Positional preferences and efficient capital accumulation when households exhibit a preference for wealth[1]

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Abstract. We consider the impact of positional preferences - not only with respect to consumption but also with respect to wealth - on growth, welfare, and corrective taxation. We operate within an endogenous growth framework with public capital, and with labor supply being exogenous. If *and only if* wealth is an argument of the utility function, the positionality implies distortions, and corrective tax rates differ (positively or negatively) from zero. Although the model exhibits three externalities - positionality in consumption, in wealth, and a production externality arising from public infrastructure investment - only two corrective tax instruments are required for internalization: a consumption- or an income tax, and the optimal choice of public investment. Numerical simulations – pointing towards high corrective tax rates and their strong impact on growth and welfare – complement the theoretical analysis.

Keywords and Phrases: Conspicuous consumption, conspicuous wealth, endogenous growth, economic distortions, optimal consumption and income taxes.

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1. Introduction

This paper considers the impact on long-run growth and welfare of positional preferences – that is, where consumption and wealth of an individual have a direct effect on the utility of other individuals. Such preference structures have been studied by eminent economic thinkers like Adam Smith and Thorstein Veblen, among others.[2] In the more recent past, positional preferences have been studied extensively, and their high empirical significance has been well established (cf. Johansson-Stenman et al. (2002), Alpizar et al. (2005), Aronsson and Johansson-Stenman (2014)). A salient feature of our model is that households exhibit positional preferences not only with respect to consumption but also with respect to wealth. On the production side, we consider an endogenous growth framework with public capital as the growth engine, a la Futagami et al. (1993), and with labor supply being exogenous. We devise corrective income- and consumption tax instruments that enable the decentralized economy to achieve the first-best outcome, and proceed to compare decentralized and optimal growth rates and welfare levels in our model.

We discuss the literature on positional preferences in more detail in Section 2 below. In our paper, the reference level represents an externality, as an agent ignores the effect that his own consumption and wealth has on the others' consumption- and wealth *reference levels* (thereby on the utility of other households). Therefore, we study whether or not this externality causes a distortionary effect. A key feature of our model is that, in addition to consumption and consumption externalities (see Liu and Turnovsky (2005), among others), wealth in the form of capital is an argument in households' utility functions, as in Zou (1994, 1995), Corneo and Jeanne (1997), Futagami and Shibata (1998) and Nakamoto (2009), etc. The implicit assumption here is that services from capital are not only useful in production, but also provide utility in consumption: for instance, private cars are used for work-related as well as pleasure trips, and computers are used for work (e.g., to download academic papers) as well as for leisure (e.g., connecting with friends via social networks).

A further interesting feature of our paper is that households may be positional with respect to wealth, which implies there is a wealth externality effect in addition to a consumption

[2] Different terms for *positional preferences* have been used in the literature, with slightly differing meanings. They include status preferences, status consumption, conspicuous consumption, conspicuous wealth, relative consumption, relative wealth, keeping up/catching up with the Joneses, jealousy/envy, external habits, or simply consumption externality.

externality effect. There is clear empirical evidence that people have stronger positional concerns in some domains than in others — for instance, they are more positional regarding durable goods, like houses and cars (which are more visible to others, and are of the wealth-augmenting type) compared to non-durable goods (which are less visible, and 'disappear' from the economy at the point within a period that it is consumed)[3]; hence, in our model, we allow for both of these positional preferences to co-exist, and study the implications of such positionalities on growth, economic distortions, and welfare.

In our paper, labor supply is inelastic. Still, if individuals derive utility from wealth, the decentralized equilibrium differs from the social optimum. This is in sharp contrast to the prior literature showing that as long as labor supply is exogenous, positional preferences with respect to consumption do not cause any distortions along a balanced growth path. In this paper, the distortionary impact of positional preferences with respect to consumption (when wealth is also present) is entirely due to the fact that agents derive utility not only from consumption but also from wealth. The distortionary impact of positional preferences necessitates the use of corrective income- and consumption taxes. In this respect, our paper is close to Nakamoto (2009), where also labor supply is inelastic. In both set-ups the distortionary effect of consumption externalities persists in the long-run because of wealth-dependent preferences. A key difference, however, is that our paper is an endogenous growth model where output is produced by public (in addition to private) capital, while he considers a neoclassical growth model. Moreover, in our model, households are positional also with respect to wealth (not only with respect to consumption). The latter feature allows us, in contrast to Nakamoto (2009), to identify a significant case in which the concern for relative consumption is *not* distortionary, despite wealth-dependent preferences.

Our paper contributes to the literature in two ways. First, in an endogenous growth framework, we investigate the joint impact of positional concerns for *both* consumption and wealth on growth, welfare and corrective taxation. To the best of our knowledge, there is no prior paper that has thoroughly investigated this question before. Second, we employ our framework to analyze several fiscal policy experiments. We examine their effects on the economy along the balanced growth as well as transition paths. Three of those experiments involve an increase in public capital spending financed by lump-sum, income- or

[3] See, for instance, Alpizar et al. (2005), Solnick and Hemenway (2005), and Carlsson et al. (2007).

consumption taxes, while the remaining two are respectively about an income- and consumption tax increase, without a corresponding spending increase.

We present six important results. First, stronger positional preferences via conspicuous consumption and conspicuous wealth *both* have a direct and positive impact on the endogenous growth rate, providing the intertemporal elasticity of substitution is less than 1. The same does not hold, however, with respect to welfare. While a higher growth rate benefits welfare *ceteris paribus*, a higher growth rate also impacts on the consumption- to capital ratio, which makes the joint impact on welfare ambiguous. Second, we demonstrate that if *and only if* wealth is present in the consumer's utility function, then the consumption externality does have a distortionary effect, even if labor supply is exogenous. This result is in contrast to the papers showing that positional concerns for consumption do not affect the steady state equilibrium if labor supply is exogenous. However, while these papers focus on intra-temporal distortions of the leisure-consumption choice, we focus on the *inter-temporal* distortion of the consumption-saving choice. Third, we derive optimal corrective income- and consumption tax rates. For plausible parameter values, the decentralized economy here achieves a lower growth rate compared to what would be attained via a notional central planner, and consequently we characterize the optimal fiscal policy that enables the first-best to be attained, as in Liu and Turnovsky (2005). Given that here the private return on capital falls below its socially optimal return, a positive tax on consumption helps offset this deviation. As positional concerns for consumption rise, both optimal growth and welfare rise, which necessitates an even lower income tax rate and a higher consumption tax rate for the decentralized economy: this, together with the higher complementary public spending, raises the growth rate and also improves welfare. Fourth, in our endogenous growth framework, where wealth impacts on utility, a wealth externality is *always* distortionary, irrespective of the presence of a consumption externality. Even if the production externality is absent, conspicuous consumption and conspicuous wealth are both distortionary so long as wealth is present in the utility function. This is one of the important contributions of this paper. Fifth, our numerical results indicate that public spending positively affects both growth and welfare in the steady state, and does so quite strongly. The production externality clearly dominates the consumption externalities in this regard. The latter is reflected also in the 'decisive' way in which some of the key variables adjust along the transition path in response to the first three fiscal shocks. Sixth, our theoretical and numerical results give rise to several policy conclusions. For empirically supported degrees of positionality, corrective tax rates are quite large, and they impose substantive effects on both growth rates and welfare. However, the policy prescription depends very much on whether households are more positional with respect to consumption or with respect to wealth. In the former case, corrective fiscal policy calls for a high tax rate on consumption and a low (or even negative) tax rate on income, in the latter case the reverse policy conclusion applies. Moreover, we (numerically) demonstrate that the behavioral response to policy shocks is strikingly lessened by the presence of positional preferences.

The paper is organized as follows. Section 2 discusses important prior contributions related to this paper. Section 3 develops the model, emphasizing the preference structure and characterizes the steady state. Section 4 derives the social optimum, identifies the fiscal policies that enable the decentralized economy to replicate the first-best scenario, and links this with growth and welfare. Section 5 studies the growth and welfare effects of several fiscal policy shocks, both along the balanced growth path and in transiting from one steady state to another. Finally, Section 6 concludes the paper.

2. Related Literature

Positional (or reference-dependent) preferences, where the reference point is social distinction and/or status in relation to others in society, were studied from ancient times by philosophers like Plato, and more recently by political philosophers and classical economists such as Adam Smith and Thorstein Veblen, among others. Meanwhile, a large body of literature has established significant empirical evidence for positional preferences.[4]

Such preferences have been discussed widely also in the (dynamic) macroeconomic literature. Typically, individual preferences depend not only on the level of one's own consumption but also on how own consumption *compares* to some standard, which is referred to as the consumption *reference level* – very much in the spirit of Johansson-Stenman et al. (2002), Alonso-Carrera et al. (2005), or Liu and Turnovsky (2005). There are two specific versions of this: the consumer's reference level could be his or her own past consumption, or it could be the consumption of others, *a la* Duesenberry (1949). These two versions are referred to as the *inward-* and *outward-looking* habits, respectively, by Carroll et al. (1997). Following Ryder and Heal (1973), the inward version is adopted, e.g., by Carroll et al. (2000) and Monteiro et

[4] For a recent review of the literature, see Truyts (2010), Eckerstorfer and Wendner (2013), or Wendner (2014).

al. (2013). However, only in the outward-looking case does the reference level represent an externality. The outward version is considered by Johansson-Stenman et al. (2002), Liu and Turnovsky (2005), Turnovsky and Monteiro (2007), and Wendner (2011), among others, while Carroll et al. (1997), Alvarez-Cuadrado et al. (2004), and Alonso-Carrera et al. (2005) consider both types of consumption reference levels. In this article, we adopt the outward case, as we are interested in the externality aspects of consumer (and, to a lesser extent, producer) behavior, and issues about how far tax- or subsidy policies in a decentralized economy can replicate the social optimum.

In this paper, households have two points of reference: relative consumption and relative wealth. The latter point of reference is analyzed in Zou (1994, 1995), Corneo and Jeanne (1997), Futagami and Shibata (1998), Nakamoto (2009), among others. The initial idea is due to Zou (1994), who argues that the incentive for accumulating capital lies not only in maximizing long-run consumption, but also to increase wealth, which in itself adds to agents' utility. Zou's model, in turn, is based on 'the theory of the spirit of capitalism' by Weber (1958), and the mathematical model of Kurz (1968). By adding a 'cultural' dimension to existing models, his set-up is able to embody all the contributions of both traditional and new growth theories.

The previous literature has established a key finding. In the absence of a labor-leisure choice, a consumption externality does *not* have any impact on the steady state equilibrium of a decentralized economy *in a neoclassical growth model* (see, for example, Rauscher (1997), Fisher and Hof (2000), Liu and Turnovsky (2005)).[5] If, however, as in Turnovsky and Monteiro (2007), there is also a positive (negative) *production* externality, then the steady-state equilibrium capital stock and output are below (above) their respective optimal levels, while the equilibrium output–capital ratio is too high (low). Thus, in the presence of a production externality, a consumption externality *does exacerbate* distortions stemming from a production externality. In an *endogenous growth framework*, Carroll et al. (1997), who consider a simple AK technology, show that the more individuals care about how consumption compares to the reference level, the higher will be the growth rate of consumption in the steady state.

