Financing public capital through land rent taxation: A macroeconomic Henry George Theorem

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Abstract

Financing productive public capital through distortionary taxes typically creates a trade-off between efficiency-enhancing public investment and perturbing market efficiency. In contrast, such a trade-off may be avoided if public capital is financed by taxing the rent of a fixed production factor, such as land. We prove that the socially optimal level of the public capital stock can be financed by a land rent tax, provided that the income share of land exceeds the public investment requirement. This result can be considered a macroeconomic version of the Henry George Theorem from urban economics. It holds for both neoclassical and endogenous growth.

JEL classification: H21, H54, Q24

Keywords: land rent tax, public investment, infrastructure, Henry George Theorem, social optimum

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1 Introduction

Public capital is a key determinant of aggregate productivity (Romp and De Haan, 2007; Bom and Ligthart, 2013): productivity increases may stem from investments into physical infrastructure, but also into the health and the education system or into the stock of publicly available knowledge. However, collecting revenue for public investment through taxation usually creates inefficient allocations (Barro, 1990; Barro and Sala-I-Martin, 1992). Typically, a trade-off between productivity growth from public investment and efficiency loss from distortionary taxation is identified, which determines the best possible level of public investment. It is lower than the socially optimal level, which thus cannot be reached when lump-sum taxation is infeasible.

In this article, we examine a case in which such a trade-off does not exist: public investment is financed by taxing rents from fixed factors of production such as land. We prove that if the land rent is higher than the socially optimal level of public investment, taxing the rent and investing the revenue in public capital is a socially optimal policy. This result can be considered a dynamic and macroeconomic analogue to the "Henry George Theorem" or the "golden rule" of local public finance. While the original theorem requires a 100 % tax on land rents, our macroeconomic result merely requires that the income share accruing to land is sufficiently high: the socially optimal tax thus need not be at a rate of 100 %. The result of this paper may thus be seen as a new starting point for addressing underfunding of public infrastructure on a national scale, while the original Henry George Theorem has been applied in urban public economics only.

Our argument is based on two premises. First, we assume that public investment is productivity-enhancing[1], be it in the form of infrastructure (Barro, 1990; Gramlich, 1994), research and development (Romer, 1990) or investment into human capital via education or the health system (Glomm and Ravikumar, 1992; Bloom et al., 2004). The nature of the investment may differ according to the state of a country's economy: In developing countries, *building* new infrastructures and public capital stocks would enhance productivity (Agénor, 2013). In developed countries, *maintaining* the existing, but deteriorating infrastructures requires public investment. Moreover, *transforming* infrastructures is required for overcoming the lock-in into carbon-intensive production processes to mitigate global warming and its economic damages (Unruh, 2000; Davis et al., 2010; Lehmann et al., 2012; Mattauch et al., 2015).

[1] For a review of the theoretical literature of the link between government spending and growth, see Irmen and Kuehnel (2009). Empirical reviews of this premise are provided by Romp and De Haan (2007), Bom and Ligthart (2013), Zagler and Dürnecker (2003) and Creel and Poilon (2008).

Second, we assume that fixed factors are relevant for the production process: In fact the rents on non-reproducible factors such as land are a highly significant share of total economic output (Caselli and Feyrer, 2007). Notably, urban land is a significant component of societal wealth as can be deduced from the macroeconomic significance of housing: in Britain, France and Germany, for instance, half of total wealth is embodied in housing and increases in wealth since 1950 are largely due to housing as well (Piketty, 2014, Ch. 3 and 4). Importantly, Piketty and Zucman (2014) find that across major industrialized countries, at least 20–30 % of new wealth generated in 1970–2010 are due to price effects. This points to a potential role for rigidities in the supply of urban land in explaining the wealth share of housing (see also Rognlie (2014)). Others go further and claim that land prices, not construction costs, primarily explain surging house prices: Knoll et al. (2014) find that, across major advanced economies, 80 % of the increase in house prices between 1950 and 2012 can be attributed to increasing land prices. Recently, Stiglitz (2015) argues that land rents and their taxation are pivotal to understanding and addressing current trends of growth and distribution.

The main result of this article is related to the Henry George Theorem, which states that local land rents equal expenditure on a local public good *provided the population size is optimal* (Arnott and Stiglitz, 1979; Arnott, 2004). A major consequence of the Henry George Theorem is that a single 100 % land rent tax is sufficient to finance a local public good. It is based on a static relationship and has chiefly been applied in the context of urban economics. In contrast, our result concerns the dynamics of relevant capital stocks and should be seen as a dynamic and macroeconomic analogue: If land is an important production factor, the land rent is sufficient to finance the socially optimal public capital level *provided that the accumulation of private capital is optimal.* Compared to the static version, the optimal public capital provision requires the assumption that the income share of land exceeds the required public investment, but then does not necessitate a 100 % land rent tax. If instead of land rents, firms' profits arising from public investment are considered, those profits are always sufficient to finance the optimal level of public investment under optimal capital accumulation in the long-run. Furthermore, while our model assumes that taxing land rents is non-distortionary, our results translate to settings in which it *is* distortionary, but beneficial (as in Feldstein (1977) or Edenhofer et al. (2015); see Section 5.2).

