the social optimum given transfers to newborns only (Section 3.2.2).

3.1 Hypergeorgism: formal result

The main result of the present article provides conditions on age-dependent redistribution schemes that ensure that land rent taxation is welfare-enhancing. In the statement and proof of the theorem, quantities will be discussed for values of K outside the steady state as if these capital levels were steady states, thus assuming that $r(K)$ is constant. We write $\bar{Z}^\dagger(K)$ and $\bar{z}^{N\dagger}(K)$ to highlight this.

Theorem 1 (Hypergeorgism)**.** *The government can increase social welfare by choosing both a land rent tax T and a permissible redistribution scheme zyielding a steady state in a way that*

- *new generations do not receive more than the average: $\bar{Z}^\dagger(K) \geq \bar{z}^{N\dagger}(K)$ for all $K \in [0, K^{kr}]$, or*
- *new generations do receive more than the average, but the tax rate T is not too high: $\bar{Z}^\dagger(K) < \bar{z}^{N\dagger}(K)$ for some K and $T \leq \phi/(\phi + \rho)$. For higher T, suboptimal overaccumulation of capital is possible, depending on the particular redistribution.*

The basic idea of an efficiency-enhancing land rent tax is implicit in Feldstein (1977), as pointed out by Petrucci (2006) and Koethenbuerger and Poutvaara (2009), but its welfare consequences as well as the dependency on the redistribution pattern have not been analysed to date. On the other hand, we only consider welfare in the steady state and not during the transition period following a tax reform.

The theorem is very general regarding the redistribution scheme, but the generality implies two disadvantages: First, only a comparison between the unregulated market outcome and a policy case is possible. One may also want to know whether a higher tax implies higher welfare in general. Given the uniform redistribution, a higher tax rate does in fact imply higher welfare, but this is not necessarily true for all other redistributions. Second, the theorem considers a welfare *improvement* only and is not informative about the achievability of the *social optimum*. But a general optimality condition for arbitrary tax rates and redistribution schemes can easily be obtained from Equation (27) if we use Equation (25) to replace $\bar{Z}^*$:

$$\bar{z}^{N*} = \frac{r(K^*)K^* + l(K^*)S}{r(K^*) + \phi}. \tag{28}$$

To assess the feasibility of a socially optimal fiscal policy[11], this general condition needs to be evaluated for specific redistribution schemes $z(\nu, \tau)$. The next subsection gives some examples.

We conclude this section with the proof of Theorem 1.

Proof of Theorem 1. We prove the first half of the theorem and then show how the second half follows under the additional assumption on the tax rate.

For the first part, the idea of the proof is to compare the steady state of the system with no policy to that of the policy case: It will be shown that although for a *fixed* capital stock, consumption is lower with the policy, both consumption and capital stock are higher in the steady state of the policy case. This is illustrated in Figure 1.

Consider two cases, one without taxes and the other with a land rent tax rate $T > 0$. Denote the steady states defined by Equations (21) and (22) for the two cases by (K^{0*}, C^{0*}) and (K^{1*}, C^{1*}) and let the superscripts 0 and 1 also indicate the no-policy and policy case for the parabola and the hyperbola. From the social welfare function chosen in Section 2.2, it follows that for an increase in social welfare it is sufficient to prove that

$$C^{0*} < C^{1*}.$$

[11] Although the condition for social optimality defines a steady-state – for any C, $r^* = \rho$ is a solution to Equation (22) –, we do not claim stability for this steady-state as it is unknown whether it holds for all redistributions considered below. However, as the redistributions which reach the social optimum also approximate this steady-state arbitrarily closely by the (stable) "hyperbolic" steady-state solution of Equation (22), the subsequent sections legitimately define a benchmark for evaluating redistribution schemes.

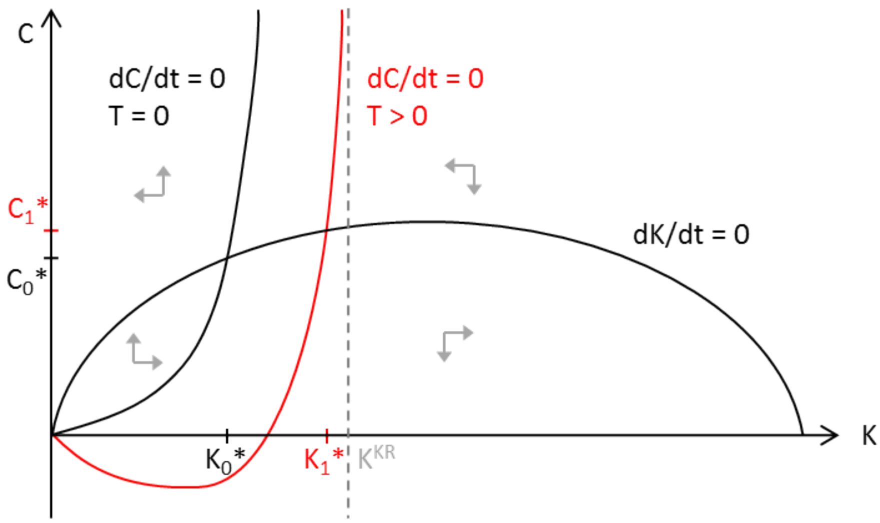

Figure 2: Phase diagram for redistributions with $\bar{Z}^{\dagger}(K) - \bar{z}^{N\dagger}(K) < 0$ for some $K \in [0, K^{kr}]$ and $T < T^{opt}$

The parabola defined by $\dot{K} = 0$ is unaffected by taxes and transfers, but the hyperbola, defined by $\dot{C} = 0$, changes: Equation (22) can be rewritten as

$$C_H^1(K) = \phi \frac{\rho + \phi}{r(K) - \rho} \left\{ K + \frac{l(K)S}{r(K)} - \frac{Tl(K)S}{r(K)} + \bar{Z}^{\dagger}(K) - \bar{z}^{N\dagger}(K) \right\}, \quad (29)$$

where we treat any value of K as if it was the steady state value (hence the †-notation). The second part of Lemma 1 can then be written as $\bar{Z}^{\dagger}(K) < Tl(K)S/r(K)$. This implies that the last three (the directly policy-dependent) terms in the curly bracket together are negative, and thus that $C_H^1(K) < C_H^0(K)$ for all $K \in [0, K^{kr}]$. In Figure 1, the hyperbola for $T > 0$ is below the no-policy case.