[5] There is one qualification though. With exogenous technical change, the consumption externality - by affecting the elasticity of marginal utility of consumption - does impact on the equilibrium (Wendner, 2011). For a similar result, but with the reference level comprising current and past consumption, see Alvarez-Cuadrado et al. (2004).

In contrast, in models with consumption externalities but with elastic labor supply, the decentralized economy diverges from the social optimum in the long-run, as in Dupor and Liu (2003), Liu and Turnovsky (2005), and Turnovsky and Monteiro (2007). In the first of these papers, an increase in aggregate consumption may raise the marginal utility of individual consumption relative to leisure when others consume more. At the same time, higher per capita consumption (holding individual consumption fixed) can trigger jealousy (admiration) so that individual utility falls (rises). In Liu and Turnovsky (2005), if labor supply is elastic, a negative (positive) consumption externality leads to over- (under-) consumption and over- (under-) supply of capital and labor, relative to the optimum, in the steady state. With endogenous labor supply, in Turnovsky and Monteiro (2007), the consumption externality affects the steady state even in the absence of any production externality. This is because it affects the marginal valuation of consumption, which in turn changes the optimal utility value of the marginal product of labor. Thus, consumption distortion results in distortion in the labor-leisure trade-off, and therefore creates production inefficiency.

In Alonso-Carrera et al. (2005), a consumption externality makes the decentralized equilibrium allocation inefficient, which can be corrected by either a consumption tax or an income tax. If consumers' willingness to shift current consumption to the future is sub-optimally low (high), then optimal fiscal policy consists of either a decreasing (an increasing) sequence of consumption taxes or a subsidy (tax) on income/output. In Nakamoto (2009), the reason for the decentralized outcome to differ from the first-best is due to wealth preference: when households feel jealousy (admiration) about others' consumption, the long-run levels of consumption and the capital stock are lower (higher) than the social optimum, calling for a positive (negative) consumption tax and a negative (positive) income tax. In our case, if wealth is an argument in the utility function, and providing the desire to raise consumption is different from the desire to increase saving (wealth), the optimal consumption and income tax rates differ from zero even if government spending is chosen optimally. In the case where the private return on capital falls below its socially optimal return, a positive tax on consumption helps offset this deviation; consequently, a larger weight on consumption relative to the average results in even larger divergence between private and social returns, and therefore calls for an even larger value of the consumption tax rate to compensate.

Finally, several papers consider the impact of reference-dependent consumption on growth. In Futagami and Shibata (1998), if all consumers are identical, the long-run balanced growth rate is positively related to the degree of status preference (but this may not hold with heterogeneous agents). Likewise, in Liu and Turnovsky (2005), where endogenous growth – but not via public capital – is considered, a positive production externality leads to the decentralized growth rate falling short of the socially optimal rate (with inelastic labor). Here, consumption externalities affect the magnitude of the distortion caused by the production externality. By contrast, within an endogenous growth set-up, Corneo and Jeanne (1997) show that the quest for status may result in a competitive economy growing too fast relative to the social optimum if the marginal status utility of relative wealth exceeds a certain threshold.

In the next section, we spell out the consumption and production sides of the model, and characterize the macroeconomic equilibrium.

3. The Model

We consider a dynamic general equilibrium model of a closed economy that allows for fully endogenous growth. Time is considered to be continuous. The source of endogeneity of growth is a public good, public capital, K_g, that serves as an input to production. There is a large number of households and firms, the respective number of which we normalize to unity. Households are homogeneous and exhibit positional preferences. They derive utility not only from own consumption and own wealth, but also from own consumption *relative to some consumption reference level*, and from own wealth *relative to some wealth reference level.*

3.1 Preferences

Relative consumption is given by individual consumption relative to some consumption reference level, $\bar{C}$: $C/\bar{C}$. As households are homogeneous in our framework, we consider the economy's average consumption level as a natural choice for a household's consumption reference level.[6] By the same token, relative wealth is given by individual wealth relative to the average wealth in the economy, $\bar{K}$: $K/\bar{K}$. That is, conspicuous consumption (CC, in the following) is captured by a relative consumption term, and conspicuous wealth (CW, in the following) is captured by a relative wealth term in the instantaneous utility function. Both $\bar{C}$ and $\bar{K}$ are considered exogenous by individual households.

[6] In a model with heterogeneous households, a household's consumption reference level may be specified more generally (cf. Eckerstorfer and Wendner 2013).

Wealth-dependent preferences have been considered before. The earlier literature primarily focused on the Pigou- (or real balance-) effect.[7] Later, wealth in the form of money was introduced directly into the utility function in Ramsey-type of optimizing models -- real money balances provide utility by facilitating transactions and reducing shopping time (see, e.g., Croushore 1993). In this paper, we consider the services from durable assets such as houses, cars and computers as constituting wealth (capital) in the utility function. This is because, as mentioned in the Introduction, one may have productive as well as utility services from the same capital good (a car could be used for official purposes as well as for family holidays, etc.).[8] We are concerned also with the interaction of positional concerns with wealth. In the context of positional preferences, (relative) wealth has been frequently considered an argument in the utility function before (cf., among others, Corneo and Jeanne 1997, 2001, Fisher and Hof 2000, Fisher and Hof 2005, Futagami and Shibata 1998, Hof and Wirl 2008, Pham 2005, Rauscher 1997). Only few papers consider both positional consumption- and positional wealth concerns (cf. Tournemaine and Tsoukis 2008). We consider this case, in which both relative consumption and relative wealth enter the utility function. The (quasi-concave) instantaneous utility function is given by:[9]

$$
\begin{aligned}
u\left(C, K, \frac{C}{\overline{C}}, \frac{K}{\overline{K}}\right) &= \frac{1}{\gamma}\left[C^{1-\eta_c}\left(\frac{C}{\overline{C}}\right)^{\eta_c}\left(K^{1-\eta_k}\left(\frac{K}{\overline{K}}\right)^{\eta_k}\right)^{\xi}\right]^{\gamma} \\
&= \frac{1}{\gamma}\left[C\overline{C}^{-\eta_c}K^{\xi}\overline{K}^{-\eta_k\xi}\right]^{\gamma}, \quad -\infty < \gamma < 1,\ 0 \le \eta_i < 1,\ i \in \{c, k\}\ ,\ \xi \ge 0,
\end{aligned}
\tag{1}
$$

that is, households exhibit constant relative risk aversion, with absolute elasticity of marginal utility of consumption equal to $[1-\gamma(1-\eta_c)]$. Parameters η_i represent marginal degrees of positionality (Johansson-Stenman et al. 2002). A marginal degree of positionality reflects the share of marginal utility of individual consumption (or wealth) that is due to the fact that own

[7] The idea behind the Pigou effect is that if the economy is stuck in a "liquidity trap" situation with unemployment and falling prices (but an unchanged nominal money stock), then at some point people would start feeling sufficiently wealthier due to the higher real balances at their disposal; this would stimulate aggregate demand via consumption (to enable the commodity and money markets to clear at an interest rate higher than the liquidity trap rate of interest) and raise income, thus overcoming the unemployment problem.

[8] A similar point about the dual role of goods is made by Chatterjee and Ghosh (2011), but in the context of *public* goods, e.g., publicly funded infrastructure (roads, highways, etc.) and education. The basic idea there, as in our current paper, is that goods could be viewed as providing a composite bundle of services affecting both production and utility.

[9] The utility function we consider is multiplicative (rather than additive) in consumption and capital as it is more general than an additive specification, which is because the marginal rate of substitution between the arguments is not constant. Both formulations are widely used in the literature.

consumption (or wealth) raises the ratio $C/\bar{C}$ or $K/\bar{K}$, ceteris paribus. There is robust empirical evidence that $\eta_i > 0$ with estimates found in the range of $\left[0.2, 0.8\right]$ (cf. Johansson-Stenman et al. 2002, Solnick and Hemenway 1998, 2005, Wendner and Goulder 2008). Parameter ξ indexes the preference for wealth. If $\xi = 0$, the household does not exhibit preferences with respect to wealth, but $\xi > 0$ implies a preference for wealth. Moreover, if also $\eta_k > 0$, the household's preferences exhibit CW in addition to CC.

Positional preferences of consumption vis-à-vis wealth could be viewed along the lines of preferences for non-durable consumption goods vis-à-vis durable goods that exhibit asset-type features mentioned earlier. From the studies by Alpizar et al. (2005), Solnick and Hemenway (2005), and Carlsson et al. (2007), where the demand for durables like houses are more positional than that for less visible consumption items, one would expect that $\eta_k > \eta_c$ holds. In contrast, for people who are more consumption-oriented (in that they value their standing relative to others in terms of good food and clothing rather than good cars, for example), one would expect $\eta_c > \eta_k$ to hold.

The intertemporal utility function, $U\left(C, K, \frac{C}{\bar{C}}, \frac{K}{\bar{K}}\right)$, is given by:

$$U\left(C, K, \frac{C}{\bar{C}}, \frac{K}{\bar{K}}\right) = \int_0^\infty u\left(C, K, \frac{C}{\bar{C}}, \frac{K}{\bar{K}}\right) e^{-\beta t}\, dt = \int_0^\infty \frac{1}{\gamma}\left[C\bar{C}^{-\eta_c} K^{\xi} \bar{K}^{-\eta_k \xi}\right]^{\gamma} e^{-\beta t} dt,\ \beta > 0. \tag{2}$$

The household has a constant rate of time preference, $\beta > 0$. Facing given market prices, reference levels $\bar{C}$ and $\bar{K}$, and equipped with perfect foresight the household chooses a plan $\left\{C(t)\right\}_{t=0}^{\infty}$ so as to

$$\begin{aligned}
&\max U\left(C, K, \frac{C}{\bar{C}}, \frac{K}{\bar{K}}\right) \\
&\text{s.t.} \\
&\dot{K} = (1-\tau_y)Y - (1+\tau_c)C - T - \delta_k K, \\
&\lim_{t\to\infty} K_t e^{-\int_0^t r_s ds} \geq 0.
\end{aligned} \tag{3}$$

The first constraint in (3) is the household's flow budget constraint, where, τ_y and τ_c are respectively the income- and consumption tax rate, and T denotes lump sum taxes. In our framework, the labor-leisure decision is exogenous. Under standard assumptions (in the absence of CC and CW), the *optimal* consumption tax is nil. Below, we are interested in the mechanisms affecting the optimal consumption tax rate in the presence of CC and CW.

The second constraint in (3) is the No-Ponzi-Game condition, where the rate of interest (economy-wide return to capital) is determined in competitive factor markets: $r = Y_K - \delta_k = \alpha A^{-\rho} y^{1+\rho} - \delta_k$, as discussed below. In equilibrium, the transversality condition requires the No-Ponzi-Game condition to hold with strict equality.