To establish our results we extend the neoclassical model of economic growth to include public capital and land as factors of production. We also examine the validity of our results in the endogenous growth variant of the AK-model with public capital (Barro, 1990; Turnovsky, 1997). We proceed as follows: In Section 2, we determine the socially optimal allocation and the corresponding decentralized equilibrium. In Section 3, we prove that financing public investment by a tax on land rent reproduces the social optimum, provided the land rent is sufficiently high. For a Cobb-Douglas production function, a formula for the socially optimal public investment in terms of the land rent is derived, both for the neoclassical growth- and the AK-regime. In Section 4, we consider a variant of the neoclassical growth version of the model: If firms make profits, a direct analogue to the Henry George Theorem can be obtained. In Section 5, we discuss several possible extensions and modifications as well as the empirical relevance of our result: we verify that the land rent may in fact be higher than the socially optimal public investment in many economies.

Our contribution is related to two strands of literature: First, while the question of financing public capital on a national scale has been studied extensively, the role of land as a source of government revenue has been hitherto ignored. Barro (1990); Futagami et al. (1993) and Turnovsky (1996, 1997, 2000) have all studied the financing of public capital in endogenous growth models which inherit the dynamics of the AK-model, clarifying the welfare effects of different options. For instance, Turnovsky (1997) and Chatterjee and Ghosh (2011) reproduce the social optimum with tax-financed public investment; however they employ (politically infeasible) lump-sum taxes to balance the government budget. Turnovsky (1996) does not use a lump-sum tax to reproduce the social optimum, but uses a constant consumption tax that is assumed to be non-distortionary. To this it has been objected that consumption taxation typically distorts the labour-leisure choice. In sum, none of these authors obtains a result on reproducing the social optimum *without recourse to lump-sum(-like) taxes to balance the governments budget*. An exception is Turnovsky (2000), addressing the shortcoming of a non-distortionary consumption tax by introducing an endogenous labour-leisure choice: In this setting the social optimum *can* be reproduced by a distortionary consumption tax for empirically plausible parameter values, provided the tax revenue is not only used to finance the socially optimal public investment, but also to subsidize wages. The present article provides an alternative to this well-explored approach to fiscal policy. We introduce a very different option that also reproduces the socially optimal allocation without lump-sum taxation under a condition on parameters: the taxation of land.

Second, in the context of urban economics, land has been considered as an income source for the financing of public capital: a dynamic Henry George Theorem has been introduced by Fu (2005) and Kawano (2012) for studying transition phenomena of cities. These authors extend the Henry George Theorem by considering the present-value of future public investments and land rents under the usual condition of optimal population size. Our extension of the theorem is different as it considers its translation to optimal capital accumulation instead of optimal population size and thus to a macroeconomic setting. In a macroeconomic context, the relationship between the land price, the land rent and the interest rate has been captured as a (no-)arbitrage condition in growth models by Feldstein (1977), Calvo et al. (1979), Burgstaller (1994) and Foley and Michl (1999). Our study adopts their treatment of the production factor land in a growth model.

2 Model

We first describe the structure of the economy and determine the socially optimal allocation. We then develop a decentralized version of the model.

2.1 Socially optimal allocation

We begin by detailing the economy's production possibilities. We then solve the social planner problem, which serves as a benchmark for evaluating policy instruments.

Output Y depends on a private capital stock K, a public capital stock G, labor L and land $\bar{S}$:

$$Y_t = F(K_t, G_t, L, \bar{S}). \tag{1}$$

The production function has the conventional properties that F_K, F_G, F_L $F_S > 0$, but $F_{KK}, F_{GG}, F_{LL}, F_{SS} < 0$, where $F_S := \mathrm{d}F/\mathrm{d}S(K_t, G_t, L, \bar{S})$ etc. In Section 3, we distinguish two cases: the production function has (i) decreasing returns to scale in the accumulable factors private and public capital and (ii) constant returns in these factors. The two cases lead to steady-state convergence and long-run endogenous growth, respectively. Labour supply is constant. Total land $\bar{S}$ is also constant over time, so the social planner seeks the optimal distribution of private capital K and public capital G. Unless noted otherwise, it is additionally assumed that the production function is linearly homogenous in private capital, labour and land. Output is divided between consumption C_t and investment into the two capital stocks, which have depreciation rates δ_k and δ_g respectively. The social planner chooses consumption C_t and investment into public capital I_{gt} to maximize the welfare of an infinitely-lived representative household with instantaneous utility given by $U(C) = (C^{(1-\eta)} - 1)/(1-\eta)$. The maximization problem of the social planner is thus

$$\max_{C_t, I_{gt}} \int_{t=0}^{\infty} U(C_t) e^{-\rho t} dt$$

$$\text{s.t.} \quad \dot{K}_t = F(K_t, G_t, L, \bar{S}) - C_t - I_{gt} - \delta_k K_t \quad \text{and} \tag{2}$$

$$\dot{G}_t = I_{gt} - \delta_g G_t. \tag{3}$$

The maximization problem is completed by initial conditions ($K(0) = K_0$, $G(0) = G_0$).[2] Solving the maximization problem by standard optimal control theory yields a Keynes-Ramsey rule for K and G :

$$\frac{\dot{C}_t}{C_t} = \frac{1}{\eta}[F_K(K_t, G_t) - \rho - \delta_k] \tag{4}$$

and similarly

$$\frac{\dot{C}}{C} = \frac{1}{\eta}[F_G(K_t, G_t) - \rho - \delta_g],$$

which implies

$$F_K(K_t, G_t) - \delta_k = F_G(K_t, G_t) - \delta_g. \tag{5}$$

2.2 Decentralized equilibrium

In this subsection the decentralized equilibrium corresponding to the social planner solution is introduced. The decentralized version of the economy consists of two stock markets for capital and land and one flow market for the final consumption good. We detail the role of the households, the firms and the government in turn.

