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Consumption aspirations in dirty and clean goods and economic growth

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ABSTRACT

This paper builds a two-sector, two-factor environmental model in which agents optimally choose the clean and dirty goods in order to display their social status. In contrast to the conventional notion, we show that greater social aspirations in consumption regardless of either clean or dirty goods have an ambiguous impact on growth, depending on whether the production of conspicuous goods is relatively labor- or capital-intensive, whether the production of conspicuous goods generates more or fewer emissions, and whether labor supply is or is not responsive to social status seeking. By connecting two conflicting aspects of consumer preference involving social aspirations and environmental concerns, our analysis offers a novel explanation for the environmental Kuznets curve and a theoretical support for the empirical possibility of a negative employment-growth relationship and the so-called Green New Deal. Our welfare analysis shows that social comparisons in consumption may increase, rather than decrease, social welfare. The Pigovian tax may only be socially *sub-optimal* in the two-sector economy because it is unable to completely correct the distortion caused by consumption externalities.

1. Introduction

This paper analyzes the impact of the desire to keep up with the Joneses on growth. There has been strong empirical evidence that interpersonal comparisons deeply influence human behavior and have crucial consequences for economic development. Frank (1985, 1997) explores the biological and psychological basis of preferences and shows that human behavior is irreducibly driven by the subjective perception of social status on the basis of interpersonal comparisons. Households are motivated in part by attempts to establish enhanced social rank through conspicuous consumption (Veblen, 1899). Status seeking represents an additional motive for acquiring goods beyond the purely physical benefit that consumption actually provides (Cole et al., 1992; Bakshi and Chen, 1996). In the macroeconomics literature, this concept of interpersonal comparisons refers to the keeping-up-with-the-Joneses preference, indicating that households derive utility from the comparison between current own consumption and the average per capita consumption level.[1] The importance of status-motivated consumption (or consumption externalities) has not only been repeatedly emphasized, but the implications have also been widely studied in many contexts.[2]

This paper make a subtle theoretical connection regarding (i) two conflicting aspects of consumer preference involving social aspirations and environmental concerns and (ii) the relative magnitude of the capital intensity in the production technology for the good that pollutes the environment (the dirty good) and the good that does not (the clean good). As for point (i), Brekke and Howarth (2000), Brekke et al. (2003), and Wendner (2003) have pointed out that consumption-based social status seeking induces not only excessive consumption, but also environmental degradation that calls for the Pigovian tax. As for point (ii), technology evolution shows that those who survive over time discover a more capital intensive technology to produce cleaner goods.

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[1] Recent studies (e.g., Luttmer, 2005) have empirically shown that individual utility crucially depends on others' consumption.

[2] Consumption externalities have provided a possible explanation for the equity premium puzzle (Abel, 1990; Galí, 1994; Campbell and Cochrane, 1999), and have included explorations of the patterns of growth (Carroll et al., 1997, 2000; Alonso-Carrera et al., 2004; Turnovsky and Monteiro, 2007), the properties of the business cycle (Lettau and Uhlig, 2000), and the effects of optimal tax policies (Ljungqvist and Uhlig, 2000; Chang et al., 2012), as well as the consequences of inefficient allocation (Fisher and Hof, 2000, Dupor and Liu, 2003, and Alonso-Carrera et al., 2004, 2005).

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Based on the model features, we show that, in sharp contrast to the conventional wisdom, keeping up with the Joneses can decrease, rather than increase, growth as consumer preference is involved social aspirations and environmental concerns. Of importance, our results potentially offer a novel explanation for the environmental Kuznets curve and provide a theoretical support for the so-called Green New Deal that has been proposed after the 2008 financial crisis.

The conventional wisdom indicates that conspicuous consumption is subject to status seeking via interpersonal competition, resulting in equilibrium overconsumption. In order to keep up with others' consumption levels, households work harder which enhances economic growth (see Carroll et al., 1997; Liu and Turnovsky, 2005). Tournemaine and Tsoukis (2008) show that greater social aspirations in consumption make people more impatient, which is unfavorable to capital accumulation. The intertemporal preferences effect may decrease, rather than increase, growth. In an overlapping-generations model with *AK* technology and gradual retirement, Wendner (2010) also indicates that keeping up with the Joneses may decrease growth, if the retirement rate is low and wealth increases with age. This paper raises a different mechanism which leads to a negative relationship between economic growth and the desire to keep up with the Joneses. A tendency toward conspicuous consumption may be unfavorable to economic growth, if the public is concerned with environmental quality and has access to both dirty and clean goods. Most studies on consumption externalities ignore the possible interaction between status-directed consumption and environmental issues.

The model we build allows households to optimally choose the clean- and dirty-goods in order to balance the concern for social status and environmental quality. Distinguishing between two goods enables us to differentiate the consequences of *commodity-specific consumption externalities*. In the balanced-growth path (BGP) equilibrium, this optimal choice gives rise to a "sectoral allocation effect," which may lead growth to negatively respond to social aspirations in consumption. In this paper, we deal with a generalized scenario. Conspicuous goods can be dirty goods produced by either a relatively capital-intensive technology, e.g., luxury cars, diamonds, and gold jewelry, or a relatively labor-intensive technology, e.g., leather products, wood except furniture, and bio-based plastics. Conspicuous goods can also be clean goods produced by either a relatively capital-intensive technology, e.g.,tobacco, food, and beverages, or a relatively labor-intensive one, e.g., fashion designer clothes, wristwatches, China pottery, and works of art. Given that the consumption of both the dirty and clean goods is subject to interpersonal influences, we find that consumption-based social comparisons have quite different impacts on the economy, being crucially related to the factor intensity ranking between the dirty and clean sectors. The impacts of greater social aspirations in the consumption of clean goods are also very different from those in the consumption of dirty goods.

Our analysis suggests that greater social aspirations in consumption regardless of either clean or dirty goods can lead to a deterioration in economic growth, provided that the conspicuous goods are relatively labor-intensive. This result is in contrast to the conventional notion, such as in Dupor and Liu (2003) and Turnovsky and Monteiro (2007). More interestingly, we find that if the production of dirty goods (such as petrol-powered cars and plastic bag) is more capital intensive than their cleaner substitutes (such as electric cars and biodegradable bags), a greater aspiration for those dirty goods increases both growth and pollution. In contrast, if the production of their cleaner substitutes is more capital intensive, a greater aspiration for those cleaner goods increases growth but decreases pollution. Causal evidence shows that through the process of economic development, technology and culture evolves in a way such that those who survive over time discover a more capital intensive technology to produce cleaner goods and the natural selection leads to a greater social desire toward cleaner goods in the culture that survives. With the observations, our results potentially offer a new explanation for the environmental Kuznets curve which refers to an inverted-U relationship between pollution and economic development (see Section 3 for more details).

In addition, due to the sectoral allocation effect, the equilibrium employment may negatively respond to more intensive social comparisons, if households display their social status by purchasing dirty goods, which are labor-intensive. In this case, our results provide theoretical support to the empirical findings of Saint-Paul (1991), Aghion and Howitt (1992) and Gordon (1997), who refer to an empirical possibility of a negative employment-growth relationship.

Moreover, we find that a pollution tax does not necessarily harm economic growth. A pollution tax may favor economic growth if the production of the clean good is relatively capital-intensive and social comparisons in the clean-good consumption are more intensive. In response to a higher tax on the production of the dirty good, the economic resources will shift from the dirty sector to the clean sector. If the production of clean goods is more capital-intensive, the sectoral reallocation from the dirty sector to the clean sector will increase the aggregate capital stock. Once this sectoral reallocation becomes substantially strong, a pollution tax can enhance, rather than retard, economic growth. This positive growth effect is more likely to be true when agents more aggressively exhibit their social status by the clean-good consumption. Social comparisons in the clean-good consumption increase the demand for clean goods and hence the induced capital demand in the clean-good sector. This amplifies the sectoral reallocation effect, and as a result, raises the balanced-growth rate. This result somehow echoes the Green New Deal. The Green New Deal attempts to not only revive the economy but also promote sustainable growth and reduce ecosystem degradation. As indicated by the London Summit – Leaders' Statement in 2009, "we will make the transition towards clean, innovative, resource efficient, low carbon technologies and infrastructure." Many countries (e.g., China, the United States, and the European Union) have proposed a low carbon strategy, including environmental tax reform in removing environmentally perverse subsidies. It is expected that cancelling the subsidies would on their own reduce greenhouse gas emissions globally by as much as 6% and add 0.1% to world GDP (see Barbier, 2009, p. 10).

2. The model

The economy consists of households, firms and a government. Households maximize their lifetime utility, firms maximize their profits, and the government levies the pollution (emission) tax and balances its budget by lump-sum transfers.