For any $K < K^{0*}$, we also have $C_H^0(K) < C_P^0(K)$ and $C_P^0(K) = C_P^1(K)$ since the parabola is policy-independent, so $C_H^1(K) < C_P^1(K)$ for $K < K^{0*}$. By the assumption that $\bar{Z}^{\dagger}(K) \geq \bar{z}^{N\dagger}(K)$ and as $T \leq 1$, C_H^1 is positive for all $K \leq K^{kr}$, and thus tends to $+\infty$ as K approaches K^{kr}. Hence the (non-trivial) intersection of parabola and hyperbola for T_1 must occur at a capital stock K^{1*} with $K^{0*} \leq K^{1*} < K^{kr}$. In this interval, $C_P(K)$ is increasing in K, thus $K^{0*} < K^{1*}$ and also $C^{0*} < C^{1*}$, as required for the first part of the theorem.

For the case $\bar{Z}^{\dagger}(K) < \bar{z}^{N\dagger}(K)$ in the second part of the theorem, over-accumulation is possible. It occurs if $K^{1*} \geq K^{kr}$, which is only possible if the hyperbola C_H^1 tends to $+\infty$ when approaching its singularity from the right. We show that this is impossible if $T \leq \phi/(\phi + \rho)$.[12] Given this bound

[12]Under some regularity conditions on higher derivatives of the production function,

on T, we prove in the following that it holds that

$$N(K) := K + (1-T)\frac{l(K)}{r(K)}S + \bar{Z}^{\dagger}(K) - \bar{z}^{N\dagger}(K) \geq 0$$

for all $K \geq K^{kr}$. This is sufficient because the intersection of parabola and hyperbola then occurs for $K^{1*} \leq K^{kr}$ by continuity of $N(K)$ (see Figures 2 and 3). The argument of the first part of the proof is then valid because then there exists some K' such that $C_H^1(K)$ is positive for $K' \leq K \leq K^{kr}$.[13] Again, we treat any value of K as if it was the steady state value.

From Lemma 1 it follows that in the steady state $\bar{z}^{N\dagger}(K) \leq Tl(K)S/\phi$ and thus

$$\bar{Z}^{\dagger}(K) - \bar{z}^{N\dagger}(K) \geq -\frac{Tl(K)S}{\phi},$$

as $\bar{Z}^{\dagger}(K) \geq 0$. It hence remains to prove that

$$K + \frac{(1-T)l(K)S}{r(K)} - \frac{Tl(K)S}{\phi} \geq 0 \quad \text{for all } K \geq K^{kr}.$$

To this end, it is sufficient to show

$$\frac{(1-T)}{r(K)} \geq \frac{T}{\phi} \quad \Leftrightarrow \quad r(K) \leq \frac{\phi(1-T)}{T} \quad \text{for all } K \geq K^{kr}.$$

For such K, $r \leq \rho$, so that it remains to verify

$$\rho \leq \frac{\phi}{T} - \phi.$$

The last equation holds if and only if $T \leq \phi/(\phi + \rho)$, as required. □

3.2 Redistribution schemes

While land rent taxation improves capital accumulation and welfare for a large class of possible redistributions of the tax revenue, we have so far not considered specific redistribution schemes. We discuss four specific redistributions: transfers that are uniform across cohorts of all ages, positive only for newborns, exponential functions of age or compensatory. All particular redistribution schemes discussed are steady-state compatible because of their symmetry. The results are summarised in Table 1 at the end of this section.

which are for example satisfied by a Cobb-Douglas function, it follows that even $T \leq \phi(\rho K^{kr} + l(K^{kr})S)/(\rho l(K^{kr})S)$ is sufficient for the second statement of the theorem, but this is not true for the general production function considered in this paper.

[13] The case that $N(K^{kr}) = 0$ is special, the argument of the proof collapses as Equation (29) cannot be derived, but the result is true because $K^{1*} = K^{kr}$.

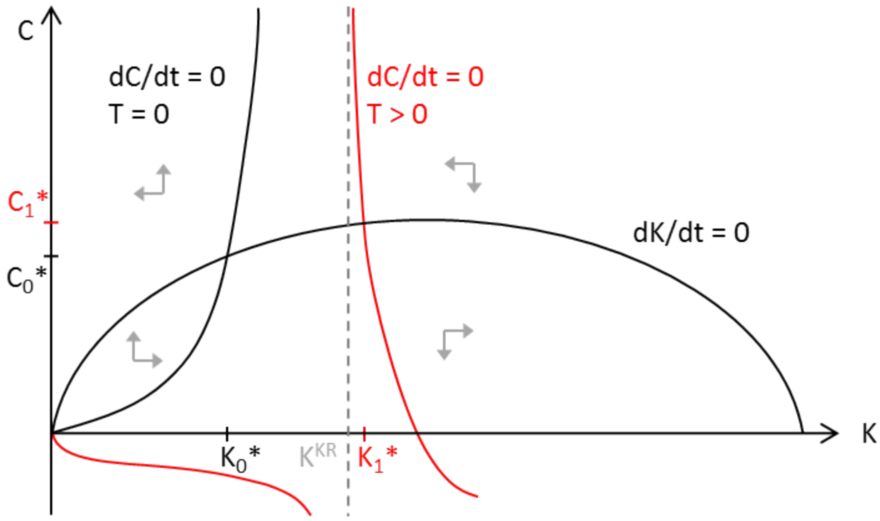

Figure 3: Phase diagram for redistributions with $\bar{Z}^{\dagger}(K) - \bar{z}^{N\dagger}(K) < 0$ for some $K \in [0, K^{kr}]$ and $T > T^{opt}$

3.2.1 Uniform distribution

Under a uniform age-independent transfer scheme, *per capita* transfers are

$$z_u(t) = Tl(t)S. \tag{30}$$

Thus, the present value of transfers to individuals and its aggregation over all cohorts have the same value:

$$\bar{z}_u(t) = \int_t^{\infty} Tl(\tau)Se^{-R(t,\tau)(\tau-t)}\mathrm{d}\tau, \tag{31}$$

$$\bar{Z}_u(t) = \int_{-\infty}^{t} \bar{z}_u(t)\phi e^{\phi(\nu-t)}\mathrm{d}\nu = \bar{z}_u(t). \tag{32}$$

In the steady-state the integrals have an explicit solution:

$$\bar{z}_u(t)^* = \bar{Z}_u(t)^* = \frac{Tl^*S}{r^* + \phi}. \tag{33}$$

One can derive

Proposition 1. *Reaching the social optimum is infeasible with the uniform redistribution of tax revenues.*

Proof. To demonstrate this, insert the values for this specific redistribution into the equations for aggregate consumption and consumption growth:

$$\frac{\dot{C}(t)}{C(t)} = r(t) - \rho - \phi(\rho + \phi)\frac{K(t) + p(t)S}{C(t)}. \tag{34}$$

The capital stock dynamics $\dot{K}$ remain unchanged.