2.2.1 Households

The economy is populated by a continuum of homogenous households, whose behavior can be described by a representative household. It seeks to maximize its intertemporal utility $V = \int_0^\infty U(C_t)e^{-\rho t}\mathrm{d}t$, with $U(C) = (C^{1-\eta} - 1)/(1-\eta)$, subject to its budget constraint:

$$\dot{K}_t + p_t\dot{\bar{S}} + C_t = r_t K_t + w_t L + (1-\tau_t)l_t\bar{S}. \tag{6}$$

Here p_t denotes the land sales price, l_t the land rental price, w_t the wage and r_t the interest rate. Initial conditions $K_0 = K(0)$ and $G_0 = G(0)$ and a transversality condition[3] are observed. Income from renting out capital and land as well as labour can be spent on consumption, invested in capital or used to (potentially) increase the amount of land assets. Although total land is fixed and homogenous households do not actually trade land among them, it makes sense to introduce a land market in this way in order to yield a price for the asset, reflecting households' wealth (see also Section 5.2).

[2] Land is not a state variable of the optimization: It is assumed that all – available, fertile – land can always be used in production and that its use has no opportunity costs.

[3] The appropriate transversality condition is:

$$\lim_{t\to\infty}[k(t) + p(t)\bar{S}]e^{-\xi(t)} = 0$$

$$\text{with}\quad \xi(t) \equiv \int_0^t r(\tilde{t})\mathrm{d}\tilde{t}.$$

Solving the intertemporal control problem, the behaviour of the household is captured by two first-order conditions: A (no-)arbitrage condition

$$r_t = (1-\tau_t)\frac{l_t}{p_t} + \frac{\dot{p}_t}{p_t} \tag{7}$$

linking the evolution of land price, land rental price and the interest rate and the Keynes-Ramsey Equation:

$$\frac{\dot{C}_t}{C} = \frac{1}{\eta}(r_t - \rho). \tag{8}$$

Solving the arbitrage condition (7) for p_t shows that the land price is equal to the net present value of all future land rent income.

2.2.2 Firms

The production sector consists of a representative firm, whose profit maximization

$$\max_{K,S} \quad F(K_t, L, \bar{S}; G_t) - \tilde{r}_t K_t - l_t \bar{S}$$

with $\tilde{r}_t = r_t - \delta_k$ implies the standard first-order conditions

$$\tilde{r}_t = F_K(K_t, L, \bar{S}; G_t) \tag{9}$$

$$w_t = F_L(K_t, \bar{S}; G_t) \tag{10}$$

and

$$l_t = F_S(K_t, \bar{S}; G_t). \tag{11}$$

Using the assumption of constant returns to scale in K, L and S, it follows that $F(K_t, \bar{S}; G_t) = F_K K + F_L L + F_S \bar{S}$ and thus the firm's profit is zero.

2.2.3 Government

The government finances the provision of the public capital stock G with the tax revenue T_t :

$$\dot{G}_t = T_t - \delta_g G_t. \tag{12}$$

The tax revenue stems entirely from the land rent tax: $T_t = \tau_t l_t \bar{S}$. Below we also consider the option of a land *value* tax and discuss why other revenue-raising options are less preferred in this framework.

3 Main results

In the decentralized equilibrium the socially optimal level of welfare may not be reached for two reasons: First, the government may not be able to mobilize funds for providing the desired steady-state level of public capital G. Second, it may be able to mobilize the resources only in a distortionary way, that is, although the steady-state level of G is socially optimal, the distribution of capital and consumption may not be optimal. We prove that if the first point is not an issue because the land rent is sufficiently high to finance the socially optimal level of public capital, generating public revenue by taxing the land rent is socially optimal. This holds for both transition phases and the long-run equilibrium. We then determine conditions for both the case of steady-state convergence and endogenous growth that indicate when the land rent actually is sufficiently high.

3.1 Land rent taxation reproduces the social optimum

In this subsection, the consequences of levying different taxes for financing public capital are examined: the main contribution of this article is that a tax on land rent permits to reproduce the social optimum if the land rent is sufficiently high (Theorem 1). Moreover, a land value tax is equivalent to a land rent tax (Corollary 2). We then briefly compare land rent taxation to other financing options: capital or output taxes are distortionary and hence cannot reproduce the social optimum. Lump-sum taxation is excluded from the spectrum of possibilities as it is politically infeasible. A consumption tax may or may not reproduce the social optimum, but a different framework would be needed to assess this (Turnovsky, 2000).