3.2 Technology

A homogeneous output, Y, is produced by private and public capital using a CES technology:

$$Y = A\left[\alpha K^{-\rho} + (1-\alpha)K_g^{-\rho}\right]^{-1/\rho},\ 0<\alpha<1,\ -1<\rho<\infty, \tag{4}$$

where K denotes private capital. The elasticity of substitution between private capital and the public good is given by $1/(1+\rho)$. To ensure positivity of growth rates along the BGP (see below), we assume

$$\alpha A - \delta_k > \beta\ . \tag{A.1}$$

The assumption implies that the rate of interest strictly exceeds the rate of time preference *at* $z=1$.

Public capital evolves according to:

$$\dot{K}_g = G - \delta_g K_g,\ G = gY,\ 0<\delta_g<1, \tag{5}$$

where G represents the flow of public expenditures for public capital and δ_g is the rate of depreciation of public capital. The flow of public expenditures is a fixed share g of output.

Let C denote aggregate consumption. As we consider a closed economy, the aggregate resource constraint is given by:

$$\dot{K} = Y - C - G - \delta_k K, \;\; 0 < \delta_k < 1, \tag{6}$$

where δ_k is the rate of depreciation of private capital.

In our set-up, the government runs a balanced budget, where its spending (G) is matched by income- consumption- and lump-sum taxation (τ_y, τ_c and T respectively). The government budget constraint is easily obtainable from (6) together with the private budget constraint in (3).

Before proceeding to the macroeconomic dynamics, our modeling choice of technology deserves a comment. Clearly, we could have adopted one of the following two alternatives. First, we could have specified public infrastructure investment as a flow, as in Barro (1990). Second, we could also have specified production as an AK model, as in Rebelo (1991). However, unlike our framework, there are no dynamics with either of those specifications (rather, a dynamic system of dimension one with a strictly positive eigenvalue). As we are also interested in the transitional dynamics, we adopt a framework with public capital that exhibits such dynamics (saddle-path stability). In addition, we verified that our results regarding the distortionary effects of positional preferences are not sensitive with respect to the technology specification that we adopt.[10]

3.3 Macroeconomic Dynamics and the Steady State

Let the current-value Hamiltonian be given by:

$$H = \frac{1}{\gamma}\left[C\overline{C}^{-\eta_c} K^{\xi} \overline{K}^{-\eta_k \xi} \right]^{\gamma} + \lambda\left[(1-\tau_y)Y - (1+\tau_c)C - T - \delta_k K \right], \tag{7}$$

[10] These results are not included in the paper for space considerations, but are available upon request.

where C is a control variable, K is a state variable, and λ is a costate variable. An interior solution satisfies the following necessary first-order conditions.

$$\frac{\partial H}{\partial C} = C^{\gamma-1}\bar{C}^{-\eta_c\gamma}K^{\xi\gamma}\bar{K}^{-\eta_k\xi\gamma} - \lambda(1+\tau_c) = 0 \tag{8}$$

$$\frac{\partial H}{\partial K} = \xi C^{\gamma}\bar{C}^{-\eta_c\gamma}K^{\xi\gamma-1}\bar{K}^{-\eta_k\xi\gamma} + \lambda\left[(1-\tau_y)Y_K - \delta_k\right] = \beta\lambda - \dot{\lambda} \ , \tag{9}$$

where Y_K is the partial derivative of Y with respect to K.

Ex post, as households are homogeneous, $\bar{C} = C$ and $\bar{K} = K$. The first-order conditions then imply:

$$C^{\gamma(1-\eta_c)-1}K^{\xi\gamma(1-\eta_k)} = \lambda(1+\tau_c) \ , \tag{10}$$

$$\xi C^{\gamma(1-\eta_c)}K^{\xi\gamma(1-\eta_k)-1} + \lambda\left[(1-\tau_y)Y_K - \delta_k\right] = \beta\lambda - \dot{\lambda} . \tag{11}$$

Next, we define the normalized variables $c \equiv C/K$, $y \equiv Y/K$, $z \equiv K_g/K$. Log-differentiating (10) and using the result in (11) yields

$$\xi c(1+\tau_c) + (1-\tau_y)Y_K - \delta_k = \beta - \frac{\dot{\lambda}}{\lambda} . \tag{12}$$

Differentiating (12) and taking (6) into account gives

$$(\gamma(1-\eta_c)-1)\frac{\dot{C}}{C} + (\xi\gamma(1-\eta_k))((1-g)y - c - \delta_k) = \frac{\dot{\lambda}}{\lambda} . \tag{13}$$

Next, using (13) in (12) and considering $\dot{c}/c = \dot{C}/C - \dot{K}/K$ yields:

$$\frac{\dot{c}}{c} = \frac{(1-\eta_k)\xi\gamma((1-g)y - c - \delta_k) + \xi(1+\tau_c)c + (1-\tau_y)Y_K - \beta - \delta_k}{1-(1-\eta_c)\gamma} - (1-g)y + c + \delta_k , \tag{14}$$

where (4) implies that $y = A\left[\alpha + (1-\alpha)z^{-\rho}\right]^{-1/\rho}$, and $Y_K = \alpha A^{-\rho}y^{1+\rho}$. Finally, from (5) and (6), it follows:

$$\frac{\dot{z}}{z} = g\frac{y}{z} - \delta_g - (1-g)y + c + \delta_k . \tag{15}$$

Differential equations (14) and (15) represent the model's two-dimensional dynamic system in the dynamic variables c and z.

The economy will in steady state follow a balanced growth path (BGP for short), defined as a path along which Y, C, K and K_g grow at constant rates. It can easily be verified that Y, C, K and K_g grow at the *same* constant growth rate Γ along a BGP. That is, in a steady state, $\dot{c} = \dot{z} = 0$.

Henceforth, we employ the following (sufficient) parameter restriction, which ensures positivity of (c, z) along the BGP:

$$Ag(1-\alpha)^{-1/\rho} > \delta_g \geq Ag\,. \tag{A.2}$$

Assumption (A.2) presents two inequalities. The left-hand side inequality requires the average productivity of public capital at $z = 0$, $A(1-\alpha)^{(-1/\rho)}$, to exceed the depreciation requirement per unit of g, δ_g / g. As a consequence, for any $c \geq 0$, $\dot{z} > 0$ at $z = 0$, according to (15). The (sufficient, not necessary) right-hand side inequality of (A.2) requires the reverse to hold. For c not too large, $\dot{z} < 0$ at $z = 1$, according to (15).

Proposition 1. (Existence and Stability)

(i) Assume (A.1) and (A.2). Then, a non-trivial steady state (c, z) *exists and is unique. The steady state is associated with a BGP along which* C, K, K_g *and Y grow with the constant growth rate* $\Gamma = g\,y/z - \delta_g$.

(ii) The unique steady state is a saddle point and is saddle-point stable.

Proof. See the Appendix.

Parameter restrictions (A.1) and (A.2) are sufficient, not necessary, for a steady state to exist. In fact, as shown in the Appendix, the two restrictions (A.1) and (A.2) imply $0 < z < 1$ along the BGP. Assumption (A.1) requires the rate of interest to exceed the pure rate of time preference at $z = 1$. Assumption (A.2) requires the rate of growth of public capital investment to be strictly positive at $z=0$ (left hand inequality) and negative at $z=1$ (right hand inequality). A violation of (A.2) might lead to $(c,z)\leq 0$.

In the Appendix it is shown that the Jacobian matrix associated with the dynamic system, evaluated in the steady state, has one eigenvalue with negative real part and one positive eigenvalue. There is one predetermined variable, z, and one jump variable, c. Thus, the saddle point is saddle path stable.

Ceteris paribus, the endogenous growth rate, $\Gamma = g\,y/z-\delta_g$, rises in g, due to the production externality.[11] The following proposition shows how positional preferences impact on the endogenous growth rate.

Proposition 2. (Positional Preferences and Endogenous Growth)

Assume (A.1) and (A.2). Then, positional preferences ($\eta_c>0$ or $\eta_k>0$) impact on the endogenous balanced-growth growth rate, Γ, independently of the presence of a production externality. Specifically, along the BGP,

$$\frac{\partial\Gamma}{\partial\eta_i}\gtreqless 0 \Leftrightarrow \gamma \lesseqgtr 0,\; i\in\{c,k\} .$$

Proof. See the Appendix.

We consider the $\gamma<0$ case (the intertemporal elasticity of substitution being less than 1) as our main case for analysis. This is because it is empirically supported by the results of Hall (1988) and Constantinides (1990), who found the elasticity of substitution in consumption to be less than 1. Here positional preferences raise the endogenous growth rate, irrespective of whether individual households exhibit a concern for relative consumption or for relative wealth. This result is not obvious, as households face a trade-off between a higher consumption level initially (a reduction in savings) together with a lower consumption growth rate on the one hand, and a higher consumption growth rate together with a lower consumption level initially on the other. In the first case, households choose consumption so

[11] Numerical simulations of the sensitivity of the endogenous growth rate with respect to key parameters of our model for both the decentralized economy and the social optimum (see section 4) are available from the authors upon request.

as to raise their initial relative consumption level – though at the cost of a lower planned relative consumption level in the future. In the second case, households choose consumption so as to lower their relative consumption level initially – at the benefit of a larger planned relative consumption level in the future.

The result is explained by considering the effects of a rise in η_i on the elasticity of intertemporal substitution (the elasticity of marginal utility). It can easily be verified that – ex post – a rise in η_i raises the long-run elasticity of intertemporal substitution, once $\gamma < 0$, and it lowers the (absolute of the) elasticities of marginal utility with respect to c or k. Intuitively, consider a rise in η_c (a parallel argument can be provided for a rise in η_k). From (14), if $\gamma < 0$, a rise in η_c, ceteris paribus, leads an individual household to raise her steady state consumption growth rate (in a bid to outshine the others). Clearly, a rise in η_c lowers the elasticity of marginal utility with respect to c (the desire for consumption smoothing), thereby necessitating a higher consumption growth rate. In other words, if $\gamma < 0$, positional concerns for consumption lower the elasticity of marginal utility – for this reason, households prefer a higher consumption growth rate over a higher initial consumption level in response to a rise in η_c. A parallel argument applies for the $\gamma > 0$ case (the intertemporal elasticity of substitution being greater than 1).

In order to derive optimal consumption- and income tax rates under CC and CW we will now consider the socially optimal allocation. From this allocation, by comparing with the market economy's allocation, we derive optimal consumption- and income tax rates for the BGP below.