While the two distribution-related terms cancel in Equation (34), the effect of the land rent tax $T > 0$ on the land price p remains and leads to a welfare improvement compared to the case without taxation. But even if the price falls to zero for the maximum tax rate $T = 1$, the last term does not vanish since aggregate growth is still lower than optimal because of the newborns' lack of capital. □

3.2.2 Redistribution to newborns only

Next, the case in which all tax revenues are given to newborn individuals and all others receive nothing is considered:

$$z_n(\nu, t) \equiv \frac{Tl(t)S}{\phi}\delta(\nu - t). \tag{35}$$

Here $\delta(\cdot)$ is a Dirac distribution defined such that

$$\int_I \delta(x) f(x) \mathrm{d}x = \begin{cases} f(0) & \text{if } 0 \in I \\ 0 & \text{otherwise} \end{cases} \tag{36}$$

for any continuous function $f : \mathbb{R} \to \mathbb{R}$ and compact interval I.

The present value of transfers to individuals and its aggregation over all cohorts are[14]

$$\bar{z}_n(t, t) = \frac{Tl(t)S}{\phi}, \tag{37}$$

$$\bar{z}_n(\nu, t) = 0 \quad \text{for } \nu > t \quad \text{and} \tag{38}$$

$$\bar{Z}_n(t) = 0. \tag{39}$$

[14] It is instructive to consider two ways of obtaining the latter result, $\bar{Z} = 0$. The first is to directly use $\bar{z}_n$ in the definition of $\bar{Z}$,

$$\bar{Z}_n(t) = \int_{-\infty}^{t} \int_{t}^{\infty} \frac{Tl(\tau)S}{\phi} \delta(\nu - t) e^{-R(t,\tau)} \mathrm{d}\tau \phi e^{\phi(\nu - t)}.\mathrm{d}\nu$$

The inner integral is TlS/ϕ for $\nu = t$ and zero for $\nu < t$. Unlike the Dirac distribution, the value at $\nu = t$ is finite – thus, the outer integral is zero.

The second approach is to approximate the Dirac distribution by an exponential function (see Section 3.2.3),

$$z(\nu, t) = Gue^{-u(t-\nu)} \overset{u\to\infty}{\to} z_n(\nu, t) \quad \text{where} \quad G = TlS/\phi,$$

which yields

$$\bar{Z}_n(t) = \frac{G\phi u}{(r + \phi + u)(\phi + u)} \overset{u\to\infty}{\to} 0.$$

In this case, aggregate consumption (11) and consumption growth (13) become

$$C(t) = (\rho + \phi)[K(t) + p(t)S + \bar{W}(t)] \tag{40}$$

$$\frac{\dot{C}(t)}{C(t)} = r(t) - \rho - (\rho + \phi)\frac{\phi[K(t) + p(t)S] - Tl(t)S}{C(t)} \tag{41}$$

Again, $\dot{K}$ remains unchanged.

If there exists a tax $T \leq 1$ such that the last term in Equation (41) is zero, the social optimum can be reproduced (see Equation 19). That is, the optimal tax in the steady state is

$$T^{opt} = \frac{\phi(r^* K^* + l^* S)}{(\phi + r^*) l^* S} = \frac{K^* + p^* S}{l^* S}. \tag{42}$$

where Equation (8) has been used for the second equality. Intuitively, the optimal tax revenue compensates a newborn for her missing share of wealth $K^* + p^* S$. If $T^{opt} \leq 1$, the social optimum is feasible. Thus we have proved:

Theorem 2 (Feasibility of the social optimum)**.** *The socially optimal outcome can be implemented with a land rent tax and a redistribution of the tax revenue to only the newborns if*

$$\phi K^{kr} \leq l^{kr} S. \tag{43}$$

This is an intuitive result, stating that a tax and targeted redistribution achieves the social optimum if the (originally) missing capital of the newborns is smaller than the transfers that they may receive – which is at most the entire land rent. So the negative effect on aggregate consumption of the former can be compensated by the latter.

The result also gives an absolute bound for reaching the social optimum in our model: in continuous OLG models, underaccumulation is the result of a lack of wealth of the newborns; thus redistributing to that generation the full revenue is the most efficient way of curing the underaccumulation. (If the revenue is so high that it leads to overaccumulation, the tax rate can be lowered.) To justify this claim we next consider a redistribution based on a function that approximates the Dirac distribution.

3.2.3 Exponential redistribution schemes

For assessing the robustness of the condition on the feasibility of the social optimum, it is instructive to consider redistributing the land tax revenue by an exponential function in age approximating the Dirac distribution.[15] This redistribution has two parameters: a_0 denotes the value of the redistribution

[15] We are indebted to Dankrad Feist for suggesting this redistribution.

at birth and a_s denotes the speed of the exponential change with age. The exponential redistribution scheme depending on a_0 and a_s is then defined by

$$z_e(\nu,\tau) = a_0 e^{-a_s(\tau-\nu)}. \tag{44}$$

For this redistribution to be permissible in the sense of Definition 1, a restriction on the choice of a_0 and a_s is required:

$$Tl^*S = \frac{a_0\phi}{(a_s+\phi)} \quad \text{with } (a_s+\phi) > 0. \tag{45}$$

The restriction is obtained by solving the integral in Equation (6) for z_e. It implies that a_0 is positive and that $a_s > -\phi$.