In the following the superscript ^{M} stands for the value of the respective variable from the decentralized model.

Theorem 1 (Land rent taxation reproduces the social optimum)**.** *A land rent tax allows reproducing the social optimum if the land rent is sufficient to finance the socially optimal public investment at all times.*

We explore in the next sections special cases in which it can be verified whether the assumption of the theorem holds, that is we derive conditions stating when the land rent tax is higher than the socially optimal investment and check available data whether such formulae plausibly hold for most economies.

In practice, it may be more feasible to tax land value rather than land rent. We provide a corollary to show the equivalence of the two options:

Corollary 2 (Land value taxation)**.** *A tax on land value allows to reproduce the social optimum if the land value is sufficiently high to finance the socially optimal public investment at all times.*

Proof of Theorem 1. The idea of proof is to show that the dynamical systems of the socially optimal allocation (Equations (2-5)) and the decentralized equilibrium (Equations (6-12)) are identical. Then, if the social planner and the decentralized equilibrium have the same initial level of both K_0 and G_0, the latter will reproduce the paths of the former.

Assume that the land rent is sufficient to fully finance the public good: the government can set the tax $\tau_t \in [0, 1)$ such that

$$T_t = \tau_t l_t \bar{S} = I_{gt}. \tag{13}$$

If the previous equation holds, then the path for the public capital stock G_t will be identical in both dynamical systems, as

$$\dot{G}_t = I_{gt} - \delta_g G_t \tag{14}$$

and

$$\dot{G_t^M} = \tau_t l_t \bar{S} - \delta_g G_t^M = I_{gt} - \delta_g G_t^M. \tag{15}$$

Since there is just one representative agent and total land is fixed, $\dot{\bar{S}} = 0$ in Equation (6). Substituting the first-order conditions of the firm (9-11) and employing the assumption that the production function has constant returns to scale in the privately available production factors then implies that Equations (6) and (8) are equivalent to:

$$\dot{K}_t^M = F(K_t^M, G_t, L, \bar{S}) - \delta_k K_t^M - I_g t - C_t^M \tag{16}$$

$$\frac{\dot{C}_t^M}{C_t^M} = \frac{1}{\eta}(F_K(K_t^M, G_t, L, \bar{S}) - \rho - \delta_k). \tag{17}$$

This implies that the respective social planner and decentralized versions of the equations for consumption and capital accumulation are identical, which completes the proof.

□

Proof of Corollary 2. For a property tax τ_t, the tax revenue amounts to $T = \tau p_t \bar{S}$ and the budget constraint of the household (6) becomes

$$\dot{K}_t + p_t \dot{\bar{S}}_t + C_t = r_t K_t + w_t L + l_t S_t - \tau_t p_t \bar{S}_t. \tag{18}$$

Similarly to the previous proof, it can be shown that the aggregate variables are at the socially optimal level.[4] □

[4]However, the arbitrage condition is modified for this case:

$$r = \frac{l}{p} + \frac{\dot{p}}{p} - \tau. \tag{19}$$

If the land rent is lower than public investments, it may still be beneficial that the government obtains more funds for public investment through levying another tax. However, if no other non-distortionary possibilities for taxation exist, the usual trade-off between productivity-enhancing investment in the public capital stock and distortionary taxation exists again for that part of the investment need that exceeds the land rent. For other financing possibilities in the context of this model, the usual results about taxation in a neoclassical growth or AK model apply: Capital and thus output taxation cannot reproduce the social optimum as they are distortionary ((Groth, 2011, ch.11), (Acemoglu, 2008, ch.8)) and Barro (1990)).

In the model presented in this article a labour income tax and a constant consumption tax would also be non-distortionary. However, addressing the effects of a labour income or consumption tax properly would require to consider a labour-leisure choice (Turnovsky, 2000; Chatterjee and Turnovsky, 2012; Klenert et al., 2014). If agents have the possibility to adjust their labour supply in response to a consumption or labour income tax, these will also be distortionary. A potential remedy for this is – at least theoretically – to tax consumption *as well as* to subsidize wages (as an application of the Ramsey principle of optimal taxation). This opens up another possibility of reaching the social optimum if some condition on parameters holds (Turnovsky, 2000).

3.2 A macroeconomic Henry George Formula

Having established the main result that land rent taxation can reproduce the socially allocation when a government needs to finance productive public investment, we investigate the premise of this result: The land rent has to be sufficient, namely higher than the socially optimal public investment. For the specific case of a Cobb-Douglas function, we derive a formula for this both for the case of neoclassical growth in the steady-state and the balanced growth path when there is endogenous growth. Such a "Simple Macroeconomic Henry George Formula" is derived for the socially optimal allocation, by the equivalence of Theorem 1 this also gives the socially optimal tax to be levied on the market for land rental.

3.2.1 The case of the neoclassical growth model

We first derive a "Macroeconomic Henry George Formula" for the case of steady-state convergence, which occurs if the production function has decreasing returns to scale in accumulable factors. The case of endogenous growth is similar and will be briefly treated subsequently.