4. The Social Optimum

We adopt the primal approach to derive the socially optimal allocation. In contrast to private households, the government takes into account both externalities, CC and CW. The current value Hamiltonian of the government's problem is given by:

$$\hat{H} = \frac{1}{\gamma}\left[C^{1-\eta_c} K^{\xi(1-\eta_k)}\right]^{\gamma} + \hat{\lambda}\left[(1-g)Y - C - \delta_k K\right] + \mu\left[gY - \delta_g K_g\right], \tag{16}$$

where C is a control variable, and K, K_g are state variables. An interior solution satisfies the following necessary first-order conditions:

$$\frac{\partial \hat{H}}{\partial C} = (1-\eta_c) C^{\gamma(1-\eta_c)-1} K^{\xi\gamma(1-\eta_k)} - \hat{\lambda} = 0 \ , \tag{17}$$

$$\frac{\partial \hat{H}}{\partial K} = \xi(1-\eta_k) C^{(1-\eta_c)\gamma} K^{\xi\gamma(1-\eta_k)-1} + \lambda[(1-g)Y_K - \delta_k] + \mu g Y_K = \beta\hat{\lambda} - \dot{\hat{\lambda}} \ , \tag{18}$$

$$\frac{\partial \hat{H}}{\partial K_g} = \lambda(1-g)Y_{K_g} + \mu(gY_{K_g} - \delta_g) = \beta\mu - \dot{\mu} \ . \tag{19}$$

Let $q \equiv \mu / \hat{\lambda}$. Then from (19) it directly follows that

$$\frac{\dot{q}}{q} + \frac{1}{q}(1-g-qg)Y_{K_g} - \delta_g = \beta - \frac{\dot{\hat{\lambda}}}{\hat{\lambda}} \ , \tag{20}$$

where $Y_{K_g} = (1-\alpha)A^{-\rho}(y/z)^{1+\rho}$. First-order condition (17) in (18) yields:

$$\frac{\xi(1-\eta_k)}{1-\eta_c} c + (1-g+qg)Y_K - \delta_k = \beta - \frac{\dot{\hat{\lambda}}}{\hat{\lambda}} \ . \tag{21}$$

Combining (20) with (21) yields a differential equation in q, where both partial derivatives of Y are functions of z (only):

$$\frac{\dot{q}}{q} = \frac{\xi(1-\eta_k)}{1-\eta_c} c + (1-g+qg)Y_K - \delta_k - \frac{1}{q}(1-g-qg)Y_{K_g} + \delta_g \ . \tag{22}$$

As in the section above,

$$\frac{\dot{z}}{z} = g\frac{y}{z} - \delta_g - (1-g)y + c + \delta_k \ . \tag{23}$$

Finally, the dynamic equation for c is found by differentiating (17) with respect to time and taking (21) into account for $\dot{\lambda}/\lambda$:

$$\frac{\dot{c}}{c} = \frac{\xi\gamma(1-\eta_k)[(1-g)y - c - \delta_k] + \xi(1-\eta_k)/(1-\eta_c)c + (1-g+qg)Y_K - (\beta+\delta_k)}{1-\gamma(1-\eta_c)} \tag{24}$$
$$-(1-g)y + c + \delta_k .$$

For a given government expenditure share for public investment, the *three*-dimensional dynamical system of the economy is given by the differential equations (22) – (24) in the dynamic variables (c, q, z).

However, if the government follows its optimal policy, then $\partial\hat{H}/\partial g = 0$, implying $q = 1$ and $\dot{q} = 0$. This is when the government has an additional control (*g*) at its disposal in addition to the choice variables, C, K and K_g. In this case, the dynamical system becomes two-dimensional (as for the market economy). Again, the economy will, in a steady state, follow a BGP. Along the BGP $\dot{c} = \dot{z} = 0$, and C, K, K_g and Y grow at the same constant endogenous growth rate. In a parallel way as presented for Proposition 1, one can establish existence of a unique, nontrivial, saddle point stable steady state. We are now ready to consider the optimal taxation results.

4.1 Optimal Taxation

Given that income and consumption taxes impact on the economy in very different ways, what tax and expenditure rates in the decentralized economy will replicate the social planner's optimum? Let these choices be represented by the vector $(\hat{g}, \hat{\tau}_y, \hat{\tau}_c)$. Then, by definition, this vector is a description of optimal fiscal policy in the decentralized economy. To determine these optimal choices, we will compare the equilibrium outcome in the decentralized and centrally planned economies. Since our focus is on the two distortionary tax rates, we will assume that *g* is set optimally at $\hat{g}$, given by the solution to (22) – (24), and is appropriately financed by some combination of distortionary taxes and lump-sum taxes. Given $\hat{g}$, a comparison of (14) and (24) yields the following long-run optimal relationship between the income and consumption tax rates:

$$\tau_y = \frac{\left[\tau_c + (\eta_k - \eta_c)/(1-\eta_c)\right]\xi c}{\alpha A^{-\rho} y^{1+\rho}} . \tag{25}$$

As (15) and (23) are identical, (25) shows that only *one* tax rate is required to be chosen (independently) to attain the first-best equilibrium. This implies that the government has a choice in the 'mix' between the income and consumption tax rates: if one is set arbitrarily, the other automatically adjusts to satisfy (25) to replicate the first-best allocation. But what kind of a policy 'mix' should the government choose? Even if one individual tax instrument is at its non-optimal level, (25) suggests that the government can still adjust the other appropriately to attain the social optimum.

To see this flexibility in designing optimal fiscal policy, note that the income and consumption tax rates are positively related in (25). A useful benchmark, then, is to derive the tax on income, say, $\hat{\tau}_y$, when $\tau_c = 0$. Given this benchmark rate, we can evaluate the role of the consumption-based tax when the actual income tax rate differs from its benchmark rate, $\hat{\tau}_y$. Likewise, we can evaluate the role of the income-based tax when the actual consumption tax rate differs from its benchmark rate, $\hat{\tau}_c$. When consumption (income-) taxes are absent, that is, $\tau_c = 0$ (that is $\tau_y = 0$), the optimal taxes on income and consumption are given by:

$$\hat{\tau}_y = \frac{\left[(\eta_k - \eta_c)/(1-\eta_c)\right]\xi c}{\alpha A^{-\rho} y^{1+\rho}}$$
$$\hat{\tau}_c = \begin{cases} \dfrac{\eta_c - \eta_k}{1-\eta_c}, & \text{for } \xi > 0 \\ 0, & \text{for } \xi = 0 \end{cases} \tag{26}$$

As is evident from (25) and (26), either instrument, by itself, can be used to attain the social optimum.

Proposition 3. (Optimal Taxation).
Assume (A1) and (A2). If and only if (i) wealth is an argument in the utility function ($\xi > 0$) and (ii) $\eta_c > 0$ or $\eta_k > 0$ ($\eta_c \neq \eta_k$), then the optimal tax rates differ from 0 and take the values given by (26).

Proof. Follows immediately from comparing (24) with (14).

In general, income- or consumption taxes are needed to correct for the distortions caused by the concern for relative wealth and relative consumption. As numerical simulations show (see below), the optimal tax rates may become quite large.

Corollary 1

If wealth is an argument of the household utility function ($\xi > 0$), then the consumption and wealth externalities by themselves do cause distortionary effects (even in the absence of a production externality).

In the presence of wealth in the household utility function, the Keynes-Ramsey rule does not hold anymore. This is because the derivative of the Hamiltonian with respect to the capital stock contains a term, the marginal utility of wealth, that itself depends on the consumption externality. Individuals do not internalize this externality, whereas the government does so. As a consequence, a modified Keynes-Ramsey rule requires the government to choose a capital stock that is affected by the strength of the consumption externality. Notice that this result also holds if preferences exhibit no concern for *relative* wealth ($\xi > 0, \eta_k = 0$). So, a wealth externality is *always* distortionary (unless the marginal degrees of positionality of consumption and wealth are equal), regardless of whether or not we have a consumption externality. The Keynes-Ramsey rule requires to be even more strongly modified if η_k is strictly positive *in addition* to $\xi > 0$. That is, the marginal benefit from consuming an additional unit of capital today rises not only by a preference for *relative* wealth in addition to wealth per se. In a different framework, in which there are no externalities in production and therefore growth is not endogenous and in which households do not have a concern for relative wealth, Nakamoto (2009) points out a parallel argument.

Corollary 2.

If wealth is not an argument of the household utility function, then the consumption externality does not cause any distortionary effect in spite of the presence of a production externality. This holds true, even if g is not chosen optimally.

A related argument in a framework in which the engine of growth stems from private capital accumulation is provided by Liu and Turnovsky (2005). We extend this argument to a framework in which the public capital stock serves as an engine of growth. Liu and

Turnovsky (2005, p.1121) show that their consumption externality alone does not introduce a distortion. However, in the presence of an additional production externality, the consumption externality exacerbates or reduces the distortion created by the production externality. In contrast, in our framework, as long as $\xi = 0$, the consumption externality does not have a distortionary effect, regardless of the presence of the production externality, and regardless of whether or not g is optimally chosen.

As long as $\xi = 0$ (wealth does not enter the utility function), the concern for relative consumption is non-distortionary. Hence, the optimal tax rates equal zero. However, if $\xi > 0$, the optimal tax rates differ from zero if and only if $\eta_k \neq \eta_c$. In this case, the opposing forces of the consumption- and wealth externalities, which cause an increase in consumption and a corresponding reduction in saving (wealth), do not cancel out. Intuitively, if $\eta_k = \eta_c$, the desire to raise consumption is exactly matched by the desire to increase saving (wealth). In this case, the consumption externalities do not lead to a change in household behavior relative to the social optimum.[12]

To get a flavor of how the optimal values of the income- and consumption taxes are affected by the key behavioral parameters of the model (η_c, η_k, ξ), we calculate $\hat{\tau}_y$ and $\hat{\tau}_c$ based on benchmark parameter values commonly employed in the literature. Preference parameters are assigned the following values: $\beta = 0.04, \gamma = -1.5$. The latter parameter gives rise to an intertemporal elasticity of substitution equal to $1/(1-\gamma) = 0.4$, as suggested by Guvenen (2006). Technology parameters are assigned the following values: $A = 0.6, \alpha = 0.8, \rho = 1, \delta_g = \delta_k = 0.08$. First, following common practice, we use the total factor productivity, A, as a scale parameter to help us obtain plausible values for the growth rate, and a value of 0.6 achieves that. The value of α (which is the output-elasticity of private capital) is set at 0.8, which is plausible if private capital is meant to include human capital, as in Romer (1986). This also implies that the elasticity of public capital is 0.2, which is consistent with the empirical evidence provided by Gramlich (1994). There is not much empirical evidence on the elasticity of substitution between private and public capital (Lynde and Richmond, 1993, provides an exception); $\rho = 1$, which corresponds to this elasticity

[12] It would be interesting to study the effects of redistributive taxation in an economy with heterogeneous (rather than homogeneous) agents, and to check how far the results obtained in this section hold when consumers are heterogeneous in terms of wealth and have positional concerns, but that is the subject of another paper.

being equal to $1/(1+\rho)=0.5$, is one of the values for this parameter chosen by Chatterjee and Ghosh (2011). Finally, the depreciation rates for the private and public capital stocks are each set at 8% in line with Chatterjee and Ghosh (2011).[13]

Based on these benchmark values, we focus on the impact of different values of the key preference parameters (η_c, η_k, ξ) on the optimal tax rates ($\hat{\tau}_c, \hat{\tau}_y$) as well as on the optimal level of government spending, g.