When can this redistribution be socially optimal? For $-\phi < a_s < 0$, the redistribution is permissible, but exponentially increasing with age. It can be shown that for this parameter range it cannot be socially optimal. For $a_s > 0$, on the contrary, a condition for social optimality can be calculated. Evaluating the integrals in the respective definitions yields

$$\bar{z}_e^* = \frac{a_0}{r^*+\phi+a_s} \quad \text{and} \tag{46}$$

$$\bar{Z}_e^* = \frac{\phi a_0}{(r^*+\phi+a_s)(\phi+a_s)}. \tag{47}$$

To determine when the social optimum can be reached by this redistribution, Equations (28), (45) and (46) need to be combined to calculate a_0 and a_s explicitly. It can be shown that

$$a_0 = \frac{Tl^*Sr^*(r^*K^*+l^*S)}{Tl^*S(r^*+\phi)-\phi(r^*K^*+l^*S)}. \tag{48}$$

Note that a_0 is positive if the denominator is. Setting $T=1$, and determining when the denominator in Equation (48) is positive, it is proved that

Proposition 2. *A redistribution scheme in which land rents are given back to individuals according to an exponential function decreasing in age can reach the social optimum if*

$$\phi K^{kr} < l^{kr}S. \tag{49}$$

This confirms that the exponential function used approximates the Dirac distribution. Moreover, if social optimality is feasible, the optimal tax is

$$T^{opt} = \frac{(r^*+\phi)a_0 - r^*(r^*K+l^*S)}{a_0\phi(r^*K+l^*S)} \tag{50}$$

for arbitrary $a_0 > 0$, $a_s > 0$ that satisfy Equation (45).

3.2.4 Compensatory redistribution

Isolating the effect of the tax as a shift in relative prices requires compensating the tax payers. A simple compensation would be to continuously remunerate land owners for the flow of taxes on recurring rents, as considered for example by Calvo et al. (1979). Fane (1984) points out that this does not constitute a *full* compensation as used in tax incidence analysis. Instead it would be required that the initial wealth loss due to the drop in land price also be compensated: the government issues bonds (when the tax is announced) to finance a lump-sum payment to land owners, and using tax revenues for interest payments subsequently. Since our steady state analysis neglects transitory effects, we consider the simpler scheme compensating land owners for the flow of tax payments only.

For the model in this study, it can then be shown that land rent taxation combined with such a compensatory redistribution of revenues to individuals cannot establish the social optimum and even yields lower welfare than a uniform redistribution scheme. In the following, a sketch of the argument is presented.

Starting from the uniform redistribution, some of the transfers from some selected young generations are shifted to selected older generations, which will have accumulated more land and thus have a higher land rent tax burden. At time $\tilde{t}$, the shift of *contemporaneous* transfers does not have an effect on aggregate consumption (Equation 11) since any cohort consumes the same fraction of their wealth. However, the expectation of *future* transfers of the same pattern does have an effect, since the expected increased transfers towards today's youngest generations will be at the cost of unborn generations ($\nu > \tilde{t}$), whose future loss finances today's consumption. Technically, $\bar{Z}(\tilde{t})$ is higher than without the shift. By itself, this effect increases aggregate consumption at any given capital stock level - the hyperbola described by Equation (22) with shifted transfers is above the original hyperbola for all values of the capital stock.[16] However, since higher aggregate consumption implies foregone investment and thus a lower steady state capital stock, the overall effect on the steady-state level of aggregate consumption is negative.

Thus, since the uniform redistribution from which we started is not socially optimal, the compensatory redistribution which gives more transfers to older cohorts owning more land can neither be optimal.

[16] Additionally, $\bar{z}^N$ is lower when transfers are shifted, since increased transfers in the far future are discounted more than losses in the nearer future. This strengthens the overall effect of the shift of transfers, $(\bar{Z}^* - \bar{z}^{N*})$ in Equation (22).

Distribution	$\bar{Z}^*$	$\bar{z}^{N*}$	Social optimum	T^{opt}
Uniform	$\frac{Tl^*S}{r^*+\phi}$	$\frac{Tl^*S}{r^*+\phi}$	infeasible	N/A
Newborns only	0	$\frac{Tl^*S}{\phi}$	$\phi K^* \leq l^*S$	$\frac{\phi(r^*K^*+l^*S)}{(\phi+r^*)l^*S}$
Exponential	$\frac{\phi a_0}{(a_s+r^*+\phi)(\phi+a_s)}$	$\frac{a_0}{a_s+r^*+\phi}$	$\phi K^* < l^*S$	(Eq. 50)
Compensatory	unknown	unknown	infeasible	N/A
Capital subsidy	N/A	N/A	$\phi K^* \leq \frac{l^*S}{(\rho+\phi)}\frac{C^*}{K^*}$	(Eq. 53)

Table 1: Properties of redistributions of land tax revenue in the steady-state: The dependencies of l^* and r^* on K are suppressed for readability. The parameters a_0, a_s of the exponential redistribution are subject to restrictions, see Section 3.2.3.

3.3 Capital subsidy

An alternative to redistributing tax revenues directly to individuals is to subsidise capital in the form of a markup on the market interest rate. This does not change the results in Section 2 except that r is replaced by $\tilde{r} \equiv r+\epsilon$, with ϵ being the markup financed by land rent tax revenues. Specifically, aggregate consumption growth becomes

$$\dot{C}(t) = C(t)\left[r(t) + \epsilon - \rho\right] - \phi(\rho+\phi)\left[K(t) + p(t)S\right] \tag{51}$$

so restoring the Keynes-Ramsey case requires

$$\epsilon C = \phi(\rho+\phi)(K(t) + p(t)S). \tag{52}$$

Using $\epsilon K^* = Tl(K^*)S$ and $p^* = (1-T)l(K^*)/r^*$, a steady state condition for the optimal tax is obtained:

$$\left[\frac{l^*S}{K^*} + \phi(\rho+\phi)\frac{l^*S}{r^*C^*}\right]T^{opt} = \phi(\rho+\phi)\left[\frac{K^*}{C^*} + \frac{l^*S}{r^*C^*}\right]. \tag{53}$$

Hence a proposition on the feasibility of the social optimum for the capital subsidy can be deduced by inserting $T \leq 1$:

Proposition 3. *Reaching the socially optimal level of aggregate consumption with a tax on land rents to finance a capital subsidy is feasible if*

$$\phi K^* \leq \frac{1}{(\rho+\phi)}\frac{C^*}{K^*}l^*S. \tag{54}$$

Of course, subsidizing capital does not achieve the socially optimal level of aggregate consumption by *redistribution,* so that if one is concerned with reaching also the static socially optimal allocation of consumption, further redistribution would be required (see Sections 2.2 and 4.2).

4 Discussion

We discuss the empirical relevance of our theoretical result for fiscal policy and also delineate its normative validity. To this end we first test the feasibility conditions for meeting the social optimum under a capital subsidy or transfers to newborns using empirical results from the literature (Section 4.1). Second, we detail under which conditions the suggested policy instruments are desirable (Section 4.2). We finally outline potential modifications and extensions of our framework, notably possibilities of financing public capital with the land rent tax revenue (Section 4.3).