For any initial capital stocks (K_0, G_0) the economy converges to a (nontrivial and saddle-point stable) steady state (K^*, G^*, C^*, I_g^*) as there are decreasing returns to scale in accumulable production factors. In the steady-state, time-derivatives in Equations (2), (3) and (4) are zero, whence the steady-state is characterized by:

$$F_K^* = F_K(K^*, G^*, L, \bar{S}) = \rho + \delta_k \tag{20}$$

$$F_G^* = F_G(K^*, G^*, L, \bar{S}) = \rho + \delta_g \tag{21}$$

$$F(K^*, G^*, L, \bar{S}) = C^* + I_g^* + \delta_k K^* \tag{22}$$

$$I_g^* = \delta_g G^*. \tag{23}$$

To obtain a relation between the optimal public investment I_g^* and the land rent $R = F_S \cdot \bar{S}$ in the steady state, assume that the production function has Cobb-Douglas form:

$$F(K, G, L, \bar{S}) = G^\gamma K^\alpha L^\beta \bar{S}^{1-\alpha-\beta} \tag{24}$$

(with $0 < \alpha, \beta, \gamma < 1$ and $\alpha + \gamma < 1$), which implies

$$F_G = \gamma \frac{Y}{G}. \tag{25}$$

The land rent R is thus given by

$$R = F_S(K_t, G_t, L, \bar{S}) \cdot \bar{S} = (1 - \alpha - \beta)Y. \tag{26}$$

When is the land rent greater than the socially optimal amount of public investment?

Proposition 3 (Simple Macroeconomic Henry George Formula)**.** *Suppose production can be described by the Cobb-Douglas function given by Equation (24). Then, in the steady state of the socially optimal allocation, the investment in public capital is related to the land rent as follows:*

$$I_g^* = \frac{\delta_g}{\rho + \delta_g} \frac{\gamma}{1 - \alpha - \beta} R. \tag{27}$$

The result has the intuitive interpretation that if the national income share of land is greater than that of the public capital stock, the socially optimal investment in public capital is lower than the land rent (assuming that the first factor is approximately equal to one). So Theorem 1 applies to the steady state of the neoclassical growth case if $\frac{\delta_g}{\rho+\delta_g} \frac{\gamma}{1-\alpha-\beta} < 1$ and the socially optimal land rent tax rate to be implemented by the government needs to be $\tau = \frac{\delta_g}{\rho+\delta_g} \frac{\gamma}{1-\alpha-\beta}$.

Proof. We exploit the steady state relationships. By Equations (23) and (25),

$$I_g^* = \delta_g \gamma \frac{Y^*}{F_G^*}. \tag{28}$$

To eliminate F_G^*, Equation (21) is used:

$$I_g^* = \frac{\delta_g}{\delta_g + \rho} \gamma Y^*. \tag{29}$$

Inserting Equation (26) yields the claimed formula. □

3.2.2 The case of endogenous growth

A similar formula can be derived for the balanced growth path in the case of endogenous growth. Assume, contrary to the previous subsection, that the production function has *constant* returns to scale in the accumulable factors K and G. Thus in the specification of the production function as Cobb-Douglas in Equation (24) assume $\alpha + \gamma = 1$. For simplicity, we only consider the case $\delta := \delta_k = \delta_g$. The socially optimal allocation converges to a balanced growth path, on which aggregate variables grow at the same rate:

$$\frac{\dot{C}_t}{C_t} = \frac{\dot{K}_t}{K_t} = \frac{\dot{G}_t}{G_t} = g. \tag{30}$$

To obtain a formula for the common growth rate g^* use that, from Equations (5) and (24),

$$G_t = \frac{\gamma}{1-\gamma} K_t \tag{31}$$

so that

$$F_K(G_t, K_t, L, \bar{S}) = F_G(G_t, K_t, L, \bar{S}) = \frac{\gamma^\gamma}{(1-\gamma)^{\gamma-1}} L^\beta \bar{S}^{1-\alpha-\beta}. \tag{32}$$

Inserting this in Equation (4) yields

$$g^* = \frac{1}{\eta}\left(\frac{\gamma^\gamma}{(1-\gamma)^{\gamma-1}} L^\beta \bar{S}^{1-\alpha-\beta} - \rho - \delta\right). \tag{33}$$

The analogue of Proposition 3 for the balanced path of the case of endogenous growth is as follows:

Proposition 4 (Macroeconomic Henry George Formula for the endogenous growth case)**.** *Suppose production can be described by the Cobb-Douglas function given by Equation (24) with $\alpha + \gamma = 1$. Then, on the balanced growth path of the socially optimal allocation, the investment in public capital is related to the land rent as follows:*

$$I_{gt} = \frac{(\delta + g)}{F_G} \frac{\gamma}{1-\alpha-\beta} R_t \tag{34}$$

where F_G is constant with the value given in Equation (32).

As in the case of neoclassical growth, the socially optimal allocation can be reached if the two fractions are smaller than 1. In particular, this is true if the national income share of land is greater than that of the public capital stock and

$$\frac{(\delta + g)}{F_G} < 1. \tag{35}$$

By inserting Equation (33), it can be verified that this inequality is true for all $\eta \geq 1 - \frac{\rho}{F_G - \delta}$, so in particular for all $\eta \geq 1$.