In Table 1, we focus on the following preferred benchmark values for the key behavioral parameters: $(\eta_c, \eta_k, \xi) = (0.3, 0.25, 0.5)$. Empirical evidence supports the chosen values of the strength of positional concerns. Compiling several empirical studies, Wendner and Goulder (2008) find that η_c and η_k are found to fall into the range, $\eta_i \in [0.2, 0.4]$. Other studies find empirical evidence for even larger values of η_i (cf. Johansson-Stenman et al. 2002, Solnick and Hemenway 1998, 2005). Newer empirical studies corroborate this evidence (Alvarez-Cuadrado et al. 2012, Dynan and Ravina 2007). Panel C shows that a rise in ξ has a minor impact on $(\hat{\tau}_c, g)$ and only slightly raises $\hat{\tau}_y$. A more comprehensive sensitivity analysis with respect to ξ reveals the following robust patterns. The optimal consumption tax rate is not affected by ξ, as seen in (26). The impact of the consumption externalities on the optimal income tax becomes stronger with ξ. The impact of ξ on optimal g is small irrespective of (η_c, η_k).[14]

As discussed above, while $\hat{\tau}_c$ increases (decreases) in η_c (in η_k), $\hat{\tau}_y$ increases (decreases) in η_k (in η_c). The table indicates that – depending on the specific parameter constellation (η_c, η_k, ξ) – the corrective tax rates (i) may be either positive or negative; (ii) the magnitudes of the corrective tax rates can be quite substantial.

[13] See also Baxter and King (1993), where the value for the rate of depreciation of the capital stock in the US is chosen at 10%.

[14] These results are not reported but are available from the authors upon request.

Table 1. The optimal levels of $(g, \hat{\tau}_y, \hat{\tau}_c)$ when respectively η_c, η_k and ξ are gradually increased

Panel A. $\eta_k = 0, \xi = 0.5$	$\eta_c = 0$	$\eta_c = 0.1$	$\eta_c = 0.2$	$\eta_c = 0.3$	$\eta_c = 0.4$	$\eta_c = 0.5$
Optimal g	0.1528	0.1572	0.1622	0.1679	0.1745	0.1821
$\hat{\tau}_c$ ($\tau_y = 0$)	0.0000	0.1111	0.2500	0.4286	0.6667	1.0000
$\hat{\tau}_y$ ($\tau_c = 0$)	0.0000	-0.0416	-0.0896	-0.1458	-0.2124	-0.2927
Panel B. $\eta_c = 0, \xi = 0.5$	$\eta_k = 0$	$\eta_k = 0.1$	$\eta_k = 0.2$	$\eta_k = 0.3$	$\eta_k = 0.4$	$\eta_k = 0.5$
Optimal g	0.1528	0.1540	0.1552	0.1564	0.1577	0.1589
$\hat{\tau}_c$ ($\tau_y = 0$)	0.0000	-0.1000	-0.2000	-0.3000	-0.4000	-0.5000
$\hat{\tau}_y$ ($\tau_c = 0$)	0.0000	0.0386	0.0770	0.1152	0.1532	0.1910
Panel C. $\eta_c = 0.3, \eta_k = 0.25$	$\xi = 0$	$\xi = 0.1$	$\xi = 0.2$	$\xi = 0.3$	$\xi = 0.4$	$\xi = 0.5$
Optimal g	0.1841	0.1817	0.1792	0.1768	0.1743	0.1719
$\hat{\tau}_c$ ($\tau_y = 0$)	0.0000	0.0714	0.0714	0.0714	0.0714	0.0714
$\hat{\tau}_y$ ($\tau_c = 0$)	0.0000	-0.0048	-0.0096	-0.0144	-0.0193	-0.0241

NOTE. (c, z, g) are simultaneously derived employing the benchmark parameter values.

4.2 Growth and Welfare along the Balanced Growth Path

The endogenous growth rate along the BGP, Γ (decentralized) together with (c, z) is derived from (14) – (15) in the decentralized framework. Without loss of generality, we consider the baseline income- and consumption tax rates to be zero. We assume that $g = 0.05$.[15] The endogenous growth rate for the social optimum Γ (optimal) together with (c, z, g) is derived from (22) – (24).

In the Appendix, we show that for both, the decentralized as well as the centralized framework, the steady state welfare expression is given by:

[15] The pre-shock value for g is set at 5% also in Chatterjee and Ghosh (2011).

$$W_0 = \frac{c^{\gamma(1-\eta_c)}}{\gamma\left\{\beta - \gamma\Gamma\left[(1-\eta_c)+\xi(1-\eta_k)\right]\right\}} \ . \tag{27}$$

Welfare expression (27) is an implicit function of c and $\Gamma(z)$. Both variables, (c,z), generally differ between the decentralized and centralized economies. Consequently, so do growth rates and welfare. As demonstrated in the Appendix, $\left[\beta - \gamma\Gamma\left((1-\eta_c)+\xi(1-\eta_k)\right)\right] > 0$ is a necessary and sufficient condition for the welfare integral to be bounded.

A rise in η_i impacts upon both, the growth rate Γ and c. As seen in (27), the effects on welfare W_0 are ambiguous. For example, if $\gamma < 0$, a rise in η_c raises both the numerator and the denominator. The sign of the steady state welfare effect then depends on the respective changes in c and Γ.

To gain more insight, we employ numerical simulations (Table 2). Specifically, we gradually raise η_c and η_k respectively, and calculate the associated (decentralized and optimal) growth rates and welfare levels.

As is clear from the table below, implementation of optimal fiscal policy has significant effects on growth and welfare.

For the social optimum, as η_c rises, g rises, but (c,z,y) fall, and growth rises. The fall in c is greater than the fall in y (and there is higher g as well). Looking at it the other way, the rise in g and fall in z more than compensate for the fall in y. Optimal growth and optimal welfare, both rise, following the rise in η_c. Optimal fiscal policy in this case calls for a lower $\hat{\tau}_y$ (which is negative) and a higher $\hat{\tau}_c$ as the value of η_c is raised. So higher η_c results in a lower income tax rate (higher income subsidy in our case) and a higher subsidy on private saving (a higher consumption tax rate), which together with the higher complementary public spending, raises the growth rate, and also improves welfare (because of the growth effect, despite the lower consumption-to-capital ratio).

Table 2. Growth rates (Γ) and welfare (W) along the BGP when η_c and η_k are gradually increased

Panel A. $\eta_k = 0, \xi = 0.5$	$\eta_c = 0$	$\eta_c = 0.1$	$\eta_c = 0.2$	$\eta_c = 0.3$	$\eta_c = 0.4$	$\eta_c = 0.5$
Γ (decentralized)	0.0166	0.0168	0.0171	0.0174	0.0177	0.0180
Γ (optimal)	0.0899	0.0959	0.1028	0.1108	0.1201	0.1311
W (decentralized)	-138.34	-108.92	-85.68	-67.33	-52.87	-41.48
W (optimal)	-24.946	-21.269	-18.089	-15.335	-12.946	-10.866
Panel B. $\eta_c = 0, \xi = 0.5$	$\eta_k = 0$	$\eta_k = 0.1$	$\eta_k = 0.2$	$\eta_k = 0.3$	$\eta_k = 0.4$	$\eta_k = 0.5$
Γ (decentralized)	0.0166	0.0167	0.0168	0.0170	0.0171	0.0172
Γ (optimal)	0.0899	0.0896	0.0894	0.0891	0.0887	0.0883
W (decentralized)	-138.34	-141.09	-143.95	-146.96	-150.11	-153.42
W (optimal)	-24.946	-25.415	-25.913	-26.443	-27.009	-27.614

NOTE. $\tau_c = \tau_y = 0$, $g = 0.05$.

Also, for the social optimum, as η_k rises, *g, c, z, y* rise, and growth falls. The rise in *c* is greater than the rise in *y.* Although *g* and *y* rise, *z* rises more, which leads to growth falling. Optimal growth and optimal welfare both fall, following the rise in η_k. (This contrasts with optimal growth and optimal welfare, both rising, following a rise in η_c.) Optimal fiscal policy in this case calls for a higher $\hat{\tau}_y$ and a lower $\hat{\tau}_c$ (which is negative) as the value of η_k is raised. So, higher η_k results in a higher income tax rate and higher tax on private saving due to a lower consumption tax rate (higher consumption subsidy in our case), which together lead to lower growth, despite the higher public spending. Welfare is also lower (due to the growth effect, despite the higher consumption-to-capital ratio).

At first sight it might seem surprising that in the decentralized economy a rise in η_c is associated with a higher endogenous growth rate. On closer inspection it is possible that households postpone current for future consumption, which boosts saving and provides an impact to the growth rate. This is in fact what happens as is clear from the expression given by (15) where y is only a function of z, and given that g is fixed, the growth rate can also be expressed in terms of $z = K_g / K$ only: $\Gamma = Ag[(1-\alpha)+\alpha z^{\rho}]^{-1/\rho} - \delta_g$. A decline in z raises the growth rate by increasing the marginal productivity of capital (due to the complementarity between public and private capital). As household saving (K) rises, z in fact declines.

While the effects of the consumption externalities on welfare and growth in the social optimum roughly correspond to those in the decentralized economy, Table 2 displays one important difference. Households in the decentralized economy have a tendency to over-accumulate capital corresponding to higher values of η_k (due to their concern for relative wealth). The central planner, in an effort to correct this externality, picks a growth rate that reduces the rate of capital accumulation.

4.3 Link between Optimal Taxation, Growth and Welfare

In Table 1, Panel A, the decentralized income tax rate (which is =0) is above the corrective rate $\hat{\tau}_y$ (which is <0): so the private return on capital falls below its socially optimal return. In this case, a positive tax on consumption helps offset this deviation by raising the private return to capital relative to consumption. Consequently, higher η_c, which implies that $\hat{\tau}_y$ becomes even lower (a larger value in absolute terms) results in even larger divergence between private and social returns, and therefore calls for an even larger value of the consumption tax rate to compensate. This in turn implies a higher growth rate, which has a positive effect on welfare.

In Table 1, Panel B, note that the decentralized income tax rate (=0) is below $\hat{\tau}_y$: so the private return on capital exceeds its social return and a consumption subsidy corrects this deviation by lowering the private return on capital relative to consumption. Consequently, higher η_k results in even larger divergence between private and social returns, and therefore calls for an even larger value of the consumption subsidy to compensate. This also implies that the growth rate falls with η_k, which has a negative effect on welfare.