4.1 Empirical Relevance

Can our conditions for implementing the social optimum be fulfilled in practice? First we consider the feasibility of reaching the social optimum by redistributing all land tax revenues to the newborns, as in Section 3.2.2. Assume a Cobb-Douglas production function[17]

$$Y = F(L, K, S) = F_0 L^{(1-\alpha-\beta)} K^{\alpha} S^{\beta}, \tag{55}$$

so that $l^* S = \beta Y^*$. Denoting the steady-state ratio of the total capital stock to total output by $\kappa = K^*/Y^*$, the feasibility condition (43) becomes

$$\phi\kappa \leq \beta. \tag{56}$$

We use estimation results from Caselli and Feyrer (2007) for κ and to approximate β.[18] Their study covers a wide variety of countries, ranging from Côte d'Ivoire and Peru to Switzerland and the USA.

[17]With this simplifying assumption we follow Caselli and Feyrer (2007), also because we use their parameter estimates in the following.

[18]Caselli and Feyrer (2007) do not report β directly, but estimates of "one minus the labor share" (p.541) in income and the share of reproducible capital in income. The difference - our approximation for β - is the income share of land and other natural resources, some of which are not fixed factors. However, the authors report "Proportions of different types of wealth in total wealth" (p.547) which demonstrate that while subsoil resources are important for some countries (their mean wealth share is 10.5%, with a standard deviation of 16.4, compared to a 34.8% mean share of land-related wealth), land wealth dominates in most cases (subsoil resources' median wealth share is only 1.5%, compared to a 23.5% median share of land-related wealth). Since the dataset does not include any countries that mainly rely on fossil fuel extraction, such as countries on the Arabic Peninsula, and given the wide margin by which the sufficiency condition is fulfilled for most countries (see below), we consider this rough approximation as sufficient for our purposes.

We find that the feasibility condition is satisfied with realistic values of ϕ for all 53 countries quoted, often by a wide margin.[19]

For the Cobb-Douglas case, the optimal steady state tax is

$$T_{CD}^{opt} = \frac{\phi\kappa\alpha + \phi\kappa\beta}{\alpha\beta + \phi\kappa\beta}. \tag{57}$$

This implies that the lower κ and the higher β, the lower the share of the land rent that has to be redistributed to the newborns.

Second, for the feasibility of a social optimum by capital subsidies from Section 3.3, again assume the Cobb-Douglas production function given by Equation (55). From Equation (12), we have $\dot{K} = Y^* - \delta K^* - C^* = 0$ in the steady state, thus by eliminating C^* the feasibility condition (54) becomes

$$\phi\kappa \leq \frac{1}{(\rho + \phi)}(\frac{1}{\kappa} - \delta)\beta. \tag{58}$$

Even if we assume high values for the additional parameters in this equation – for instance $\rho = 0.05$ and $\delta = 0.15$ –, we find that this feasibility condition is weaker than for the case of transfers by a factor of two or more for the 53 countries quoted (Caselli and Feyrer, 2007). It is weaker by a factor of ten and more if we assume $\rho = 0.01$ and a more realistic depreciation rate of $\delta = 0.05$.

4.2 Normative cogency

In this subsection we detail implications and justifications of the normative viewpoint chosen and outline three limitations for the fiscal policies suggested above.

The social planner of the above model is a preference-satisfaction utilitarian in the sense of Calvo and Obstfeld (1988) who only cares about the dynamically optimal allocation. Being in this paper solely concerned with policy measures that raise total consumption, we thus ignore the question of its static distribution: when social welfare is increased, it is permissible that some individuals lose if others gain more.

An alternative conception of social welfare is to assume the social structure of perfect altruism between generations: a single dynasty of households

[19]For example, Switzerland has the highest $\kappa = 3.59$ and lowest $\beta = 0.06$ in the dataset (Caselli and Feyrer, 2007), so we need $\phi \leq 0.017$. The real birth rate is 0.010 (Eurostat, 2012), so there is even scope to accommodate modest population growth (the death rate is 0.008 (Eurostat, 2012). Also, ϕ is lower than the real birth rate because in reality there are *some* bequests. For comparison, the USA have $\kappa = 2.19$ and $\beta = 0.08$ (Caselli and Feyrer, 2007), implying $\phi \leq 0.037$. Most other developed countries in the dataset range between Switzerland and the USA, while most industrializing and developing countries have lower capital-to-output ratios and higher shares of land in output (e.g. Morocco with $\kappa = 1.31$, $\beta = 0.19$ and thus $\phi \leq 0.145$, which would allow sufficient transfers to newborns even for a high population growth rate).

with no fundless newborns, as captured by the optimal growth model. From the perspective of a social planner maximizing social welfare, there is then no distinction between individuals, so if the death rate equals the birth rate the replacement dynamics can be ignored. This alternative conception is equivalent to the preference-satisfaction approach for the purpose of evaluating policies, as follows from the calculation in Section 2.2.

We now point to three limitations of the normative position of the paper.

First, our analysis only compares the welfare outcome in steady-states while we do not consider transitional dynamics.[20] This means that our policies are no Pareto-improvements as some generations might be worse off during the transition from a steady-state without policies to one with a policy in place. Smoothing the transition for all generations to find a Pareto-improving tax policy is likely to involve an elabourate scheme of lump-sum transfers (Heijdra and Meijdram, 2002).

Second, even if aggregate welfare is higher in one steady-state than another, our suggested redistribution schemes are not Pareto-improving when comparing steady-states only: older generations – "rentiers" – will be worse off in some cases. However, the fact that aggregate welfare is higher in all suggested redistribution schemes implies that our policies satisfy the Kaldor-Hicks criterion (Hicks, 1940; Kaldor, 1939), that is, they constitute a potential Pareto-improvement.

Third, we emphasise that a preference-satisfaction social optimum would only be achieved if also the static, not only the dynamic optimum were implemented. Picking a redistribution of rents that also implements the statically optimal distribution seems possible, but whether this can be achieved without practically infeasible lump-sum taxes is an open problem for further work. This limitation applies to the case of the capital subsidy; by contrast, the redistribution to newborns *does* achieve the dynamic optimum by also providing the statically optimal allocation.

What does this mean in practice? While we identify in this paper empirically plausible possibilities for increasing total welfare by a land rent tax, the redistribution scheme chosen by a government would also need to take into account transitional dynamics and political feasibility given that rentiers may be made worse off.

4.3 Extensions and Modifications

We delineate three further ways to examine the validity of hypergeorgism.