Proof. The proof is similar to that of the previous proposition. From Equation (3), it follows that for the case of endogenous growth, $I_{gt} = (g^* + \delta)G_t$. The formula is then obtained by combining the equations for the factor shares for G_t and the land rent R_t and inserting Equation (32). $\square$

4 Dynamising the Henry George Theorem: Taxing firms' profits instead of the land rent

In this section we elaborate on the kinship of the main result of the present article and the Henry George Theorem of local public finance. The theorem states that "with identical individuals, in a city of optimal population size, differential land rents (the aggregate over the city of urban land rent less the opportunity cost of land in non-urban use) equal expenditure on pure local public goods" (Arnott, 2004, p.1057). This means that confiscating the entire land rent – a Georgist "single tax" – is sufficient to finance any level of the public good, whether socially optimal or not. The theorem is a very general relationship that has been discovered in different forms independently by several scholars. We are here concerned with its simplest version, proved by Stiglitz (1977), that considers profits instead of land rents: it is socially optimal to use the total profit in a static urban economy to finance a local public good provided the population size is optimal (see also: (Atkinson and Stiglitz, 1980, p.522-525), Arnott and Stiglitz (1979)).

So far the analogy to our result has been that a single (land) rent tax is necessary and (sometimes) sufficient to finance the optimal public investment, under the modification that the macroeconomic setting requires optimal capital accumulation instead of optimal population size. In this section we demonstrate that the analogy can be even closer: If not land, but firms' profits are considered, the original Henry George Theorem uses that the benefit of the public good is fully captured in firms' profits. This partially carries over to a growth model in which the public and the private capital stocks are optimal – although the benefit of the public capital stock is then not fully captured by profits, these are sufficient to finance the optimal investment in the steady state. Because of the dynamic context, the pure rate of time preference causes the profit to be higher than the required optimal public investment in the steady state (as Proposition 5 will show).

To demonstrate the analogy, we consider a slightly modified model. Assume for this section that the production function is linearly homogenous in all four arguments: public capital, private capital, labor and land. Thus we are here only concerned with the case of convergence to a steady state, not with endogenous growth. The provision of public capital by the government results in a positive externality that allows firms to make profit Π_t under this functional form:[5]

[5]This is a credible assumption for some public investments, such as technology parks.

$$\Pi_t = F(K_t, \bar{S}; G_t) - \tilde{r}_t K_t - w_t L - l_t \bar{S} = F_G(K_t, \bar{S}; G_t) G_t. \tag{36}$$

These profits can be taxed to finance public expenditure. While this policy is socially optimal if profits are higher than the socially optimal public investment both in the steady state and the transitional dynamics of the model, one can show more for the steady state:

Proposition 5 (Macroeconomic Analogue of Stiglitz' Henry George Theorem)**.** *The social optimum can be implemented by taxing firms' profits, if these are higher than the socially optimal investment. In the steady state, taxing profits is always sufficient: The optimal tax rate on profits is* $\tau = \frac{\delta_g}{\delta_g + \rho}$.

In Stiglitz' result $\tau = 1$. In our dynamic setting a non-zero rate of pure time preference ρ causes $\tau < 1$. This reflects that in neoclassical growth models the optimal capital stock does not maximize instantaneous consumption. If the steady-state marginal productivity of public capital (21) was independent of ρ, then the analogy would be complete.[6]

Proof. With a tax on profits, tax revenue is $T = \tau \Pi_t$ and the budget constraint of the household (6) becomes

$$\dot{K}_t + p_t \dot{\bar{S}}_t + C_t = r_t K_t + l_t \bar{S}_t + (1 - \tau)\Pi_t. \tag{37}$$

Assuming that the tax revenue from taxing profits is sufficient to finance the socially optimal level of G_t,

$$T = \tau_t \Pi_t = I_{gt}. \tag{38}$$

It can then be verified with arguments similar to those in the proof of Theorem 1 that all aggregate variables of the decentralized equilibrium have their socially optimal steady state values by comparing the corresponding systems of differential equations.

In particular, for the steady state $F_G(K, G; \bar{S}) = \delta_g + \rho$ by Equation (21). Thus

$$\Pi_t = F_G(K^*, G^*, L, \bar{S}) G^* = (\delta_g + \rho) G^*. \tag{39}$$

Combining Equations (23), (38) and (39) yields

$$\tau(\delta_g + \rho) G^* = \delta_g G^*.$$

However the focus of this section is on highlighting the close kinship of our results with the Henry George Theorem, not on exploring which assumptions concerning the impact of public investments on the economy are most realistic.

[6]Stiglitz' Henry George Theorem is valid even if the local public good is not of optimal size (that is, if the corresponding Samuelson condition is violated). In the model under discussion, it is not the case that for arbitrary production functions and any level of G, a profit tax would fully finance it in a modified steady-state because the stock of private capital may be too small so that $F_G(K, G; \bar{S}) > \delta_g$, thus violating Equation (40).