5. Fiscal Policy Experiments

The panels of Table 3 report the long-run impact of five fiscal policy shocks, PS1 – PS5, on equilibrium growth rates and welfare levels in the decentralized economy. PS1 – PS3 pertain to an increase in g from 5% to 8% of GDP. For PS1 the increase in g is financed by an increase in lump-sum taxes (with $\tau_c = \tau_y = 0$). PS2 considers a simultaneous increase in g and an increase in the income tax rate, τ_y, from zero to 3%. Likewise PS3 considers a simultaneous increase in g and an increase in the consumption tax rate, τ_c, from zero to 3%. The last two policy shocks relate to the replacement of the lump-sum tax as a means of financing the benchmark rate of government spending ($g = 0.05$) by introducing an income tax, $\tau_y = 0.03$ (PS4) and a consumption tax, $\tau_c = 0.03$ (PS5). In our discussion below, we will focus on growth and welfare implications respectively of a gradual increase in η_c, keeping $\eta_k = 0$ (Panel A in Table 3), and a gradual increase in η_k, keeping $\eta_c = 0$ (Panel B in Table 3).

5.1 Long-Run Growth and Welfare Effects of Fiscal Policy

We report the growth- and welfare effects of the five fiscal policy experiments in the table below. In the first two rows of both panels A and B we report the initial (pre-policy) values of the growth rate and welfare. In the policy experiments, we report percentage deviations from those values.

The effects on growth and welfare for PS1 to PS3 are driven by the strong effect of public spending, irrespective of whether or not part of the additional government spending is financed by income- or consumption taxation, which is an important observation. As the table shows, the gradual increase in η_c or η_k does not have a pronounced influence on the magnitude of the growth- and welfare effects. Clearly, the production externality dominates the consumption externalities.

The rise in g strongly positively affects both growth and welfare. The positive impact on growth is evident from the fact that endogenous growth is generated by public spending, which complements private spending. The positive impact on welfare stems from the fact that the pre-policy level of government spending is well below the optimal level, e.g., the optimal level of g equals 0.1528 (see Table 1, Panel A).

For PS4 and PS5, the impact on growth and welfare is rather small, which can immediately be attributed to the fact that in these two policy experiments the production externality from an increase in government spending – which was present for PS1 to PS 3 – is absent.

Table 3. Growth and welfare effects along the BGP for different fiscal policy experiments

Panel A. $\eta_k = 0, \xi = 0.5$	$\eta_c = 0$	$\eta_c = 0.1$	$\eta_c = 0.2$	$\eta_c = 0.3$	$\eta_c = 0.4$	$\eta_c = 0.5$
Pre-policy initial Γ	**0.0166**	**0.0168**	**0.0171**	**0.0174**	**0.0177**	**0.0180**
initial W	**-138.34**	**-108.92**	**-85.68**	**-67.33**	**-52.87**	**-41.48**
PS1 % change in Γ	+178.2	+179.0	+179.9	+180.8	+181.8	+182.8
% change in W	+62.91	+60.71	+58.39	+55.94	+53.34	+50.60
PS2 % change in Γ	+174.4	+175.3	+176.2	+177.1	+178.1	+179.2
% change in W	+63.21	+60.98	+58.63	+56.13	+53.49	+50.69
PS3 % change in Γ	+180.4	+181.2	+182.1	+182.9	+183.9	+184.8
% change in W	+62.72	+60.54	+58.24	+55.82	+53.25	+50.54
PS4 % change in Γ	-1.80	-1.78	-1.77	-1.76	-1.74	-1.72
% change in W	+0.75	+0.64	+0.54	+0.43	+0.31	+0.19
PS5 % change in Γ	+1.46	+1.45	+1.44	+1.42	+1.41	+1.40
% change in W	-0.63	-0.54	-0.45	-0.36	-0.27	-0.17
Panel B. $\eta_c = 0, \xi = 0.5$	$\eta_k = 0$	$\eta_k = 0.1$	$\eta_k = 0.2$	$\eta_k = 0.3$	$\eta_k = 0.4$	$\eta_k = 0.5$
Pre-policy initial Γ	**0.0166**	**0.0167**	**0.0168**	**0.0170**	**0.0171**	**0.0172**
initial W	**-138.34**	**-141.09**	**-143.95**	**-146.96**	**-150.11**	**-153.42**
PS1 % change in Γ	+178.2	+178.6	+179.0	+179.5	+179.9	+180.3
% change in W	+62.91	+62.51	+62.10	+61.66	+61.19	+60.70
PS2 % change in Γ	+174.4	+174.8	+175.3	+175.7	+176.2	+176.6
% change in W	+63.21	+62.83	+62.43	+62.01	+61.56	+61.08
PS3 % change in Γ	+180.4	+180.8	+181.2	+181.6	+182.1	+182.5
% change in W	+62.72	+62.32	+61.90	+61.45	+60.97	+60.46
PS4 % change in Γ	-1.80	-1.79	-1.78	-1.78	-1.77	-1.76
% change in W	+0.75	+0.78	+0.81	+0.84	+0.87	+0.90
PS5 % change in Γ	+1.46	+1.45	+1.45	+1.44	+1.44	+1.43
% change in W	-0.63	-0.66	-0.68	-0.71	-0.73	-0.76

For PS4, the effect on the growth rate is negative, which is intuitive. A higher income tax rate reduces the private rate of return on capital, and there is no complementary increase in public capital spending. Regarding the welfare effect, a rise in the income tax rate to finance the fixed amount of government spending implies a lowering of lump-sum taxes, which can lead to a rise in consumption. Our numerical results show that in this case not only is there a rise in the consumption-capital ratio but this rise also outweighs the negative growth effect resulting from a rise in income taxes leading to a rise in welfare.

For PS5, the effect on the growth rate is positive, which is intuitive. A higher consumption tax rate discourages consumption and raises the relative return on private capital, and thereby encourages saving and boosts growth. Regarding the welfare effect, a rise in the consumption tax directly affects consumption, and tends to reduce it. On the other hand, higher consumption taxes to finance the fixed amount of government spending imply a lowering of lump-sum taxes, which can lead to a rise in consumption. Our numerical results show that in this case, not only is there a fall in the consumption-capital ratio but this fall also outweighs the positive growth effect resulting from a rise in consumption taxes, and this leads to an overall decrease in welfare.

The important policy conclusions stemming from the tables are the following. Even for low degrees of positionality, corrective tax rates are quite large, and they impose substantive effects on both growth rates and welfare. However, the policy prescription depends very much on whether households are more positional with respect to consumption or with respect to wealth. In the former case, corrective fiscal policy calls for a substantive consumption tax together with a low income tax. In the latter, empirically more likely case,, corrective fiscal policy calls for a substantive income tax together with a low consumption tax. Moreover, production externalities via public spending clearly have a strong impact on growth and welfare.

5.2 Transitional Dynamics

Finally, we consider the transitional dynamics of the five policy shocks. Specifically, we consider the transitional paths of (c, z) as well as those of the growth rates (g_K, g_{Kg}, g_C). To solve numerically for the transitional paths, we employ the Mathematica implementation of the *Relaxation Algorithm* (Trimborn et al., 2008).

Figures 1 and 2 contain grids of graphs displaying the transitional effects of PS1 to PS5 on c and z (Figure 1) as well as on the growth rates of C, K, and K_g (Figure 2). Both figures show the results for $\eta_c = \eta_k = 0$. Figure 3 shows the sensitivity of responses to policy shock PS1 with respect to varying degrees of positionality.

Along the transitional paths, we observe three robust patterns.[16] First, for all investigated policy shocks, the transitional paths of (c, z, g_K, g_{Kg}, g_C) are monotone. As the dynamic system of the decentralized economy is characterized by one differential equation of state variable *z* and by one differential equation of jump variable *c*, we essentially expect transitional paths of these variables to be monotone.[17] However, as seen in Figure 2, the sign of initial responses can differ from that of steady state responses (as is the case for the growth rate of capital in PS1 to PS3). Moreover, for some variables, overshooting occurs (as for the growth rate of public capital in PS1 to PS3).

Second, for PS1 to PS3, both *c* and *z* change "strongly" along the transitional path, while for PS4 and PS5 the policy impact on the transitional paths of these variables is small. This behavior becomes clear when considering the steady state effects of the policy shocks on *c* and *z*. As discussed above, the steady state effects of PS4 and PS5 are minor. Also, as the transitional paths are monotone, we conclude that the effects of PS4 and PS5 on the transitional paths of *c* and *z* must be minor as well.

[Figure 1 about here]

Third, focusing on a tax reform with *g* being unchanged, the transitional dynamics (and steady state) effects of PS4 are opposite to those of PS5.

[16] These patterns also occur for all other parameter constellations we simulated. In particular, these patterns also hold true for different values of η_i.

[17] In Carroll et al. (1997), the introduction of consumption externalities leads to the economy approaching its balanced growth equilibrium along a transitional path, this sluggishness in adjustment being caused by the consumption externality (i.e., in spite of the Rebelo-type AK technology that they consider). However, as demonstrated by Alvarez-Cuadrado et al. (2004), the transitional adjustment paths may exhibit non-monotonic behaviour if the production function is neoclassical rather than AK-type. This is because then the transitional dynamics are governed by two opposing forces: one generated by preferences (the status effect) and the other by technology (diminishing returns to capital).

PS4. Consider a rise in τ_y with (g,τ_c) constant. Initially, the net-return on savings declines, and individuals respond with an upwards jump in consumption (thereby c). Initially, z, being a state variable, does not change. The lowering in savings lowers K. Both (K,K_g) still grow at a positive rate. But $g_{Kg} > g_K$ as the former is directly proportional to output, while the latter is reduced by a rising c (cf. (5) and (6)). Consequently, z starts to increase. The rise in z, lowers the rate of interest. Subsequently individuals lower the growth rate of consumption, as seen in the modified Keynes-Ramsey rule (14) due to a still lower net return on savings. As a consequence, private capital starts to accumulate at a rate *higher* than initially, just after the introduction of the policy shock, towards its new steady state level. In the BGP, though g_K is still below its pre-policy level, as discussed in the previous subsection.

PS5. Consider a rise in τ_c with (g,τ_y) constant. Initially, the net-return on saving increases as income is taxed while consumption is not taxed. That is, initially, individuals respond with a downward jump in consumption (thereby c). The initial rise in savings increases the growth rate of private capital (initial upwards jump). As the growth rate of public capital is initially fixed (cf. (5)), $g_{Kg} < g_K$, and z starts to decline. Thus, the rate of interest rises, and so does the growth rate of consumption, due to (14). As a consequence, the growth rate of private capital declines towards its new steady state level. Both, along the transitional path and in the new BGP, g_K is above its pre-policy level. As a consequence, Y increases and the growth rate of public capital rises towards its new BGP-level. In the post-policy BGP, the endogenous growth rate is higher than in the pre-policy BGP (see previous subsection).

The transitional effects of the policy shocks on the growth rates (as discussed above) are shown in Figure 2. Along the transitional paths (K,K_g,C) grow at *differing* rates.

[Figure 2 about here]

The final figure represents the sensitivity of the responses to policy shock PS1 with respect to different degrees of positionality.[18] The main insight from Figure 3 is that the basic transition

[18] Numerical simulations of the other policy shocks show similar patterns.

patterns are robust with respect to different values of η_i. However, the same does not apply for levels.