First, it would be desirable to study the implications of the fiscal policies

[20]Throughout we compare an existing steady-state without policy and a new steady-state with policies in place *that results from the existing one.* So some agents will live in the conditions of both states. If instead one compared two separate dynamical systems, all welfare-improving policies would also be Pareto improving, but that case is politically irrelevant.

suggested above not only by comparing steady states, but also by taking account of the transitional dynamics between a steady state without the policies and one with the policies in place. Such an analysis would need to follow the approach taken by Heijdra and Meijdram (2002) for the case of financing productive public capital.

Second, it should be analysed whether hypergeorgism is also a valid theory for other causes of underaccumulation of capital than that implicit in the continuous OLG model, imperfect altruism between generations. Further potential causes of underaccumulation that need to be considered are: inefficient capital investment by firms (Scharfstein and Stein, 2000), uninternalised spillovers raising the social value of investment above the private value (Romer, 1986), inefficient capital markets (Fama, 1970, 1991), time-inconsistent preferences by households that have self-control problems about saving (Laibson, 1997; Thaler and Benartzi, 2004). Additionally, a bubble on the real estate market may lead to underinvestment in productive capital (Buiter, 2010) and conversely, high land prices may be a sign of underaccumulation.

Third, land rent taxation may be also desirable because the revenue could be used for reducing other inefficiencies than suboptimal capital accumulation, notably investments in productive public capital. For the case of a single dynastic household, Mattauch et al. (2013) provides some results that can be extended to the setting of overlapping generations (see also Heijdra and Meijdram, 2002). While using the tax revenue for investment in public capital will constitute a welfare improvement, this will not generally be socially optimal if no further revenue is left for redistributive transfers to the newborns. Only if the land rent exceeds the sum of the socially optimal investment in public capital and the minimum amount ϕK required for curing the inefficient capital accumulation can the social optimum be reproduced. The content of the neoclassical Henry George Theorems is that in some circumstances confiscating (land) rents is sufficient for financing the optimal level of a public good (Stiglitz, 1977). The suggested analysis would be an extension of that content to the context of intertemporal infrastructure financing with a redistributive twist.

A further extension would be to translate the results of this study to a setting with a portfolio of capital assets and natural resources other than land (Siegmeier et al., 2014).

5 Conclusion

This paper studied the welfare effect of land rent taxation and how the revenues should be redistributed to a population of heterogeneous households with imperfect intergenerational altruism. It was shown that taxing land rents leads to an increase in aggregate welfare and that by redistributing the tax revenue to the newborns the government can achieve the social optimum. This is true as long as the land rent tax is not too high. Achieving the social optimum by such policies is possible as long as the total land rent is greater than the stock of productive capital multiplied by the birth rate, a condition which could be confirmed for a diverse set of countries. By contrast, the government cannot implement the social optimum with a compensatory or a uniform redistribution, which nevertheless increase welfare. Subsidizing productive capital is also a potentially socially optimal policy.

In summary, our findings support the view that under imperfections in the accumulation of productive assets, taxing and redistributing rents on fixed production factors is a policy measure that leads to a welfare gain – a view we label *hypergeorgism*.

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A Appendix

A.1 Derivation of the Keynes-Ramsey rule and the arbitrage condition

The budget constraint (2) can be split into a constraint on monetary terms and a constraint on land size by defining $d(\nu,t) = \phi s(\nu,t) - \dot{s}(\nu,t)$. Dropping the time arguments, we obtain:

$$\dot{k} = w + [r + \phi]k + (1 - T)ls + pd + z - c \tag{59}$$

$$\dot{s} = \phi s - d. \tag{60}$$

Individuals maximise utility given by Equation (1) by choosing $c(\nu,\tau)$ and $d(\nu,\tau)$, subject to Equations (59), (60) and the transversality condition (5). Writing λ and μ for the multipliers of (59) and (60) in the current value

Hamiltonian H_c, we obtain the following first order conditions:

$$\frac{\partial H_c}{\partial c} = \frac{1}{c} - \lambda = 0 \tag{61}$$

$$\frac{\partial H_c}{\partial d} = \lambda p - \mu = 0 \tag{62}$$

$$\frac{\partial H_c}{\partial k} = (\rho + \phi)\lambda - \dot{\lambda} \quad \Rightarrow \quad \lambda(r + \phi) = (\rho + \phi)\lambda - \dot{\lambda} \tag{63}$$

$$\frac{\partial H_c}{\partial s} = (\rho + \phi)\mu - \dot{\mu} \quad \Rightarrow \quad \lambda(1 - T)l + \mu\phi = (\rho + \phi)\mu - \dot{\mu}. \tag{64}$$

Inserting the time derivative of (61) into Equation (63) yields the Keynes-Ramsey rule (7). Using Equation (62) and its time derivative to replace μ and $\dot{\mu}$ in Equation (64) and applying Equation (63) gives the arbitrage condition for investing in land or capital (8).

A.2 Individual lifetime budget constraint and consumption level

First, the lifetime budget constraint (9) is derived, from which the individual consumption level can then be obtained. Dropping the time arguments ν and τ where no confusion is possible, regrouping terms in (2) and adding $\dot{p}s - (r + \phi)ps$ on both sides, it follows that:

$$\begin{aligned} \dot{k} + p\dot{s} + \dot{p}s - (r + \phi)(k + ps) &= w + (1 - T)ls + z + \dot{p}s - rps - c = \\ &= w + z - c. \end{aligned}$$

The last equality follows from (8). This leads to

$$\begin{aligned} &\frac{d}{d\tau}\left[(k + ps)e^{-R}\right] = (w + z - c)e^{-R} \\ \Rightarrow &\int_t^\infty \frac{d}{d\tau}\left[(k + ps)e^{-R}\right] \mathrm{d}\tau = \int_t^\infty (w + z - c)\, e^{-R}\mathrm{d}\tau. \end{aligned}$$

For the integral on the left-hand side, note that $\exp(-R(t,t)) = 1$ and use (5) to obtain

$$\begin{aligned} &\int_t^\infty \frac{d}{d\tau}\left[(k + ps)e^{-R}\right] \mathrm{d}\tau = \\ &= \lim_{\tau\to\infty}([k(\nu,\tau) + p(\tau)s(\nu,\tau)]e^{-R(t,\tau)}) - k(\nu,t) - p(t)s(\nu,t) = \\ &= -\, k(\nu,t) - p(t)s(\nu,t). \end{aligned} \tag{65}$$

Using the definition of $\bar{w}(t)$ and $\bar{z}(\nu,t)$ from the main text, the right-hand side can be written as

$$\int_t^\infty (w + z - c)\, e^{-R}\mathrm{d}\tau = \bar{w}(t) + \bar{z}(\nu,t) - \int_t^\infty c(\nu,\tau)e^{-R}\mathrm{d}\tau. \tag{66}$$

Combine Equations (65) and (66) to obtain the lifetime budget constraint (9).