Hence

$$\tau = \frac{\delta_g}{\delta_g + \rho} < 1. \tag{40}$$

□

5 Discussion

We discuss modifications, limitations and the empirical relevance of our results. First, as many alternative formulations of government investment are considered in the literature, we outline why our results do not essentially change when some other formulations are chosen. Second, we briefly discuss that a crucial limitation of a neoclassical growth model with several stock markets is that due to household homogeneity, there is no trade on these markets. Third, we delineate the role of labour- and land-augmenting technological progress when growth is not endogenous. Finally, we compare data on public investment needs and non-producible factor income and find that the latter plausibly exceeds the former.

5.1 Alternative models of government spending

Alternative formulations of government expenditure besides investing into a productive public capital stock have been extensively considered in public economics, for instance productive government flow expenditure or investment into utility-enhancing public or private goods, which each may or may not be congestible (Barro and Sala-I-Martin, 1992; Turnovsky, 1997; Irmen and Kuehnel, 2009). We limit our discussion to two close variants of the above model that seem most interesting in the specific context of land rent taxation financing public investment: first, the public capital stock may enter the utility function instead of the production function; second, the difference between investment in a public capital stock and productive government flow expenditure is examined.

Concerning the first variant, assume that government expenditure provides private goods entering the individuals' utility function. Then, no simple proportionality between optimal government expenditure and land rent as in Proposition 3 or 4 can be derived even with the simplest functional forms, since there is no direct link between the public good and land via the production function anymore. However, in the decentralized model, the households' and firms' optimization problem remains virtually unchanged since G only appears in the utility function and disappears from the production function, but does not become a control variable. Thus, it can be shown that Theorem 1 still holds.[7]

[7] Proposition 5 is pointless if G generates no profits.

For the second case, it can be shown that the findings of this study are all valid regardless of whether the productive public good is formulated as a stock (to which the government expenditure continuously adds) or flow (equal to government expenditure). However, the stock formulation seems preferable as we are chiefly concerned with *productivity-enhancing* public expenditure such as infrastructure provision. Considering a public capital stock is also more convenient for further empirical analyses because of symmetry: for instance, depreciation parameters for public and private capital may be different. Moreover, it is plausible that in developed economies land rents are sufficient to finance what is generally defined as public investment up to the socially optimal level (see Section 5.4) – but it is doubtful that they can additionally cover the much broader category of government flow spending.

5.2 Stock markets and household heterogeneity

Analysing the dynamics of stock markets for fixed factors of production, such as land, with the neoclassical growth model has severe limitations. (This may have been first noted by Feldstein (1977); see Burgstaller (1994) for a comprehensive overview.) Although a price for land – the present value of all future land rent income – is formed, land will not be traded: the continuum of homogenous agents of this model own an equal share of land, but have neither an incentive nor a trade partner to buy or sell any of it. A neoclassical growth model with land, as introduced above, thus exhibits "partial equilibrium" properties concerning the factor land: for instance, land rent taxation is non-distortionary and the tax falls entirely on the owners of land, although this is not the case in more general circumstances (Feldstein, 1977). There is in particular no rebalancing of households' savings portfolios: households have no incentive to invest more in capital when a land rent tax is introduced. Edenhofer et al. (2015) explore, by means of a continuous overlapping generations model, the social optimality of land rent taxation when heterogeneous households acquire more land as they get older. In such a model, which exhibits suboptimal capital accumulation, when land is taxed, households invest into other assets, notably private capital. Thus land rent taxation is distortionary, but beneficial. The results of the present study can be reproduced in such a framework with some minor modifications due to the demographic structure.

More generally, as long as the unregulated equilibrium exhibits underaccumulation in private capital the conclusions of the present study hold in frameworks in which such a "macroeconomic portfolio effect" exists. Only if overaccumulation prevails in an economy, this effect may create again a trade-off between the welfare loss caused by the land tax and the benefits from public investment.

5.3 Labour- and land-augmenting technological progress

Our results are valid for both the case of a steady state and endogenous growth. For the steady state, they have been cast in a simple neoclassical growth model without technological progress in order to isolate the specific fiscal policy this article is concerned with. Here we explore the impact of adding (exogenous) technological progress to our model for the case of steady state convergence.

The main results of this paper hold as long as the economy is on a balanced growth path. Such a path can exist if and only if productivity growth in land equals productivity growth in labor (including population growth). If the economy is not on the balanced growth path, factor shares may be different, depending on the production function. The feasibility of the social optimum depends on the factor shares according to Proposition 3: outside the balanced growth path an increasing factor share accruing to land makes reaching the social optimum more likely. For example, for the case of a CES production function with substitution elasticity σ, the factor share accruing from land grows faster than the factor share accruing from labour if and only if either $\sigma > 1$ and productivity growth in land is greater than that in labour or $\sigma < 1$ and labour productivity growth is greater than that in land.

Henry George claimed that the factor share accruing to land grows faster than that accruing to labour.[8] While this is not possible in the steady state or under a Cobb-Douglas production function in general, outside a balanced growth path Henry George's claim about the role of the land rent may be true. In particular the condition that $\sigma < 1$ and productivity growth in labour was greater than in land seems to have some plausibility for economic development in the 19^{th} century. It is less plausible for current developed economies, for which it may be supposed that $\sigma > 1$, but still that labour productivity grows faster than land productivity.