[Figure 3 about here]

As seen in Figure 3, the (steady state) response of c depends strongly on the respective degrees of positionality. PS1 roughly raises c from 0.16 to 0.20 (in steady state, without positional preferences), and from 0.16 to 0.18 with $\eta_c = 0.3$ and $\eta_k = 0.25$. That is, the presence of positional preferences takes away almost 50% of the response to PS1. A lesson to take with us from this is that positional preferences (substantially) lower the behavioral responses to policy shocks.

Two observations are worth mentioning. First, any one of the externalities requires substantive corrective tax rates, even for low values of η_i. Second, positional preferences with respect to wealth or consumption counteract each other. One type of positional preference lowers the distortion imposed by the other. In terms of Proposition 3, if $\eta_c = \eta_k$, positional preferences do not cause any distortion, and the optimal tax rates are both equal to zero.

6. Conclusions

This paper contributes to the literature on positional preferences by introducing conspicuous wealth in the agent's utility function, in addition to conspicuous consumption. And it does so within an endogenous growth set-up where the engine of growth is public capital. Production externalities have been captured extensively in much of the growth literature, but the same cannot be said about consumption externalities. And even when the latter have been considered, the reference level has mostly been conspicuous consumption rather than wealth. Our paper attempts to plug this gap, given that one objective in foregoing current consumption and accumulating capital, which increases wealth, is that this in itself adds to agents' utility. Also, in the process of enhancing wealth, individual wealth relative to the average is considered as an argument in the utility function.

In the paper we demonstrate that if wealth is present in the consumer's utility function, then – despite labor supply being inelastic – the consumption externality does have a distortionary effect, irrespective of the production externality. This modifies the previous results from endogenous growth models where, with inelastic labor supply, such distortionary effects are obtained only with production externalities. Interestingly, in our framework, if wealth is not present in the consumer's utility function, this distortion disappears. In some sense, this result resembles those in models with conspicuous consumption (but not wealth), where there are no distortions; however, such models are typically neoclassical rather than endogenous growth models. While the effects of consumption externalities on growth and welfare in the decentralized economy broadly correspond to those in the social optimum, the effect of wealth externalities is to cause over-accumulation of capital by households in the decentralized economy. Here the social planner, in an effort to correct this externality, picks a growth rate that reduces the rate of capital accumulation to optimal levels. We also conduct some fiscal policy experiments where our results demonstrate that where an increase in public spending occurs, this positively and strongly affects both growth and welfare in the steady state and along the transition path: here the production externality clearly dominates the consumption externalities.

A number of important policy conclusions emerge from our findings, which are worth emphasizing. First, policymakers should acknowledge the importance of wealth (per se and also conspicuous wealth) in affecting utility, and implement corrective taxation recognizing this aspect of preferences. Second, the simultaneous use of income and consumption tax/subsidy instruments as policy tools when preferences are positional is important. Thus, if households are more positional with respect to wealth (consumption), then income (consumption) should be taxed for corrective reasons. Finally, if there are externalities in production, in addition to consumption and wealth externalities, then public spending should be encouraged as it impacts on growth and welfare in a decisive way.

We have performed our analysis in the context of a closed economy, following much of the literature. Our paper could be extended to an open economy context – either a small open economy that has to take the world interest rate as given, or a large economy where economic policies would determine the domestic interest rate – where consumption and wealth externalities could be generated not only at home but also abroad. This would add an interesting new dimension to the growth and welfare analysis that we have conducted thus far, and make our analysis richer. To our knowledge, there have not yet been many studies that proceed in this direction: Fisher and Hof (2005) provides an attempt.

Also, the standard growth models typically consider a constant rate of time preference, but recently a "preference-driven theory of economic growth" has been proposed by Strulik (2012), among others, where the rate of impatience varies negatively with wealth, i.e., as wealth increases, individuals tend to become more patient. Given that in our existing set-up, the inclusion of wealth and conspicuous wealth in the utility function makes a significant difference to the workings of the baseline model (where positional preferences are defined with respect to consumption alone), the introduction of wealth-driven time preference will surely introduce another interesting element in the determination of growth and welfare.

Finally, we have in our paper devised appropriate income- and consumption-taxes (under perfect information) to correct distortions. If, instead, we considered agents that were status-conscious but heterogeneous, then one could work out the optimal redistributive taxes for such an economy (see, for example, Mirrlees (1971)). One source of heterogeneity could be the ability level (i.e., the presence of low- and high-ability households), in which case one needs to take into account asymmetric information regarding the ability level. In the context of our model, another source of heterogeneity might be different levels of wealth or different (positional/non-positional) preferences for wealth.

We have made some progress in pursuing research in all these directions, but that would obviously be the subject of other papers and beyond the scope of the current one.

Appendix

Proof of Proposition 1. *Part (1).* From differential equations (14) and (15), the steady state values (c, z) cannot be explicitly derived. However, at $\dot{c} = \dot{z} = 0$, both differential equations can be analytically solved for c as a function of z. Let $cc(z)$ denote this solution associated with (14) and $cz(z)$ denote the solution associated with (15). Furthermore, let $\Delta(z) \equiv cc(z) - cz(z)$. Obviously, at a steady state $\Delta(z) = 0$. We first note that

$$\Delta'(z) = -\frac{B1\left(B2 + z(1-\alpha)\left(A^{\rho}(1-g)\xi + \alpha\left(A\left(z^{-\rho}(1-\alpha)+\alpha\right)^{-1/\rho}\right)^{\rho}(1+\rho)\right)\right)}{z^{2}\left(1+\left(-1+z^{\rho}\right)\alpha\right)\left(1+\xi+\gamma\left(-1+\eta_{c}+\left(-1+\eta_{k}\right)\xi\right)\right)} < 0,$$

$$B1 \equiv A^{1-\rho}\left(z^{-\rho}(1-\alpha)+\alpha\right)^{-1/\rho} > 0, \tag{28}$$

$$B2 \equiv A^{\rho} g z^{\rho}\alpha\left(1+\xi+\gamma\left(-1+\eta_{c}+\left(-1+\eta_{k}\right)\xi\right)\right) > 0.$$

That is, the slope of $\Delta(z)$ is *strictly* negative. As a consequence, a steady state, if it exists, is unique. We now argue that $\Delta(0) > 0$ and $\Delta(1) < 0$. Then, by the Intermediate value theorem (and by strict monotonicity), there exists a unique, strictly positive $z \in (0,1)$ for which $\Delta(z) = 0$. Furthermore,

$$\Delta(0) = \underbrace{\left(1+\xi-\gamma\left(1-\eta_{c}+\left(1-\eta_{k}\right)\xi\right)\right)}_{\geq 0}\underbrace{\left(Ag-\delta g(1-\alpha)^{\frac{1}{\rho}}\right)}_{>0\,\text{by}\,(\text{A}.2)} + \underbrace{(1-\alpha)^{\frac{1}{\rho}}\left(\beta+\delta_{k}(1+\xi)\right)}_{>0} > 0,$$

$$\Delta(1) = -\underbrace{\left(\alpha A-\delta_{k}-\beta\right)}_{>0\,\text{by}\,(\text{A}.1)} - \underbrace{\xi\left(A(1-g)-\delta_{k}\right)}_{\geq 0} - \underbrace{\left(1+\xi+\gamma\left(-1+\eta_{c}+\left(-1+\eta_{k}\right)\xi\right)\right)}_{\geq 0}\underbrace{\left(\delta_{g}-Ag\right)}_{\geq 0\,\text{by}\,(\text{A}.2)} < 0$$

As can easily be seen, (A.1) and (A2) imply $\Delta(0) > 0$ and $\Delta(1) < 0$.

Part (2). The determinant of the Jacobian matrix, evaluated at the steady state, is unambiguously negative:

$$-\frac{B3\left(B2 + z(1-\alpha)\left(A^{\rho}(1-g)\xi + \alpha\left(A\left(z^{-\rho}(1-\alpha)+\alpha\right)^{-1/\rho}\right)^{\rho}(1+\rho)\right)\right)}{z\left(1+\left(-1+z^{\rho}\right)\alpha\right)\left(1-\gamma\left(1-\eta_{c}\right)\right)} < 0,$$

$$B3 \equiv A^{1-\rho}c\left(z^{-\rho}(1-\alpha)+\alpha\right)^{-1/\rho} > 0.$$

Therefore one eigenvalue is positive and the other eigenvalue of the dynamic system is negative. As we have one predetermined variable, z, and one jump variable, c, the steady state is a saddle point and saddle path stable.

Proof of Proposition 2. As

$$\Gamma = g\,y/z - \delta_{g} = gA\left[\alpha z^{\rho} + (1-\alpha)\right]^{-1/\rho} - \delta_{g},$$

the endogenous growth rate *negatively* depends on z: $\Gamma(\underset{(-)}{z})$. In what follows, we graphically analyze the impact of a rise of η_i on the steady state value of *z*. Specifically, we consider the $cc(z)$ - and $cz(z)$ -loci (as defined in the proof of Proposition 1) in (z,c)-plane.

$$cz(z) = (1-g)y - g(y/z) + (\delta_g - \delta_k),$$
$$cz(0) = -\left[Ag(1-\alpha)^{-1/\rho} - \delta_g \right] - \delta_k < 0,$$
$$cz(1) = \left[A(1-g) - \delta_k \right] - (Ag - \delta_g) > 0.$$

$cz(0)$ is strictly negative ($cz(1)$ is strictly positive) by Assumption (A.2). As y is increasing in z, and (y/z) is decreasing in z, the slope of the $cz(z)$-locus is strictly positive in (z,c)-plane. Notice that the $cz(z)$-locus is independent of the preference parameters η_i.

The $cc(z)$-locus is given by

$$cc(z;\eta_c,\eta_k) = \underbrace{\left[(1-g)y - \delta_k\right]}_{\geq 0} E_1(\eta_c,\eta_k) + \underbrace{\left[(1-\tau_y)Y_K - \delta_k - \beta\right]}_{>0 \text{ by(A.1)}} E_2(\eta_c,\eta_k),$$

$$E_1(\eta_c,\eta_k) = \frac{\xi\gamma(1-\eta_k) - 1 + \gamma(1-\eta_c)}{\xi\gamma(1-\eta_k) - 1 + \gamma(1-\eta_c) - \xi(1+\tau_c)},$$

$$E_2(\eta_c,\eta_k) = \frac{1}{\xi\gamma(1-\eta_k) - 1 + \gamma(1-\eta_c) - \xi(1+\tau_c)},$$

where the auxiliary terms E_1 and E_2 depend only on parameters. For $z = 0$, $cc(0;\eta_c,\eta_k) > cz(0)$, as shown in the proof of Proposition 1. That is, at the unique steady state, the $cc(z)$- locus crosses the $cz(z)$-locus from above. In other words, at the unique steady state, the (positive or negative) slope of the $cc(z)$- locus is lower than the (positive) slope of the $cz(z)$-locus in (z,c)-plane.