Then, the individual consumption level follows in two steps. First, solve the Keynes-Ramsey rule for c,

$$\begin{aligned}(7) \Rightarrow \int_{c(\nu,t_0)}^{c(\nu,\bar{t})} \frac{1}{c(\nu,\tau)} \mathrm{d}c &= \int_{t_0}^{\bar{t}} (r(\tau)-\rho)\mathrm{d}\tau \\ \Rightarrow c(\nu,\bar{t}) &= c(\nu,t_0) \exp\left(\int_{t_0}^{\bar{t}} (r(\tau)-\rho)\mathrm{d}\tau\right).\end{aligned}$$

Second, setting $t_0 = t$ and $\bar{t} = \tau$ in the last expression and replacing c in the lifetime budget equation,

$$\begin{aligned}k(\nu,t) + p(t)s(\nu,t) + \bar{w}(t) + \bar{z}(\nu,t) &= \int_t^{\infty} c(\nu,t) e^{\int_t^{\tau}[r(\tilde{t})-\rho]\mathrm{d}\tilde{t}} e^{-R(t,\tau)} \mathrm{d}\tau = \\ &= c(\nu,t) \int_t^{\infty} e^{-\int_t^{\tau}(\rho+\phi)\mathrm{d}\tilde{t}} \mathrm{d}\tau = \\ &= c(\nu,t)/(\rho+\phi).\end{aligned}$$

Thus, the level of individual consumption is a fixed fraction of wealth independent of time or the individual's age.

A.3 Aggregate solution

We derive the aggregate quantity for general age-dependent transfers $z(\nu,t)$ as given in Section 2.

The aggregate consumption level $C(t)$ for general transfers is obtained directly from aggregation of Equation (10), as given by Equation (11) in the main text.

The dynamics of the total capital stock (12) are obtained by applying Leibniz' rule to

$$K(t) = \int_{-\infty}^{t} k(\nu,t)\phi e^{\phi(\nu-t)} \mathrm{d}\nu,$$

replacing $\dot{k}$ by its expression from the individual budget constraint (2), and using Equation (4) for aggregate changes in land ownership:

$$\begin{aligned}
\dot{K}(t) &= \underbrace{k(t,t)}_{=0}\phi e^{\phi(t-t)} - 0 + \int_{-\infty}^{t} \frac{\mathrm{d}}{\mathrm{d}t}\left[k(\nu,t)\phi e^{\phi(\nu-t)}\right]\mathrm{d}\nu = \\
&= -\phi K(t) + \int_{-\infty}^{t} \dot{k}(\nu,t)\phi e^{\phi(\nu-t)}\mathrm{d}\nu = \\
&= w(t) + r(t)K(t) + [1-T(t)]l(t)S + \\
&+ p(t)\underbrace{\left[\phi S - \int_{-\infty}^{t} \dot{s}(\nu,t)\phi e^{\phi(\nu-t)}\mathrm{d}\nu\right]}_{=0} - C(t) + \underbrace{\int_{-\infty}^{t} z(\nu,t)\phi e^{\phi(\nu-t)}\mathrm{d}\nu}_{=T(t)l(t)S} = \\
&= w(t) + r(t)K(t) + l(t)S - C(t).
\end{aligned}$$

The government budget constraint (6) was used in the last step, so taxes and transfers always cancel out in the last step and the result does not directly depend on the redistribution $z(\nu, t)$. However, it may have an indirect effect via prices, stock levels and consumption.

Similarly, we derive the dynamics of aggregate consumption given by Equation (13):

$$\begin{aligned}
\dot{C}(t) &= c(t,t)\phi e^{\phi(t-t)} - 0 + \int_{-\infty}^{t} \frac{\mathrm{d}}{\mathrm{d}t}\left[c(\nu,t)\phi e^{\phi(\nu-t)}\right]\mathrm{d}\nu = \\
&= \phi(\rho+\phi)[\bar{w}(t) + \bar{z}(t,t)] - \phi C(t) + \underbrace{\int_{-\infty}^{t} \dot{c}(\nu,t)\phi e^{\phi(\nu-t)}\mathrm{d}\nu}_{=(r(t)-\rho)C(t)} = \\
&= [r(t)-\rho]\,C(t) - \phi(\rho+\phi)[K(t) + p(t)S + \bar{Z}(t) - \bar{z}(t,t)].
\end{aligned}$$

The first equality follows from Leibniz' rule. For the second, $c(t,t) = (\rho + \phi)[k(t,t) + p(t)s(t,t) + \bar{w}(t) + \bar{z}(t,t)] = (\rho+\phi)[\bar{w}(t) + \bar{z}(t,t)]$ is used. In the third step, $\phi C(t)$ is replaced using Equation (11).

A.4 Solution of the static optimisation problem of the social planner

We justify that the solution to the static part of the social planner problem

$$U(C(t)) = \max_{\{c(\nu,t)\}_{\nu=-\infty}^{t}} \int_{-\infty}^{t} \ln c(\nu,t)\phi e^{-\phi(t-\nu)}\mathrm{d}\nu \tag{67}$$

$$\text{subject to:} \quad C(t) = \int_{-\infty}^{t} c(\nu,t)\phi e^{-\phi(t-\nu)}\mathrm{d}\nu \tag{68}$$

is

$$U(C(t)) = \ln(C(t)).$$

The result is intuitive as all agents have the same utility function. To prove it, one can solve the maximisation problem with integral constraint: writing λ as multiplier to the integral constraint, one obtains the current-value Hamiltonian

$$H_c = \phi \ln c(\nu, t) + \lambda \phi c(\nu, t)$$

and thus finds the first-order conditions:

$$\frac{\partial H_c}{\partial c} = \frac{\phi}{c(\nu, t)} + \lambda \phi = 0 \tag{69}$$

$$(t-\nu)\lambda = (t-\nu)\lambda - \dot{\lambda}. \tag{70}$$

The last equation implies that λ is constant, so that from Equation (69) it follows that the optimal $c(\nu, t)$ is constant for all ν, too. Setting $c(\nu, t) = c'(t)$ in Equation (68) implies

$$C(t) = c'(t).$$

Inserting this in Equation (67) finally implies that $U(C(t)) = \ln(C(t))$.