2.1. Households

There are two types of commodities. One is the dirty good, y_1, which may be either consumed or accumulated as capital stock. The other is the clean good, y_2, which is consumed only.[3] In practice, clean goods are usually consumption goods, while dirty goods are more likely to be kinds of investment goods which create more pollution in their production process (Comolli, 1977). The household is not only concerned with its own consumption (c_1 for the dirty-good consumption and c_2 for the clean-good consumption), but also cares about its consumption relative to the benchmark level, measured by the contemporaneous level of aggregate consumption ($\bar{c}_1$ for the dirty good and $\bar{c}_2$ for the clean good). In addition to the utility from consumption, the household incurs disutility from work h and the damage from pollution Z generated from the production of dirty goods. Both consumption comparisons

[3] Such a model setting of commodity asymmetry is not only common in the literature, but is also more realistic. For a similar model setting, one can refer to the literature on economic development (e.g., Echevarria, 1997; Cao and Birchenall, 2013), real business cycles (e.g., Barsky et al., 2007; Sudo, 2012), and international economics (e.g., Razin, 1984; van Wincoop, 1993).

($\bar{c}_1$ and $\bar{c}_2$) and pollution are externalities, which are taken as given by all households. Nonetheless, the intra-household externality and environmental pollution are endogenously determined in the model; both influence an individual household's behavior.

Specifically, we assume that the household's instantaneous utility is additively separable and follows the following function:

$$U = \ln(c_1 - \phi_1\bar{c}_1) + \Lambda_c \ln(c_2 - \phi_2\bar{c}_2) - \Lambda_Z \ln Z - \Lambda_h \frac{h^{1+\theta}}{1+\theta};$$
$$\phi_1, \phi_2, \Lambda_c, \Lambda_Z, \Lambda_h, \theta > 0. \tag{1}$$

Per the taxonomy of Dupor and Liu (2003, p. 424), the utility function (1) possesses the feature of "keeping up with the Joneses." The strength of consumption-based social comparisons is bounded by the restrictions $\phi_1 < 1$ and $\phi_2 < 1$ such that the household's utility is monotonically increasing with consumption in a symmetric equilibrium. By normalizing the preference weight of the dirty-good consumption to unity, Λ_c is defined as the preference weight of the clean-good consumption, Λ_Z is that of the environment (pollution), and Λ_h is that of leisure (labor), relative to the dirty-good consumption. The term θ is the inverse Frisch elasticity of labor supply. The utility function (1) is logarithmic with respect to consumption and pollution, which yields a BGP equilibrium and is isoelastic with respect to labor hours, which allows us to highlight the importance of the employment effect of keeping up with the Joneses.[4]

Define $p(=\frac{p_2}{p_1})$ as the relative price of the clean good to the dirty good, where p_1 and p_2 are the prices of the dirty and clean goods, respectively. By taking the market prices (the capital rental rate r, the real wage rate w, and the relative price p) and externalities ($\bar{c}_1$, $\bar{c}_2$, and Z) as given, the household chooses consumption (c_1 and c_2), hours worked (h), and capital (k), so as to maximize its discounted sum of future utilities. Given a fixed time preference rate ρ, the household's optimization problem can be expressed as:

$$\max \int_0^\infty U \cdot e^{-\rho t} dt,$$
$$s.t. \quad \dot{k} = wh + rk + T - (c_1 + pc_2). \tag{2}$$

Equation (2) is the budget constraint linking capital accumulation ($\dot{k}$) to the difference between disposable income (capital and labor incomes $wh + rk$ and lump sum transfers from the government T) and expenditure (consumption $c_1 + pc_2$). Accordingly, the first-order conditions of this optimization problem are satisfied by:

$$\frac{\frac{\Lambda_c}{c_2-\phi_2\bar{c}_2}}{\frac{1}{c_1-\phi_1\bar{c}_1}} = p, \tag{3}$$

$$\Lambda_h h^\theta (c_1 - \phi_1\bar{c}_1) = w, \tag{4}$$

$$\frac{\dot{\lambda}}{\lambda} = \rho - r, \tag{5}$$

where λ is the shadow value of capital. Equation (3) indicates that the marginal rate of substitution (MRS) between the clean and dirty goods is equal to its relative price. This implies that given the relative price p, greater social aspirations in the dirty-good (clean-good) consumption ϕ_1 (ϕ_2) increase (decrease) the MRS between the clean and dirty goods, inducing the household to demand more dirty (clean) goods. Equation (4) indicates that the *MRS* between consumption and leisure is equal to the wage rate. This implies that, given the wage rate w, greater social aspirations in the dirty-good consumption ϕ_1 increase the marginal utility of c_1, which leads the household to substitute more consumption (in c_1) for leisure and results in a higher labor supply h. Equation (5) is the standard Euler equation of capital.

[4] This utility function with a separable ln$Z$, on the one hand, leads the utility to be bounded and, on the other hand, yields the common growth rate for consumption and pollution.

2.2. Firms

In the dirty and clean industries, goods are produced according to the following Cobb-Douglas technologies, respectively:

$$y_1 = \widetilde{A}_1 (uk)^{\alpha_1} (sh)^{1-\alpha_1};\ 0 < \alpha_1 < 1, \tag{6}$$

$$y_2 = \widetilde{A}_2 \left[(1-u)k\right]^{\alpha_2} \left[(1-s)h\right]^{1-\alpha_2};\ 0 < \alpha_2 < 1, \tag{7}$$

where k is the capital stock, h is the labor input, u $(1 - u)$ is the fraction of capital used in the dirty- (clean-) good sector, and s $(1 - s)$ is the fraction of labor used in the dirty- (clean-) good sector. In each sector, $\widetilde{A}_1$ ($\widetilde{A}_2$) is knowledge externalities in the production, measured by the average stock of capital $\bar{k}$, and is available to all producers (firms). In line with Romer (1986), production is implicitly augmented by the accumulation of human capital which is formulated as a process of learning by doing. Accordingly, knowledge grows proportionally to, and as a by-product of, cumulative private investments in capital. Thus, to ensure sustained growth, we specify the production externalities $\widetilde{A}_1 = A_1\bar{k}^{1-\alpha_1}$ for the dirty-good sector and $\widetilde{A}_2 = A_2\bar{k}^{1-\alpha_2}$ for the clean-good sector. The existence and importance of the economy-wide production externalities have been highlighted by the theoretical studies of Benhabib and Farmer (1994) and by the empirical studies of Basu and Fernald (1997).

There is a by-product – pollution, denoted by Z – in the production process of the dirty good. For simplicity, the pollution quantity (emission) is assumed to be proportional to the output level of the dirty good y_1, i.e.,[5]

$$Z = \beta y_1;\ 0 < \beta < 1, \tag{8}$$

where β is a constant unit emission coefficient (emissions per unit of output).[6] Z is subject to a pollution tax at the rate τ_e. For simplicity, we assume that clean goods do not generate any pollution, as in Bovenberg and de Mooij (1994). Nonetheless, in Appendix A we have shown that our main results still hold even though the production of clean goods generates pollution but the pollution parameter is substantially lower than that of dirty goods.

There is a continuum of identical firms that operate in a perfectly competitive market. By taking the market prices (r, w, and p) and taxation (the emission tax rate τ_e) as given, the firm's optimization problem is to choose capital k and labor h so as to maximize its profits. The corresponding first-order conditions for this maximization problem are:

$$r = (1-\tau_e\beta)\alpha_1\widetilde{A}_1(uk)^{\alpha_1-1}(sh)^{1-\alpha_1}$$
$$= p\alpha_2\widetilde{A}_2\left[(1-u)k\right]^{\alpha_2-1}\left[(1-s)h\right]^{1-\alpha_2}, \tag{9}$$

$$w = (1-\tau_e\beta)(1-\alpha_1)\widetilde{A}_1(uk)^{\alpha_1}(sh)^{-\alpha_1}$$
$$= p(1-\alpha_2)\widetilde{A}_2\left[(1-u)k\right]^{\alpha_2}\left[(1-s)h\right]^{-\alpha_2}. \tag{10}$$

The "factor price equalization" theorem indicates that given that capital and labor are perfectly mobile across the two sectors, the factor prices (the rental and wage rates) must be the same in equilibrium. Thus, (16) and (17), as we will see later, allow us to determine the endogenous capital u and labor allocation s between the dirty-good and clean-good sectors.

[5] In our model, emissions are modeled as a by-product of output, rather than a polluting input. Copeland and Taylor (2003) show that these two model settings are very similar under reasonable conditions. We are grateful to an anonymous referee for bringing this point to our attention.