For *any given* z, a rise in η_i lowers (raises) E_j, $j = 1,2$ if $\gamma < 0$ (if $\gamma > 0$). That is,

$$\operatorname{sgn}\frac{\partial E_j}{\partial \eta_i} = \operatorname{sgn}\gamma,\ i \in \{c,k\},\ j \in \{1,2\}.$$

If $\gamma < 0$, which is overwhelmingly suggested by empirical evidence, a rise in η_i makes the $cc(z)$-locus shift downwards. As a consequence, the steady state value of z decreases. As $\Gamma(\underset{(-)}{z})$, the endogenous growth rate increases as of a rise in η_i.

Welfare. Regardless of whether we consider a decentralized economy or a centralized framework, along a BGP (where c is constant and K grows at the constant rate Γ), welfare is given by:

$$W_0 = \int_0^\infty \frac{1}{\gamma}\left[C^{1-\eta_c} K^{\xi(1-\eta_k)}\right]^\gamma e^{-\beta t} dt = \frac{1}{\gamma}\int_0^\infty C^{(1-\eta_c)\gamma} K^{\gamma\xi(1-\eta_k)} e^{-\beta t} dt = \frac{1}{\gamma}\int_0^\infty c^{(1-\eta_c)\gamma} K^{(1-\eta_c)\gamma+\gamma\xi(1-\eta_k)} e^{-\beta t} dt$$

$$= \frac{c^{(1-\eta_c)\gamma}}{\gamma}\int_0^\infty K^{(1-\eta_c)\gamma+\gamma\xi(1-\eta_k)} e^{-\beta t} dt = \frac{c^{(1-\eta_c)\gamma}}{\gamma}\int_0^\infty K_0^{(1-\eta_c)\gamma+\gamma\xi(1-\eta_k)} e^{\left[(1-\eta_c)\gamma+\gamma\xi(1-\eta_k)\right]\Gamma t} e^{-\beta t} dt$$

$$= \frac{K_0^{(1-\eta_c)\gamma+\gamma\xi(1-\eta_k)} c^{(1-\eta_c)\gamma}}{\gamma}\int_0^\infty e^{-\left[\beta-\gamma\Gamma\left((1-\eta_c)+\xi(1-\eta_k)\right)\right]t} dt = \frac{c^{(1-\eta_c)\gamma}}{\gamma}\int_0^\infty e^{-\left[\beta-\gamma\Gamma\left((1-\eta_c)+\xi(1-\eta_k)\right)\right]t} dt,$$

where the last line follows from the initial condition $K_0 = 1$. This expression is defined only if $\left[\beta-\gamma\Gamma\left((1-\eta_c)+\xi(1-\eta_k)\right)\right] > 0$. Noting (10), this inequality is equivalent with the transversality condition, $\lim_{t\to\infty} \lambda_t K_t e^{-\beta t} = 0$. As the transversality condition is required to hold at a solution to the optimization problem, we find the welfare expression

$$W_0 = \frac{c^{(1-\eta_c)\gamma}}{\gamma\left[\beta-\gamma\Gamma\left((1-\eta_c)+\xi(1-\eta_k)\right)\right]},$$

where c and $\Gamma(z)$ are implicitly given.

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FIGURE 1. Transitional dynamics under the policy shocks PS1 to PS5.

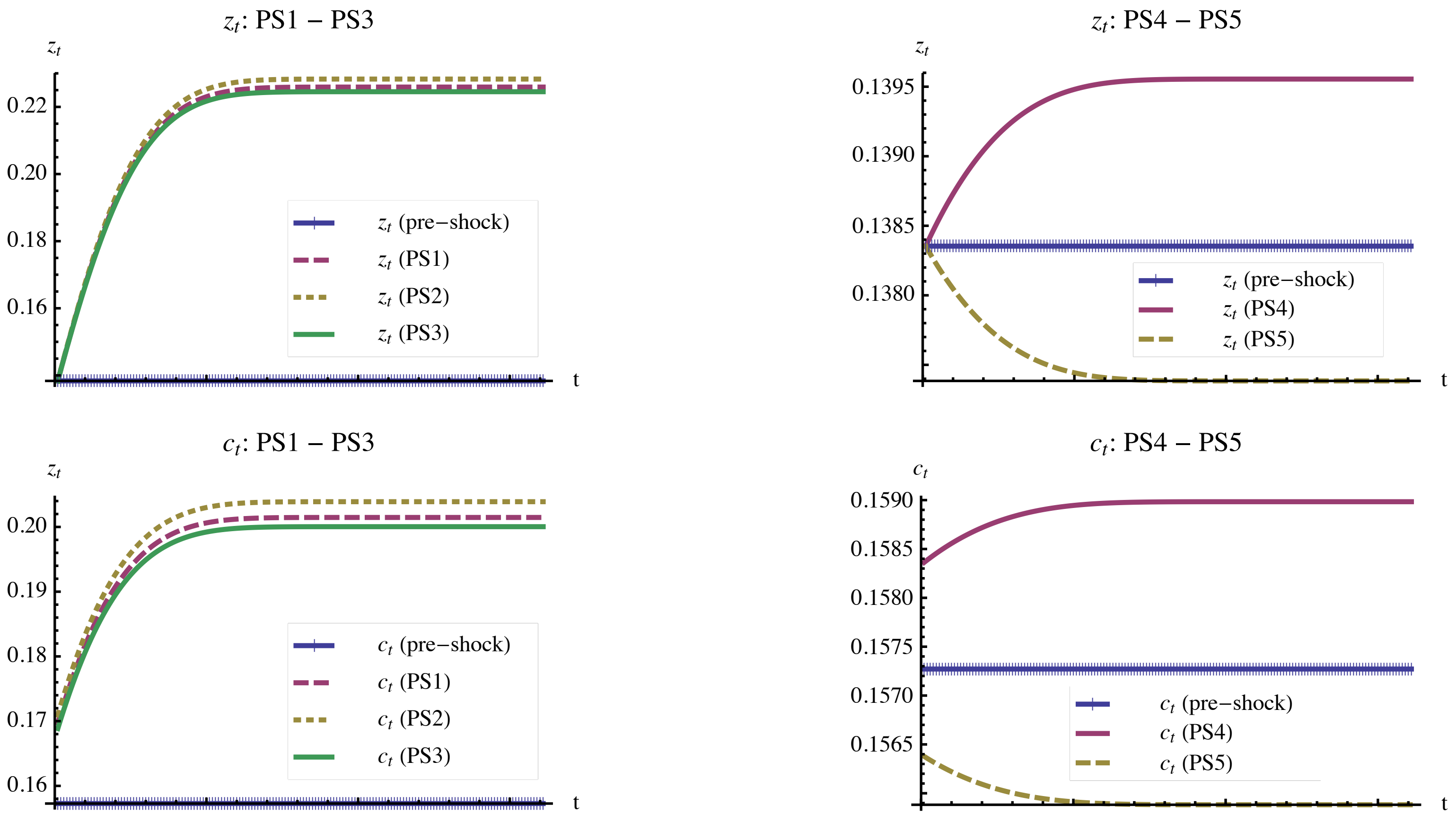

FIGURE 2. Transitional dynamics.

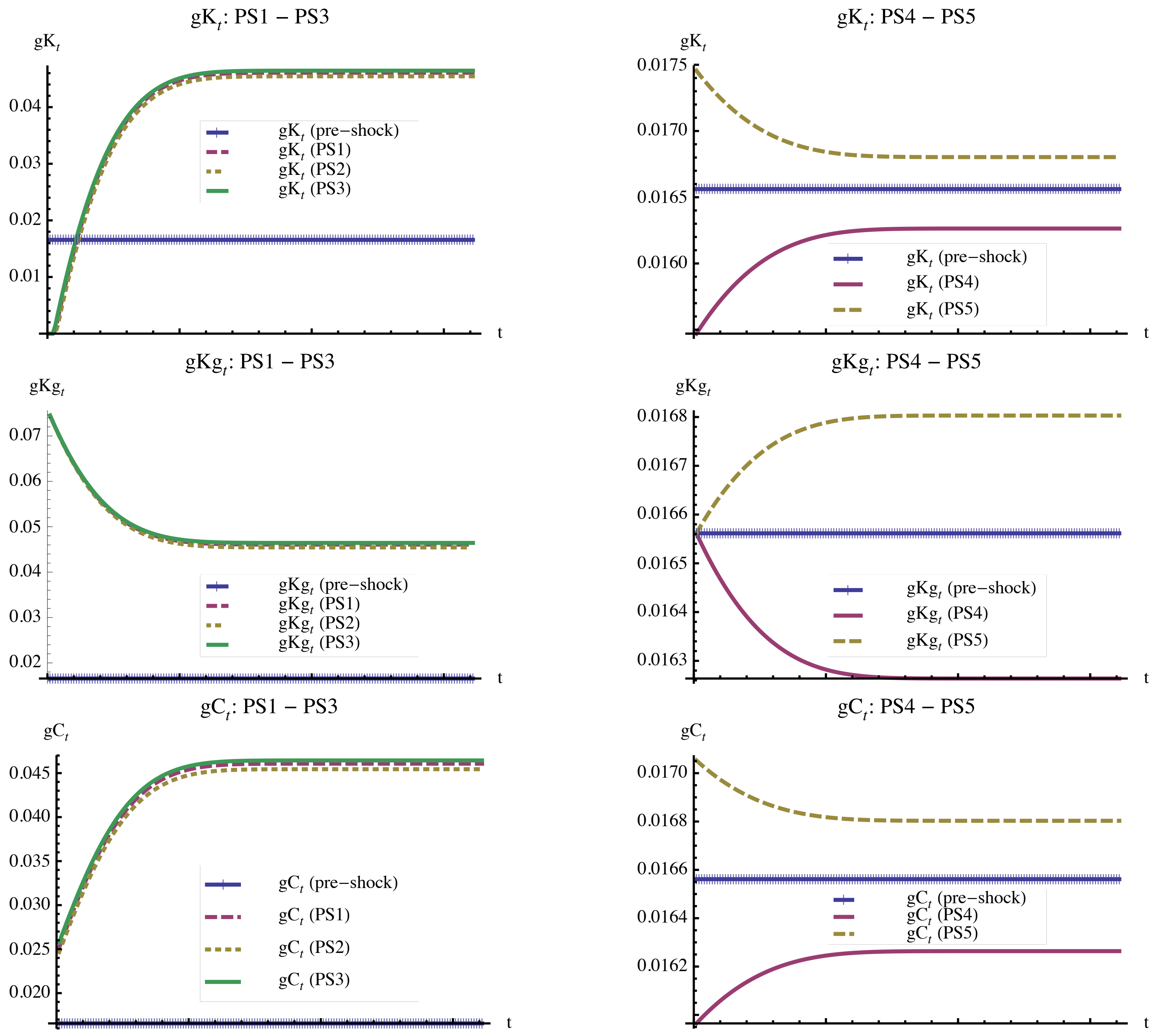

FIGURE 3. Transitional dynamics under PS1
for varying degrees of positionality.