References

Bach, S., Beznoska, M., Steiner, V., 2014. A wealth tax on the rich to bring down public debt? Revenue and distributional effects of a capital levy in germany. Fiscal Studies 35(1), 67–89.

Blanchard, O. J., 1985. Debts, deficits, and finite horizons. Journal of Political Economy 93(2), 223–247.

Buiter, W. H., 1988. Death, birth, productivity growth and debt neutrality. The Economic Journal 98, 279–293.

Buiter, W. H., 1989. Debt neutrality, Professor Vickrey and Henry George's single tax. Economics Letters 29(1), 43–47.

Buiter, W. H., 2010. Housing wealth isn't wealth. Economics: The Open-Access, Open-Assessment E-Journal 4(22), 1–29.

Burgstaller, A., 1994. Property and prices: Toward a unified theory of value. Cambridge University Press, Cambridge.

Calvo, G. A., Kotlikoff, L. J., Rodriguez, C. A., 1979. The incidence of a tax on pure rent: A new (?) reason for an old answer. Journal of Political Economy 87(4), 869–874.

Calvo, G. A., Obstfeld, M., 1988. Optimal time-consistent fiscal policy with finite lifetimes. Econometrica 56(2), 411–432.

Caselli, F., Feyrer, J., 2007. The marginal product of capital. Quarterly Journal of Economics 122(2), 535–568.

Chamley, C., Wright, B. D., 1987. Fiscal incidence in an overlapping generations model with a fixed asset. Journal of Public Economics 32(1), 3–24.

Demailly, D., Chancel, L., Waisman, H., Guivarch, C., 2013. A post-growth society for the 21st century. Does prosperity have to wait for the return of economic growth? IDDRI study no. 08/13, Institut du développement durable et des relations internationales, Paris.

Engel, C., Kletzer, K., 1990. Tariffs and saving in a model with new generations. Journal of International Economics 28(1), 71–91.

Eurostat, 2012. Population data. Database, available at http://epp.eurostat.ec.europa.eu/, retrieved 2012-11-14.

Fama, E. F., 1970. Efficient capital markets: A review of theory and empirical work. The Journal of Finance 25(2), 383–417.

Fama, E. F., 1991. Efficient capital markets: II. The Journal of Finance 46(5), 1575–1617.

Fane, G., 1984. The incidence of a tax on pure rent: the old reason for the old answer. The Journal of Political Economy 92(2), 329–333.

Feldstein, M. S., 1977. The surprising incidence of a tax on pure rent: A new answer to an old question. Journal of Political Economy 85(2), 349–360.

Foley, D. K., Michl, T. R., 1999. Growth and Distribution. Harvard University Press, Cambridge, MA.

Fried, J., Howitt, P., 1988. Fiscal deficits, international trade and welfare. Journal of International Economics 24, 1–22.

George, H., 1920. Progress and Poverty: An Inquiry into the Cause of Industrial Depressions and of Increase of Want with Increase of Wealth: The Remedy. Doubleday, Page & Co., New York, 4th edition.

Hashimoto, H., Sakuragawa, M., 1998. Land-tax, transfer and growth in an endogenously growing economy with overlapping generations. Japanese Economic Review 49(4), 412–425.

Heavey, J. F., 2003. Comments on Warren Samuels's "Why the Georgist movement has not succeeded". American Journal of Economics and Sociology 62(3), 593–599.

Heijdra, B. J., 2009. Foundations of modern macroeconomics. Oxford University Press, Oxford, 2nd edition.

Heijdra, B. J., Meijdram, L., 2002. Public investment and intergenerational distribution. Journal of Economic Dynamics and Control 26, 707–735.

Hicks, J. R., 1940. The valuation of the social income. Economica 7(26), 105–124.

IEA, 2013. World energy outlook 2013. Technical report, International Energy Agency, available at http://dx.doi.org/10.1787/weo-2013-en.

Kaldor, N., 1939. Welfare propositions of economics and interpersonal comparisons of utility. The Economic Journal 49, 549–552.

Koethenbuerger, M., Poutvaara, P., 2009. Rent taxation and its intertemporal welfare effects in a small open economy. International Tax and Public Finance 16(5), 697–709.

Laibson, D., 1997. Golden eggs and hyperbolic discounting. The Quarterly Journal of Economics 112(2), 443–478.

Marini, G., van der Ploeg, F., 1988. Monetary and fiscal policy in an optimising model with capital accumulation and finite lives. The Economic Journal 98(392), 772–786.

Mattauch, L., Siegmeier, J., Edenhofer, O., Creutzig, F., 2013. Financing public capital through rent taxation. CESifo Working Paper No. 4280, Center for Economic Studies and ifo Institute, Munich.

Petrucci, A., 2006. The incidence of a tax on pure rent in a small open economy. Journal of Public Economics 90(4-5), 921–933.

Piketty, T., Zucman, G., 2014. Capital is back: Wealth-income ratios in rich countries, 1700-2010. The Quarterly Journal of Economics .

Romer, P. M., 1986. Increasing returns and long-run growth. The Journal of Political Economy 94(5), 1002–1037.

Scharfstein, D. S., Stein, J. C., 2000. The dark side of internal capital markets: Divisional rent-seeking and inefficient investment. The Journal of Finance 55(6), 2537–2564.

Siegmeier, J., Mattauch, L., Edenhofer, O., 2014. The macroeconomic portfolio effect of climate policy. Mimeo, Mercator Research Institute of Global Commons and Climate Change, Berlin.

Stiglitz, J., 1977. The theory of local public goods. In: Feldstein, M. S., Inman, R. P. (Eds.), The Economics of Public Services, MacMillan, London.

Thaler, R. H., Benartzi, S., 2004. Save more tomorrow: Using behavioural economics to increase employee saving. Journal of Political Economy 112(S1), S164–S187.

Weil, P., 1989. Overlapping families of infinitely-lived agents. Journal of Public Economics 38(2), 183–198.

Wilson, J. D., 1986. A theory of interregional tax competition. Journal of Urban Economics 19(3), 296–315.

Yaari, M. E., 1965. Uncertain lifetime, life insurance and the theory of the consumer. Review of Economic Studies 32(2), 137–150.

Zodrow, G., 2010. Capital mobility and capital tax competition. National Tax Journal 63, 865–881.

Zodrow, G. R., Mieszkowski, P., 1986. Pigou, tiebout, property taxation, and the underprovision of local public goods. Journal of Urban Economics 19(3), 356–370.