[6] To focus on our point, we introduce pollution into the model in a simple way, while the specification of (8) is common in the literature (see, for example, Xepapadeas, 2005). Our main results still hold if pollution accumulates in the law of motion: $\dot{Z} = \beta y_1 - \delta Z$, where δ is the natural decay rate of pollution.

2.3. The government

The government budget constraint is simplified as:

$$T = \tau_e Z = \tau_e \beta y_1. \tag{11}$$

Equation (11) shows that the emission tax revenues are rebated to households in a lump-sum manner, which allows us to isolate the effect of the consumption externality from the government's tax revenues. Accordingly, the government balances its budget by adjusting the lump-sum transfer.

2.4. Symmetric competitive equilibrium

The symmetric competitive equilibrium is defined as a set of market clearing prices (p, r, w), sectoral fractions (u, s), and quantities $(c_1, c_2, k, h, y_1, y_2, Z)$ such that: (i) households maximize their lifetime utility, i.e., (2)–(5); (ii) firms in the dirty- and clean-good sectors maximize their profits, i.e., (9) and (10); (iii) the government budget constraint is balanced, i.e., (11); (iv) the factor resource constraints $k = k_1 + k_2 = uk + (1-u)k$ and $h = h_1 + h_2 = sh + (1-s)h$ are met; and (v) all markets are clear under a symmetric equilibrium, i.e., $c_1 = \bar{c}_1$, $c_2 = \bar{c}_2$ and $k = \bar{k}$. Assume that the dirty good y_1 can either be consumed or accumulated as capital stock, while the clean good y_2 is a pure consumption good. Thus, from (2), (9), (10), and (11) we have the market-clearing conditions of the dirty and clean goods as follows:

$$c_1 + \dot{k} = y_1 = A_1 u^{\alpha_1} k (sh)^{1-\alpha_1}, \tag{12}$$

$$c_2 = y_2 = A_2 (1-u)^{\alpha_2} k \left[(1-s)h\right]^{1-\alpha_2}. \tag{13}$$

Note that our main results still hold if both dirty and clean goods can be consumed and accumulated as capital stock (see Section 4 for the detailed Proof). It is clear from (12) and (13) that the dirty good y_1 can either be consumed or accumulated as capital stock, while the clean good y_2 is a pure consumption good. In line with a common specification in the literature, the economy-wide *real* gross domestic product (*gdp*) is defined as a simple linear aggregation of the dirty and clean goods, i.e., $gdp = y_1 + \frac{p_2}{p_1} y_2 = y_1 + p y_2$, measured in units of the dirty good.[7]

Let us define the transformed variable as $x = c_1/k$. Thus, (3) and (13) allow us to obtain the relative price of the clean to dirty good:

$$p = \frac{(1-\phi_1)\Lambda_c x}{(1-\phi_2) A_2 (1-u)^{\alpha_2} \left[(1-s)h\right]^{1-\alpha_2}}. \tag{14}$$

From (3), (4), (9), (10), and (14), we have three instantaneous relationships as follows:

$$(1-\phi_1) x \Lambda_h h^{\alpha_1+\theta} = (1-\tau_e\beta)(1-\alpha_1) A_1 u^{\alpha_1} s^{-\alpha_1}, \tag{15}$$

$$(1-\phi_2)(1-\tau_e\beta)\alpha_1 A_1 (1-u) u^{\alpha_1-1} (sh)^{1-\alpha_1} = \alpha_2 (1-\phi_1)\Lambda_c x, \tag{16}$$

$$(1-\phi_2)(1-\tau_e\beta)(1-\alpha_1) A_1 (1-s) u^{\alpha_1} s^{-\alpha_1} h^{1-\alpha_1} = (1-\alpha_2)(1-\phi_1)\Lambda_c x. \tag{17}$$

Equation (15) refers to the tradeoff between consumption (in terms of c_1) and leisure. Specifically, greater social aspirations in the dirty-good consumption ϕ_1, as noted above, lead the household to substitute more consumption in c_1 for leisure, resulting in higher labor supply h. Equations (16) and (17) indicate that perfect mobility across sectors leads to the factor price (the interest rate and the wage rate) equalization in the capital and labor markets. Greater social aspirations in the dirty-good (clean-good) consumption ϕ_1 (ϕ_2) induce stronger demand for dirty (clean) goods that lowers (raises) the relative price of clean to dirty goods p, as shown in (14). Thus, economic resources in terms of capital and labor shift from the clean-good sector to the dirty-good sector. Therefore, (16) and (17) show that a higher ϕ_1 (ϕ_2), *ceteris paribus*, increases (decreases) the fractions of capital u and labor s devoted to the dirty-good sector. Moreover, from (16) and (17), we have:

$$\frac{u(1-s)}{s(1-u)} = \frac{\alpha_1(1-\alpha_2)}{\alpha_2(1-\alpha_1)}. \tag{18}$$

Obviously, $\alpha_1 > \alpha_2$ ($\alpha_1 < \alpha_2$) implies that $u^* > s^*$ ($u^* < s^*$) so that if $\alpha_1 > \alpha_2$ the dirty good is capital-intensive relative to the clean good, while if $\alpha_1 < \alpha_2$ the dirty good is labor-intensive relative to the clean good. Given the transformed variable x, (15), (16), and (17) allow us to pin down h, u, and s. Because these three equations are too non-linear to be solved explicitly, we use the implicit function theorem to obtain their implicit functions:

$$h = h(\underset{(-)}{x}, \underset{(+)}{\phi_1}, \underset{(\pm)}{\phi_2}, \underset{(-)}{\tau_e}),\ u = u(\underset{(-)}{x}, \underset{(+)}{\phi_1}, \underset{(-)}{\phi_2}, \underset{(-)}{\tau_e}),\ \text{and}$$
$$s = s(\underset{(-)}{x}, \underset{(+)}{\phi_1}, \underset{(-)}{\phi_2}, \underset{(-)}{\tau_e}), \tag{19}$$

We shall restrict the working time (with a unitary time endowment) and the two factor fractions at $(0,1)$. The exact derivatives are relegated to Appendix A.

By using (3), (5), (9), and (12), we derive the aggregate resource constraint and the Euler equation for optimal consumption as follows:

$$\frac{\dot{k}}{k} = A_1 u^{\alpha_1} (sh)^{1-\alpha_1} - x, \tag{20}$$

$$\frac{\dot{c}_1}{c_1} = (1-\tau_e\beta)\alpha_1 A_1 u^{\alpha_1-1} (sh)^{1-\alpha_1} - \rho, \tag{21}$$

Based on (20) and (21), we further obtain the following evolution of the transformed variable x:

$$\frac{\dot{x}}{x} = x + A_1 u^{\alpha_1-1} (sh)^{1-\alpha_1} \left[(1-\tau_e\beta)\alpha_1 - u\right] - \rho. \tag{22}$$

By substituting (19) into (22), our dynamic system can be reduced to one differential equation in terms of x. Intuitively, (22) indicates that the ratio of consumption (c_1) to capital (k) increases over time if the interest rate is higher than the time preference rate (which increases consumption, as shown in the Euler equation) but it decreases over time if output is larger than consumption (which increases capital accumulation, as shown in the aggregate resource constraint). Because both c_1 and k grow forever, the transformation variable $x = c_1/k$ is constant in the steady-state BGP. To be more specific, we establish:

Theorem 1. *There exists a unique competitive equilibrium, which is locally determinate.*

Proof. See Appendix A.

Let the superscript "$*$" denote the stationary values of relevant variables in the steady state in which $\dot{x} = 0$ holds. Define the growth rate as γ. Thus, under the BGP equilibrium, (i) each of the quantity variables, c_1, c_2, k, y_1, y_2, and Z, grows at a positive constant rate (from (6)–(8), (13), and (22)), i.e.,

$$\gamma^* = \left(\frac{\dot{c}_1}{c_1}\right)^* = \left(\frac{\dot{c}_2}{c_2}\right)^* = \left(\frac{\dot{k}}{k}\right)^* = \left(\frac{\dot{y}_1}{y_1}\right)^* = \left(\frac{\dot{y}_2}{y_2}\right)^* = \left(\frac{\dot{Z}}{Z}\right)^*;$$

(ii) the relative price, p, and hours worked, h, are positive constant values (from (14) and (19)); and (iii) the sectoral allocation variables, u and s, fall in the unit interval $(0,1)$ (from (16) and (17)). Once the steady-state x^* is determined by (22) with $\dot{x} = 0$, we can solve (15), (16), and (17) for the steady-state working time h^*, fraction of capital u^* and labor allocation s^*. With h^*, u^*, and s^*, it is easy from (21) to derive the balanced-growth rate γ^* as follows:

$$\gamma^* = (1-\tau_e\beta)\alpha_1 A_1 (u^*)^{\alpha_1-1} (s^* h^*)^{1-\alpha_1} - \rho. \tag{23}$$

[7] Our findings remain unchanged regardless of the selection of the numéraire.