5.4 Empirical relevance

In practice, fixed factor rents often exceed funding needs for public capital stocks considered here, and are thus highly relevant for financing government expenditure in general. Figure 1 illustrates this by reproducing actual public investment shares and non-producible factor income shares for 25 (mostly OECD) countries. We summarize some empirical findings, first on public investment needs and then on rents.

[8] "In identifying rent as the receiver of the increased production which material progress gives, but which labor fails to obtain; [...] we have reached a conclusion that has most important practical bearings." (Bk. 4, ch.1 §1) "[...] and wages are forced down while productive power grows, because land, which is the source of all wealth and the field of all labor, is monopolized." (Bk. 6, ch.2, §2) (George, 1920)

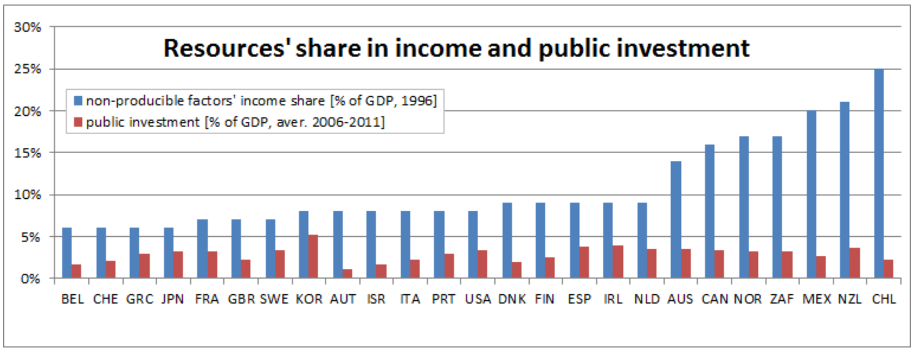

Figure 1: Income shares of non-producible factors (Caselli and Feyrer, 2007) and public investment (OECD, 2013), ISO3 country codes.

Regarding the investment needs of industrialized countries, maintaining the infrastructure and adapting it to the challenges of climate change (Davis et al., 2010) translates into significant shares of government spending: The OECD reports public investment shares averaged over 2006 to 2011 for 34 countries that range between 1.1% (Austria) and 5.22% (South Korea) of GDP. The investment needs in poorer countries are highlighted by data from the World Bank (2009) showing that access to basic utility services such as water, sanitation and electricity in low-income countries was 65%, 36% and 23%, respectively, and still only 92%, 72% and 97% for upper-middle income countries. Estache and Fay (2007) estimated overall infrastructure investment and maintenance expenditure needs between 2005 and 2015 for low, lower-middle and upper-middle income countries to be 7.5, 6.3 and 3.1 percent of GDP, respectively, just to meet increasing demand due to projected growth. While these actual or projected spending figures may not be *optimal* by some welfare criteria, they show the order of magnitude and the larger public investment needs in poorer countries lacking the most basic infrastructure.

Regarding the fixed factor rents, Caselli and Feyrer (2007) estimate income shares of non-producible factors such as land and natural resources for the year 1996 for 51 countries and find values ranging from 6% in Belgium to 47% in Ecuador, with a median of 14%. Also, non-producible factors tend to be more important for poorer countries. We do not have data that permit to isolate the income share of land across different countries. However, Caselli and Feyrer (2007) use “Proportions of different types of wealth in total wealth” (p.547) to show that land wealth is relatively more important in most cases: Although subsoil resources matter for some countries and the mean wealth share is 10.5% (with a standard deviation of 16.4), the mean share of land-related wealth is at 34.8%. The median wealth share of subsoil resources is only 1.5%; compared to a 23.5% median share of land-related wealth. Moreover, the data set of that study excludes countries in which fossil fuel extraction is a main income source, such as countries on the Arabic Peninsula.

These figures may change slowly over time (note that the diagram plots data from 2006-2011 and 1996). However, the significant gap between fixed-factor income shares and public investment persists across structurally very different economies: Even the lowest fixed-factor income, 6% for Belgium is higher than the highest public investments, 5.22% for Korea. Overall, this indicates that fixed factor rents can be assumed to be of a magnitude that is at least comparable to that of infrastructure spending needs.

6 Conclusion

This study set out to determine how public investment can be financed by a tax on the rent of fixed factors such as land. It was proved that if the land rent is sufficiently high, the social optimum can be implemented by using the tax revenue for investment into a productive public capital stock. This result is a macroeconomic analogue of the Henry George Theorem from urban public finance: the socially optimal public investment can be financed by taxing rents, whereas the usual condition of optimal population size in a static model is replaced by optimal capital accumulation in the dynamic context. The main theoretical result of this study is robust under a variety of different assumptions: (i) neoclassical growth (both short- and long-run) or an endogenous growth regime, (ii) profit-making firms instead of land rents earned by households, (iii) utility-enhancing public capital or government flow spending, (iv) underaccumulation in public capital due to for instance overlapping generations, (v) technological progress in land and labour compatible with balanced growth. It was verified that for OECD countries, land rents are significantly higher than current public investment, so that our result suggests an empirically plausible mechanism for ensuring sufficient public investment.

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