In the two-sector model, the balanced-growth rate γ^* crucially depends on the steady-state allocation of capital u^* and labor s^* between the clean- and dirty-good sectors.

3. Social comparisons and environmental considerations

In this section, we examine the effects of social comparisons on growth, employment, and the allocation between dirty- and clean-good consumption. Specifically, under various factor intensity rankings, we examine the effects of commodity-specific social comparisons in the dirty-good consumption (ϕ_1) and clean-good consumption (ϕ_2).

Proposition 1. *If the dirty good is capital-intensive relative to the clean good* ($\alpha_1 > \alpha_2$),

(i) *greater social aspirations in the dirty-good consumption (a higher ϕ_1) increase the steady-state dirty-good consumption to capital ratio x^*, labor hours h^*, the fraction of capital u^* and labor s^* used in the dirty-good sector, and the balanced-growth rate γ^*;*

(ii) *greater social aspirations in the clean-good consumption (a higher ϕ_2) decrease the steady-state dirty-good consumption to capital ratio x^*, the fraction of capital u^* and labor s^* used in the dirty-good sector, but increase labor hours h^*. In particular, social comparisons in the clean-good consumption have an ambiguous effect on the balanced-growth rate γ^*.*

Proof. See Appendix A.

Intuitively, more intensive social comparisons in the dirty-good consumption induce households to consume more dirty goods and hence the steady-state dirty-good consumption to capital ratio (x^*) rises. An increase in the demand for the dirty good shifts the economic resources from the clean-good sector to the dirty-good sector and, therefore, the steady-state fractions of capital (u^*) and labor (s^*) used in the dirty sector rise as well.

The impacts on labor hours and growth are attributed to two channels: the demand-side and supply-side factors. The supply-side channel for factors stems from the trade-off between consumption and leisure. It indicates that as agents more aggressively exhibit their social status by increasing the dirty-good consumption, the marginal utility of the dirty-good consumption becomes higher. Thus, the dirty-good consumption substitutes leisure and hence labor supply increases, giving rise to a positive impact on the equilibrium employment. The demand-side channel for factors stems from the sectoral reallocation. When greater social aspirations in the dirty-good consumption shift resources from the clean-good to the dirty-good sector, the demand for factors increases in the dirty sector, but decreases in the clean sector. Given that the dirty sector is capital-intensive relative to the clean one ($\alpha_1 > \alpha_2$), the aggregate capital stock increases, but the total labor hours decrease. Since the resources shift from the clean-good sector to the dirty-good sector, the output of the dirty good increases, which stimulates more rapid capital accumulation.[8] This weakens the negative demand-side effect, and therefore the supply-side effect becomes dominant, referring to a positive impact on the equilibrium employment (h^*). This positive employment effect, together with a positive sectoral allocation effect on the aggregate capital stock, gives rise to a positive impact on the balanced-growth rate (γ^*). Since pollution Z increases proportionately with the output of the dirty good, high growth goes side by side with high pollution in the BGP equilibrium. Thus, the desire to keep up with the Joneses leads to over production and consumption which contribute to environmental degradation.

Greater aspirations in the clean-good consumption have quite different impacts on the economy. In contrast to ϕ_1, ϕ_2 increases the demand for the clean good, which draws resources away from the dirty sector to the clean sector. Thus, the equilibrium dirty-good consumption to capital ratio (x^*) and fraction of capital (u^*) and labor (s^*) used in the dirty-good sector fall. In terms of the employment effect, a higher ϕ_2 leads households to consume more clean goods and increase their labor supply. In the meantime, given that the dirty sector is relatively capital-intensive, the sectoral allocation effect gives rise to a positive impact on employment, but a negative impact on capital. Since both the supply and demand for labor increase, greater aspirations in the clean-good consumption unambiguously raise the equilibrium level of employment (h^*). However, the balanced-growth rate ambiguously responds to this kind of conspicuous consumption. While employment rises, the sectoral allocation effect leads to a deterioration in the aggregate capital stock. Thus, the balanced-growth rate (γ^*) could either increase or decrease.

To make the intuition clearer, we write out the derivatives of the growth effect of greater social aspirations in the dirty- and clean-good consumption (see Appendix A):

$$\frac{\partial \gamma^*}{\partial \phi_1} = \frac{(1-\alpha_1)\alpha_1\theta\xi\Xi}{(1-\phi_1)\Delta u^*}\left[\frac{u^*}{\theta} + (u^* - s^*)\right], \tag{24}$$

$$\frac{\partial \gamma^*}{\partial \phi_2} = \frac{(1-\alpha_1)\alpha_1\theta\xi\Xi}{(1-\phi_2)\Delta u^*}\left[\left(\frac{1-u^*}{\theta x^*}\right)\xi - (u^* - s^*)\right], \tag{25}$$

where $\Delta = \frac{\rho\Omega + (1+\theta)\xi(1-\alpha_1\Xi)}{x^*} > 0$, $\xi = A_1 u^{*\alpha_1}(s^*h^*)^{1-\alpha_1}$, and $\Xi = 1 - \tau_e\beta$. Note that $\alpha_1 > \alpha_2$ ($\alpha_1 < \alpha_2$) implies that $u^* > s^*$ ($u^* < s^*$) in the sense that the dirty good is capital-intensive (labor-intensive) relative to the clean good. Accordingly, (24) and (25) shows that the balanced growth γ^* ambiguously responds to conspicuous consumption, regardless of whether in dirty goods ϕ_1 or clean goods ϕ_2. Two channels, as noted previously, govern the growth effect. First, in terms of the dirty-good (resp. the clean-good) consumption externality ϕ_1 (resp. ϕ_2), the supply-side channel captured by the term $\frac{u^*}{\theta}$ (resp. $(\frac{1-u^*}{\theta x^*})\xi$) gives rise to an unambiguously positive effect on growth via an increase in labor supply. If the inverse Frisch labor-supply elasticity is less elastic (a higher θ), the supply-side effect becomes less pronounced. If the labor-leisure choice is exogenous ($\theta \to \infty$), the labor supply channel turns out to be absent, as shown in (24). Second, the demand-side channel captured by the term ($u^* - s^*$) indicates that the sectoral reallocation effect affects the balanced growth via the relative factor intensiveness. Of particular importance, distinct consumption externalities (ϕ_1 or ϕ_2) have different sectoral reallocation effects and hence different growth consequences.

In response to a higher ϕ_1, the sectoral reallocation effect on growth is positive. Greater social aspirations in the dirty-good consumption (a higher ϕ_1) induce more dirty-good consumption that shifts economic resources from the clean-good sector to the dirty-good sector. As the dirty good is capital-intensive relative to the clean good ($\alpha_1 > \alpha_2$) (hence, $u^* > s^*$), such a shifting can efficiently allocate capital towards the dirty-good sector whose marginal product of capital is higher so that a higher ϕ_1 is favorable to capital accumulation and economic growth. By contrast, in response to a higher ϕ_2, the sectoral reallocation effect is negative. Greater social aspirations in the clean-good consumption (a higher ϕ_2) induce more clean-good consumption that shifts economic resources from the dirty-good sector to the clean-good sector. Because the dirty good is capital-intensive relative to the clean good, this shifting is unfavorable to capital accumulation and economic growth. In addition to the factor intensity, the sectoral reallocation effect is governed by the pollution issue. From (25), we can further show that the consumption externality leads the balanced growth to fall, instead of rise, provided that this relative factor intensiveness is substantially high, i.e., $\frac{u^*}{s^*} > \Theta(= \frac{\alpha_1\theta(1-\phi_2)\Xi}{\alpha_1\theta(1-\phi_2)\Xi - \alpha_2(1-\phi_1)})$ (see Appendix A for more details). Specifically, we have: $\frac{\partial\Theta}{\partial\beta} > 0$, implying that greater social aspirations in the clean-good consumption ϕ_2 are more likely to reduce growth if the pollution problem is less serious (a smaller ϕ_2 so that the

[8] Recall that, unlike the clean good, the dirty good can be accumulated as capital stock.

production process generates fewer emissions).[9] If the pollution problem, however, is more serious (a bigger β), it is more likely to have the condition of $\frac{u^*}{s^*} < \Theta$, instead of $\frac{u^*}{s^*} > \Theta$. In this case, greater social aspirations in the clean-good consumption ϕ_2 are more likely to increase the balanced growth γ^*. The intuition is that if the production process requires less (more) emissions, the after-tax marginal product of factors (both capital and labor) becomes lower (as shown in Eqns. (9) and (10)), amplifying (weakening) the magnitude of the negative sectoral reallocation effect, resulting in a fall (rise) in the balanced growth γ^*.

What would happen if dirty goods were produced by a relatively labor-intensive sector? Typical examples are that woods (except for furniture), leather products, and bio-based plastics, which are often used to produce conspicuous goods as a decoration, are obviously labor-intensive, while firms generate a lot of pollution in the production process for leather goods (see, e.g., Hettige et al., 1995 and Xu, 2003). Based on such a case, we then establish:

Proposition 2. *If the dirty good is labor-intensive relative to the clean good* ($\alpha_1 < \alpha_2$),

(i) *greater social aspirations in the dirty-good consumption (a higher ϕ_1) increase the steady-state dirty-good consumption to capital ratio x^*, labor hours h^*, fraction of capital u^* and labor s^* used in the dirty-good sector, while giving rise to an ambiguous effect on the balanced-growth rate γ^*;*

(ii) *greater social aspirations in the clean-good consumption (a higher ϕ_2) decrease the steady-state dirty-good consumption to capital ratio x^*, fraction of capital u^* and labor s^* used in the dirty-good sector. While the balanced-growth rate γ^* increases, the equilibrium labor hours h^* have an ambiguous response.*

Proof. See Appendix A.

As for Proposition 1, if households display their social status by conspicuous consumption of dirty goods, the equilibrium dirty-good consumption to capital ratio (x^*) rises. Since economic resources shift from the clean sector to the dirty sector, the steady-state fractions of capital (u^*) and labor (s^*) used in the dirty sector rise in response. On the contrary, if households display their social status by conspicuous consumption of clean goods, there are opposite consequences for these variables. These consequences are independent of the factor intensity ranking between the dirty and clean industries.

However, factor intensity rankings play a decisive role in terms of governing the effects of social comparisons on the steady-state employment and growth. Regardless of greater social aspirations in the dirty- or clean-good consumption (ϕ_1 or ϕ_2), the supply-side channel motivates households to work harder, giving rise to a positive employment effect. Nevertheless, through the sectoral reallocation, a higher ϕ_1 (ϕ_2) increases (decreases) employment, but decreases (increases) the aggregate capital stock, if the dirty good is relatively labor-intensive. It turns out that in response to a higher ϕ_1, the equilibrium employment unambiguously increases (h^*), while the balanced-growth rate (γ^*) may either rise or fall, depending on the relative magnitude of the positive employment effect and the negative sectoral allocation effect on capital. As shown in (24), the balanced-growth rate falls, provided that the dirty good is labor-intensive relative to the clean good ($\alpha_1 < \alpha_2$ and hence $u^* < s^*$) and the relative factor intensiveness is substantially high ($\frac{s^*}{u^*} > \frac{1+\theta}{\theta} (> 1)$). By contrast, in response to a higher ϕ_2, the resources are drawn away from the dirty sector to the clean sector. Therefore, the balanced-growth rate (γ^*) unambiguously increases (both the supply-side and demand-side channels refer to a consistently positive impact, as shown in (24)), while the equilibrium employment (h^*) could either rise or fall (the supply-side and demand-side channels are the opposite of each other).

[9] See Appendix A for the detailed deduction concerning this necessary and sufficient condition.

Based on Propositions 1 and 2, we immediately have the following two corollaries:

Corollary 1. *In an economy with social status and environmental concerns, the balanced-growth rate can be reduced by conspicuous consumption regardless of whether households display their social status by consuming either clean goods or dirty goods, provided that they are more labor-intensive.*

This negative growth effect is in sharp contrast to the conventional notion (e.g., Carroll et al., 1997; Dupor and Liu, 2003; Liu and Turnovsky, 2005; Turnovsky and Monteiro, 2007), which refers to a positive relationship between social comparisons in consumption and growth (or output).

By summarizing the effects of the status-motivated consumption on employment and growth, we next establish:

Corollary 2. *In an economy with social status and environmental concerns, in response to greater social aspirations in consumption, a lower level of employment can coexist with a higher balanced-growth rate.*

Bean and Pissarides (1993) find that there is little evidence of a robust bivariate relationship, either positive or negative, over a long time period (1950s-1980s). Moreover, Saint-Paul (1991) and Gordon (1997) show that there may exist a negative correlation between employment and growth. In Corollary 2, we provide theoretical support to the empirical possibility of a negative employment-growth relationship.

In addition, Propositions 1 and 2 could be integrated to offer a novel explanation for the environmental Kuznets curve which refers to an inverted-U relationship between pollution and economic development (income). Our results potentially point out that if the production of dirty goods (such as petrol-powered cars and plastic bag) is more capital intensive than their cleaner substitutes (such as electric cars and biodegradable bags), a greater aspiration for those dirty goods increases both growth and pollution (see Proposition 1(i)). In contrast, if the production of their cleaner substitutes is more capital intensive, a greater aspiration for those cleaner goods increases growth but decreases pollution (see Proposition 2(ii)).[10] Causal evidence shows that through the process of economic development, technology and culture evolves in a way such that (a) those who survive over time discover a more capital intensive technology to produce cleaner goods and (b) the natural selection leads to a greater social desire toward cleaner goods in the culture that survives. In our model, the consequence of Proposition 2(ii) can be referred to a more developed economy with higher income (conforming with the observations (a) and (b)) in which low pollution and higher income coexist (the downward-sloping part of the Kuznets curve). However, as for a less developed economy with lower income, the production of dirty goods is relatively capital intensive and a greater social desire favors dirty goods. Under such a situation, Proposition 1(i) predicts that the economy develops at the cost of polluting the environment (the upward-sloping part of the Kuznets curve).[11]

In our model, social status and environmental concern interact and jointly govern macroeconomic consequences. Thus, it is worthwhile discussing the effects of an emission tax on employment and growth.

Proposition 3. *In an economy with social status and environmental concerns, pollution tax τ_e can favor economic growth γ^*, provided that the pro-*

[10] Proposition 1(i) shows that if the production of dirty goods is relatively capital intensive, a greater social aspiration in the dirty-good consumption increases the fractions of capital u^* and labor s^* used in the dirty-good sector, resulting in higher dirty-good output and hence pollution. Proposition 2(ii) shows that if the production of clean goods is relatively capital intensive, a greater social aspiration in the clean-good consumption decreases the fractions of capital u^* and labor s^* used in the dirty-good sector, resulting in lower dirty-good output and pollution.

[11] We are grateful to an anonymous referee for bringing this point to our attention.

duction of the clean good is relatively capital-intensive. The positive growth effect is more likely to be true in the presence of more intensive social comparisons in the clean-good consumption ϕ_2 or less intensive social comparisons in the dirty-good consumption ϕ_1.

Proof. See Appendix A.

Intuitively, the emission tax raises the production cost of the dirty good, which leads the dirty firms to decrease their demand for labor and capital. A decrease in the labor demand reduces the equilibrium hours worked (h^*) and a decrease in the capital demand slows down capital accumulation and retards economic growth. Nevertheless, raising the pollution tax also creates a sectoral reallocation effect, which may favor economic growth (even the equilibrium employment unambiguously decreases). In response to a higher tax on the production of the dirty good, the economic resources will shift from the dirty sector to the clean sector and the equilibrium fraction of capital (u^*) and labor (s^*) used in the dirty sector will fall accordingly. If the clean good is more capital-intensive (or the dirty good is more labor-intensive), the sectoral reallocation from the dirty sector to the clean sector will increase the aggregate capital stock. Once the sectoral reallocation is substantially strong, the pollution tax can enhance, rather than retard, economic growth. Such a case is particularly true if ϕ_2 is higher or ϕ_1 is lower. Since more intensive social comparisons in the clean-good consumption (ϕ_2) increase the demand for clean goods and hence the induced capital demand in the clean-good sector. The sectoral reallocation effect is thereby aggravated. Similarly, less intensive social comparisons in the dirty-good consumption (ϕ_1) also amplify the capital reallocation from the dirty sector to the clean sector. Thus, the aggregate capital stock increases and the balanced-growth rises, if the production of the clean good is relatively capital-intensive.

The result of Proposition 3 somehow echoes the so-called Green New Deal. The Green New Deal have been proposed after the 2008 financial crisis. The object of this new policy is not only to revive the economy but also tries to promote sustainable growth and reduce ecosystem degradation. As indicated by the London Summit – Leaders' Statement in 2009, "we will make the transition towards clean, innovative, resource efficient, low carbon technologies and infrastructure." Many countries (e.g., China, the United States, and the European Union) have proposed a low carbon strategy, including environmental tax reform in removing environmentally perverse subsidies. It is expected that cancelling the subsidies would on their own reduce greenhouse gas emissions globally by as much as 6% and add 0.1% to world GDP (see Barbier, 2009, p. 10).

4. Discussion

In this section, we perform a welfare analysis that examines the effects of two distinct consumption externalities on welfare and reevaluate the validity of the Pigovian tax in the model with not only pollution externalities but also consumption and production externalities. In the baseline model above, capital is accumulated from dirty goods and the production functions are characterized by aggregate externalities. To perform a robustness examination, we further develop an alternative model in which capital can be accumulated from both dirty and clean goods and the production functions are characterized by sectoral externalities.

4.1. Welfare analysis

Along the BGP, given the initial capital stock $k(0)$, consumption $c_1(0)$ and $c_2(0)$, and pollution $Z(0)$, the time paths of consumption and pollution can be expressed as: $c_1 = c_1(0)e^{\gamma^* t}$, $c_2 = c_2(0)e^{\gamma^* t}$, and $Z = Z(0)e^{\gamma^* t}$. Using (6), (8), (12), and (13), we can further have: $c_1(0) = \left[A_1 u^{\alpha_1}(sh)^{1-\alpha_1} - \gamma^*\right] k_0$, $c_2(0) = A_2(1-u)^{\alpha_2}\left[(1-s)h\right]^{1-\alpha_2} k_0$, and $Z(0) = \beta_1 A_1 u^{\alpha_1}(sh)^{1-\alpha_1} k_0$. Thus, social welfare, denoted by W, is the utility obtained by the representative household, i.e.,

$$W = \int_0^\infty \left[\ln(1-\phi_1)c_1(0) + \Lambda_c \ln(1-\phi_2)c_2(0) - \Lambda_Z \ln Z(0) - \Lambda_h \frac{h^{1+\theta}}{1+\theta} + (1+\Lambda_c - \Lambda_Z)\gamma^* t\right] e^{-\rho t} dt.$$

Accordingly, we derive the welfare effects of ϕ_1 and ϕ_2 as follows:

$$\frac{\partial W}{\partial \phi_1} = \frac{1}{\rho}\left\{\frac{-1}{1-\phi_1} + \frac{1}{c_1(0)}\frac{\partial c_1(0)}{\partial \phi_1} + \frac{\Lambda_c}{c_2(0)}\frac{\partial c_2(0)}{\partial \phi_1} - \frac{\Lambda_Z}{Z(0)}\frac{\partial Z(0)}{\partial \phi_1} - \Lambda_h h^\theta \frac{\partial h^*}{\partial \phi_1} + \frac{1+\Lambda_c-\Lambda_Z}{\rho}\frac{\partial \gamma^*}{\partial \phi_1}\right\} \gtrless 0,$$

$$\frac{\partial W}{\partial \phi_2} = \frac{1}{\rho}\left\{\frac{-1}{1-\phi_2} + \frac{1}{c_1(0)}\frac{\partial c_1(0)}{\partial \phi_2} + \frac{\Lambda_c}{c_2(0)}\frac{\partial c_2(0)}{\partial \phi_2} - \frac{\Lambda_Z}{Z(0)}\frac{\partial Z(0)}{\partial \phi_2} - \Lambda_h h^\theta \frac{\partial h^*}{\partial \phi_2} + \frac{1+\Lambda_c-\Lambda_Z}{\rho}\frac{\partial \gamma^*}{\partial \phi_2}\right\} \gtrless 0.$$

As is evident from these two equations, the welfare effects are very complicated, depending on the direct relative utility effect (the first term) and induced consumption, leisure, pollution, and growth effects (the second term to the fifth term). In a pure social comparisons, a one-sector model without flexible labor supply ($\Lambda_h = 0$ and $\theta \to \infty$) and environmental concerns ($\Lambda_Z = 0$ and $\beta = 0$), higher social comparisons in consumption unambiguously decrease the level of welfare. For the sake of comparison with the traditional social comparisons model, we focus on social comparisons in the clean-good consumption ϕ_2 because the production of clean goods does not generate pollution. By focusing on the clean-good sector, if the labor-leisure choice is exogenous ($\theta \to \infty$) the labor supply channel is shut down, and consequently, social comparisons in consumption have no effect on growth. Thus, we can infer that higher social comparisons to others, say, ϕ_2, decreases the level of social welfare, i.e., $\frac{\partial W}{\partial \phi_2} < 0$ (see Appendix B for the detailed derivations). In our two-sector model with environmental concerns, the welfare, however, ambiguously responds to higher social comparisons in consumption ϕ_2 because (mainly) the growth effect ($\frac{\partial \gamma^*}{\partial \phi_2}$) is ambiguous, depending on factor intensity, labor supply elasticity, and the emission parameter, as shown in Propositions 1 and 2. In other words, unlike the pure social comparison model, our model may predict a positive welfare effect of social comparisons in consumption.

It is also interesting to reevaluate the validity of the Pigovian tax given that in our model there exist not only pollution externalities but also consumption and production externalities, all making the competitive equilibrium inefficient. To achieve the Pareto optimum, the social planner will internalize all the externalities in order to remedy this inefficiency. Thus, we compare the competitive equilibrium with the Pareto optimum and derive the optimal environmental taxation.

In the Pareto optimum, the social planner, subject to the market-clearing conditions of the dirty and clean goods, (12) and (13), and the evolution of pollution (8), maximizes the welfare function (1).

$$\max \int_0^\infty \left[\ln(1-\phi_1)c_1 + \Lambda_c \ln(1-\phi_2)c_2 - \Lambda_Z \ln Z - \Lambda_h \frac{h^{1+\theta}}{1+\theta}\right] \cdot e^{-\rho t} dt,$$

$$s.t.\quad c_1 + \dot{k} = y_1 = A_1 u^{\alpha_1} k (sh)^{1-\alpha_1},$$

$$c_2 = A_2(1-u)^{\alpha_2} k \left[(1-s)h\right]^{1-\alpha_2},$$

$$Z = \beta y_1.$$

Substituting c_2 and Z into the objective function and letting ζ be the costate variable associated with the capital stock, the conditions necessary for this optimization problem are given by:

$$\frac{1}{c_1} = \zeta, \tag{26}$$

$$\frac{\alpha_2\Lambda_c}{1-u}+\frac{\alpha_1\Lambda_Z}{u}=\alpha_1 A_1 u^{\alpha_1-1}k(sh)^{1-\alpha_1}\zeta, \tag{27}$$

$$\frac{(1-\alpha_2)\Lambda_c}{1-s}+\frac{(1-\alpha_1)\Lambda_Z}{s}=(1-\alpha_1)A_1 u^{\alpha_1}s^{-1}k(sh)^{1-\alpha_1}\zeta, \tag{28}$$

$$\frac{(1-\alpha_2)\Lambda_c-(1-\alpha_1)\Lambda_Z}{h}-\Lambda_h h^{\theta}=-(1-\alpha_1)A_1 u^{\alpha_1}h^{-1}k(sh)^{1-\alpha_1}\zeta, \tag{29}$$

$$\frac{\dot{\zeta}}{\zeta}=\rho-A_1 u^{\alpha_1}(sh)^{1-\alpha_1}-\frac{\Lambda_c-\Lambda_Z}{\zeta k}, \tag{30}$$

Let superscript "o" be the first-best tax rate associated with the relevant variables. Based on the steady-state BGP equilibrium, we compare the above equations with those of the competitive equilibrium (equations (3), (5), (9), (26), and (30)) and obtain the following (sub-)optimal pollution tax (see Appendix B for a detailed Proof):

$$\tau_e^o=\frac{MRS_{c_1Z}}{1-\phi_2}-\frac{\phi_2}{(1-\phi_2)\beta}-\frac{\left[(\alpha_2\Lambda_c-\alpha_1)u^2+\alpha_1(1-\alpha_2\Lambda_c)\right]u}{\alpha_1(1-\phi_2)\left[\alpha_2 u\Lambda_c+\alpha_1(1-u)\Lambda_Z\right]}, \tag{31}$$

where $MRS_{c_1Z}=-\frac{MU_{c_1}}{MU_Z}=\frac{\Lambda_Z c_1}{Z}$. Note again that there are not only pollution externalities but also consumption and production externalities in the model. If the production externality and consumption externalities are absent (the production parameters are independent of capital ($\widetilde{A}_1=A_1$ and $\widetilde{A}_2=A_2$) and the consumption social comparisons parameters are zero ($\phi_1=\phi_2=0$), (31) reduces to:

$$\tau_e^o=MRS_{c_1Z}, \tag{32}$$

which recovers the conventional Pigovian tax in the sense that the socially optimal pollution tax reflects the marginal damage caused by pollution. This implies that the conventional Pigovian tax is still valid even in a two-sector model without consumption and production externalities. If production externalities are present and consumption externalities are still absent ($\widetilde{A}_1=A_1\overline{k}^{1-\alpha_1}$ and $\widetilde{A}_2=A_2\overline{k}^{1-\alpha_2}$ and $\phi_1=\phi_2=0$), (31) reduces to:

$$\tau_e^o=MRS_{c_1Z}-\frac{\left[(\alpha_2\Lambda_c-\alpha_1)u^2+\alpha_1(1-\alpha_2\Lambda_c)\right]u}{\alpha_1\left[\alpha_2 u\Lambda_c+\alpha_1(1-u)\Lambda_Z\right]}. \tag{33}$$

To account for production externalities, the modified Pigovian tax is lower than the conventional one.[12] To eliminate the distortion caused by pollution externalities, the conventional Pigovian tax aims to decrease firms' output, which lowers their emissions. Production externalities, however, give rise to a positive impact on the production of firms and hence social welfare. Thus, the modified Pigovian tax becomes lower in order to account for these positive production externalities. One may emphasize that (31) is only a *sub-optimal* solution that is unable to correct all externalities, once we also take consumption externalities ($\phi_1>0$ and $\phi_2>0$) into account. Intuitively, the presence of consumption externalities distorts the labor allocation between the dirty-good and clean-good sectors via the labor supply channel, as noted in Propositions 1 and 2. This distortion leads to a distinction in the fraction of labor devoted to the dirty-good sector between the social optimum $s=\frac{(1-\alpha_1)\alpha_2 u}{\alpha_1(1-\alpha_2)+(\alpha_2-\alpha_1)u}$ and the competitive equilibrium $s=\frac{(1-\alpha_1)\alpha_2 u}{(1-\phi_2)[\alpha_1(1-\alpha_2)+(\alpha_2-\alpha_1)u]}$ under the environmental Pigovian tax of (31). In Appendix B, we show that, in addition to the pollution tax, a positive income tax is necessary for the society in order to achieve the Pareto optimum.

4.2. Capital accumulation and production externalities

In addition to the baseline model, we develop an alternative model in which capital can be accumulated from both dirty and clean goods and the production functions are characterized by sectoral externalities. By following Cassou and Hamilton (2004), the production functions are specified as:

$$y_1=\widetilde{A}_1 k_1^{\alpha_1}(sh)^{1-\alpha_1} \text{ and } y_2=\widetilde{A}_2 k_2^{\alpha_2}\left[(1-s)h\right]^{1-\alpha_2}, \tag{34}$$

where $\widetilde{A}_1=A_1\overline{k}_1^{1-\alpha_1}$ and $\widetilde{A}_2=A_2\overline{k}_2^{1-\alpha_2}$. Notice that (34) shows that the production functions are characterized by sectoral externalities, instead of aggregate externalities. The importance of sector-specific production externalities has been highlighted by the theoretical studies of Benhabib and Farmer (1994) and Benhabib et al. (2000). Empirically, Harrison (1997) identifies the existence of sector-specific production externalities.

Moreover, we rewrite the market-clearing conditions of the two goods as:

$$c_1+\dot{k}_1=A_1(sh)^{1-\alpha_1}k_1,$$

$$c_2+\dot{k}_2=A_2\left[(1-s)h\right]^{1-\alpha_2}k_2.$$

This implies that both dirty and clean goods can be consumed and accumulated as capital. Based on these modifications, we rederive the effects of consumption externalities ϕ_1 and ϕ_2 on the growth rate of dirty goods, denoted by γ_1, and that of clean goods, denoted by γ_2, as follows:

$$\frac{\partial\gamma_1^*}{\partial\phi_1}=\frac{(1-\alpha_1)\alpha_1\vartheta_1\Xi\left(\frac{c_1}{k_1}\right)^*\left\{\left[\alpha_2+\theta(1-s^*)\right]\left(\frac{c_2}{k_2}\right)^*+(1-\alpha_2)\{1-\alpha_2\vartheta_2\}\right\}}{\overline{\Delta}\,\overline{\Omega}(1-\phi_1)}>0, \tag{35}$$

$$\frac{\partial\gamma_2^*}{\partial\phi_1}=\frac{-\alpha_2\theta s^*(1-\alpha_2)\vartheta_2\left(\frac{c_1}{k_1}\right)^*\left(\frac{c_2}{k_2}\right)^*}{\overline{\Delta}\,\overline{\Omega}(1-\phi_1)}<0, \tag{36}$$

$$\frac{\partial\gamma_1^*}{\partial\phi_2}=\frac{-\theta(1-s^*)(1-\alpha_1)\alpha_1\vartheta_1\Xi}{\overline{\Delta}\,\overline{\Omega}(1-\phi_2)}<0, \tag{37}$$

$$\frac{\partial\gamma_2^*}{\partial\phi_2}=\frac{(1-\alpha_2)\alpha_2\vartheta_2\left(\frac{c_2}{k_2}\right)^*\left\{(\alpha_1+\theta s^*)\left(\frac{c_1}{k_1}\right)^*+(1-\alpha_1)\left[1-\alpha_1\Xi\right]\vartheta_1\left(\frac{c_2}{k_2}\right)^*\right\}}{\overline{\Delta}\,\overline{\Omega}(1-\phi_2)}>0. \tag{38}$$

where $\vartheta_1=A_1(s^*h^*)^{1-\alpha_1}$, $\vartheta_2=A_2\left[(1-s^*)h^*\right]^{1-\alpha_2}$, $\overline{\Omega}=\alpha_1\alpha_2+\alpha_2 s^*\theta+\alpha_1\theta(1-s^*)$, and $\overline{\Delta}=\frac{\left\{(1+\theta)\left(\frac{c_1}{k_1}\right)^*\left(\frac{c_2}{k_2}\right)^*-\rho\left\{(1-\alpha_2)(1+\theta s^*)\left(\frac{c_1}{k_1}\right)^*+(1-\alpha_1)\left[1+\theta(1-s^*)\right]\left(\frac{c_2}{k_2}\right)^*\right\}+\rho^2(1-\alpha_1)(1-\alpha_2)\right\}}{\overline{\Omega}}>0.$

[12] Note that $(\alpha_2\Lambda_c-\alpha_1)u^2+\alpha_1(1-\alpha_2\Lambda_c)>(\alpha_2\Lambda_c-\alpha_1)u^2+\alpha_1(1-\alpha_2\Lambda_c)u^2>0$.

Similar to the baseline model, greater aspirations in the dirty-good consumption ϕ_1 lead households to substitute the dirty-good consumption c_1 for leisure, resulting in an increase in labor supply. An increase in the equilibrium employment h^* gives rise to a favorable *employment* effect on the growth rates of the dirty-good and clean-good sectors. An increase in the dirty-good consumption shifts economic resources (capital and labor) from the clean-good sector to the dirty-good sector. The *sectoral reallocation* effect is favorable to the growth rate of the dirty-good sector but unfavorable to the growth rate of the clean-good sector. It turns out that greater aspirations in the dirty-good consumption increase the growth rate of the dirty-good sector γ_1^* because both the employment effect and the sectoral reallocation effect have an unambiguously positive impact on the dirty-good sector, a shown in (35). By contrast, (36) shows that greater aspirations in the dirty-good consumption decrease the growth rate of the clean-good sector γ_2^* because the sectoral reallocation effect dominates the employment effect. A similar logic can apply to the growth impacts of social comparisons in the clean-good consumption ϕ_2. The mixed impacts of consumption aspirations stated in (35)–(38) shows that our main results still hold if both dirty and clean good can be consumed and accumulated as capital stock.

5. Concluding remarks

In this paper, we have developed a two-sector, two factor, environmental model in which agents optimally choose the clean- and dirty-goods in order to balance the concern for social status and environmental quality. In particular, we have made a subtle theoretical connection regarding (i) two conflicting aspects of consumer preference involving social aspirations and environmental concerns and (ii) the relative magnitude of the capital intensity in the production technology for the good that pollutes the environment (the dirty good) and the good that does not (the clean good).

Based on the model features, we have shown that, in sharp contrast to the conventional wisdom, keeping up with the Joneses can decrease growth as consumer preference is involved social aspirations and environmental concerns. Greater social aspirations in consumption regardless of either clean goods or dirty goods may lead to a deterioration in economic growth, provided that conspicuous goods are relatively labor-intensive. Besides, due to the sectoral allocation effect, the equilibrium employment may negatively respond to more intensive social comparisons if households display their social status by consuming dirty goods, which are labor-intensive. Interestingly, employment and growth may be negatively correlated, which provides a theoretical support to an empirical possibility of a negative employment-growth relationship.

We have also found that a pollution tax can favor economic growth when the production of the clean good is capital-intensive. A tax on the production of dirty goods generates the sectoral reallocation from the dirty sector to the clean sector, which increases the aggregate capital stock and hence growth when the clean good is more capital-intensive. The positive growth effect is more likely to be true in the presence of more intensive social comparisons in the clean-good consumption since they amplify the sectoral reallocation effect. This echoes the Green New Deal.

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Appendix A

The Derivatives of (19). From (3), (4), (9), (10), and (14), we obtain:

$$(1-\phi_1)\,x\Lambda_h h^{\alpha_1+\theta} = (1-\tau_e\beta)\,(1-\alpha_1)\,A_1 u^{\alpha_1} s^{-\alpha_1}$$

$$(1-\phi_2)\,(1-s)\,(1-\tau_e\beta)\,(1-\alpha_1)\,A_1 u^{\alpha_1} s^{-\alpha_1} h^{1-\alpha_1} = (1-\alpha_2)\,(1-\phi_1)\,\Lambda_c x$$

$$(1-\phi_2)\,(1-u)\,(1-\tau_e\beta)\,\alpha_1 A_1 u^{\alpha_1-1}(sh)^{1-\alpha_1} = (1-\phi_1)\,\alpha_2\Lambda_c x$$

Applying the implicit function theorem, we have:

$\frac{\partial h}{\partial x} = -\frac{sh}{x\Omega} < 0,$	$\frac{\partial h}{\partial \phi_1} = \frac{sh}{(1-\phi_1)\Omega} > 0,$	$\frac{\partial h}{\partial \phi_2} = \frac{\alpha_1 h(u-s)}{(1-\phi_2)\Omega} \gtrless 0,$
$\frac{\partial h}{\partial \tau_e} = -\frac{\beta sh}{(1-\tau_e\beta)\Omega} < 0,$	$\frac{\partial u}{\partial x} = -\frac{u(1-u)(1+\theta)}{\Omega x} < 0,$	$\frac{\partial u}{\partial \phi_1} = \frac{u(1-u)(1+\theta)}{(1-\phi_1)\Omega} > 0,$
$\frac{\partial u}{\partial \phi_2} = -\frac{u(1-u)(\alpha_1+\theta)}{(1-\phi_2)\Omega} < 0,$	$\frac{\partial u}{\partial \tau_e} = -\frac{\beta u(1-u)(1+\theta)}{(1-\tau_e\beta)\Omega} < 0,$	$\frac{\partial s}{\partial x} = -\frac{s(1-s)(1+\theta)}{\Omega x} < 0,$
$\frac{\partial s}{\partial \phi_1} = \frac{s(1-s)(1+\theta)}{(1-\phi_1)\Omega} > 0,$	$\frac{\partial s}{\partial \phi_2} = -\frac{s(1-s)(\alpha_1+\theta)}{(1-\phi_2)\Omega} < 0,$	$\frac{\partial s}{\partial \tau_e} = -\frac{\beta s(1-s)(1+\theta)}{(1-\tau_e\beta)\Omega} < 0,$

where $\Omega = \alpha_1 u(1+\theta) + (1-\alpha_1)\theta s > 0$. ∎

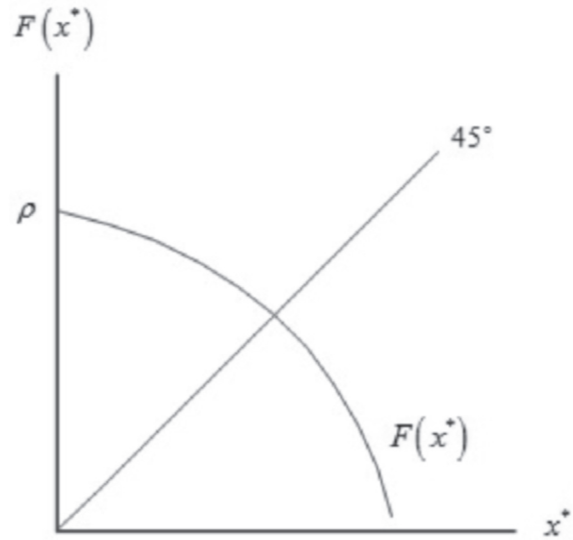
Proof of Theorem 1. We apply the Brouwer Fixed Point Theorem to prove the existence of the BGP equilibrium. It follows from (22) with $\dot{x} = 0$ that the steady-state consumption-capital ratio is satisfied by the following equation:

$$x^* = F(x^*) = \rho - A_1 u^{*\alpha_1-1}(s^*h^*)^{1-\alpha_1}[(1-\tau_e\beta)\alpha_1 - u^*],$$

where h, u, s are reported in the instantaneous relationships (15)–(17), respectively. Accordingly, we can derive that the F function is downward sloping, i.e.:

$$F'(x^*) = -\frac{\xi}{\Omega x^*}\left\{\Omega\left[\alpha_1\Xi - u^*\right] + (1+\theta)\left[1-\alpha_1\Xi\right]u^*\right\} < 0$$

where $\xi = A_1 u^{*\alpha_1}(s^*h^*)^{1-\alpha_1} > 0$. Note that $\alpha_1(1-\tau_e\beta) - u^* > 0$ and $\Xi = 1-\tau_e\beta$ given that the aggregate production function is strictly concave. Moreover, the F locus intersects the vertical coordinate at $\lim_{x\to 0} F(x^*) = \rho > 0$. Because of the monotonicity of F, the Brouwer Fixed Point Theorem indicates that the steady-state x^* exists and is unique, as shown in the figure below.



In addition, from (22), we have:

$$\frac{\partial \dot{x}}{\partial x} = \frac{\rho\Omega + A_1 u^{\alpha_1}(sh)^{1-\alpha_1}(1+\theta)\left[1-\alpha_1(1-\tau_e\beta)\right]}{\Omega} > 0.$$

Given that there is only one jump variable x in this dynamic system, this implies that this unique perfect-foresight equilibrium is locally determinate. ∎

Proof of Propositions 1–3. The steady-state equilibrium is characterized by $\dot{x} = 0$. Thus, (19) and (21)-(22) enable us to derive:

$$\frac{\partial x^*}{\partial \phi_1} = \frac{\xi}{(1-\phi_1)\Delta u^*}\left\{(\alpha_1\Xi - u^*)\Omega + (1+\theta)(1-\alpha_1\Xi)u^*\right\} \gtrless 0,$$

$$\frac{\partial h^*}{\partial \phi_1} = \frac{s^* h^*}{(1-\phi_1)\Delta} > 0,$$

$$\frac{\partial u^*}{\partial \phi_1} = \frac{u^*(1-u^*)(1+\theta)}{(1-\phi_1)\Delta} > 0,$$

$$\frac{\partial s^*}{\partial \phi_1} = \frac{s^*(1-s^*)(1+\theta)}{(1-\phi_1)\Delta} > 0,$$

$$\frac{\partial \gamma^*}{\partial \phi_1} = \frac{(1-\alpha_1)\alpha_1\theta\Xi\xi}{(1-\phi_1)\Delta u^*}\left[\frac{u^*}{\theta} + (u^* - s^*)\right] \gtrless 0,$$

and

$$\frac{\partial x^*}{\partial \phi_2} = \frac{\xi}{(1-\phi_2)\Delta u^*}\left\{\alpha_1\theta\left[(1-\alpha_1)\Xi + u^*\right](u^*-s^*) - \left[\alpha_1(1-u^*) + \theta(1-s^*)\right]u^*\right\} \gtrless 0,$$

$$\frac{\partial h^*}{\partial \phi_2} = \frac{h^*}{(1-\phi_2)\Delta x^*}\left\{(u^*-s^*)\left[x^* - (1-\alpha_1)\rho\right] + (1-u^*)\xi\right\} \gtrless 0,$$

$$\frac{\partial u^*}{\partial \phi_2} = \frac{-u^*(1-u^*)}{(1-\phi_2)\Delta x^*}\left[(x^*-\rho) + \theta x^* + \alpha_1\rho\right] < 0,$$

$$\frac{\partial s^*}{\partial \phi_2} = \frac{-s^*(1-s^*)}{(1-\phi_2)\Delta x^*}\left[(x^*-\rho) + \theta x^* + \alpha_1\rho\right] < 0,$$

$$\frac{\partial \gamma^*}{\partial \phi_2} = \frac{(1-\alpha_1)\alpha_1\theta\xi\Xi}{(1-\phi_2)\Delta u^*}\left[\left(\frac{1-u^*}{\theta x^*}\right)\xi - (u^*-s^*)\right] = -\frac{\alpha_1\theta(1-\alpha_1)\Xi\xi s^*}{(1-\phi_2)\Delta\Theta u^*}\left[\frac{u^*}{s^*} - \Theta\right] \gtrless 0.$$

where $\Delta = \frac{\rho\Omega + (1+\theta)\xi(1-\alpha_1\Xi)}{x^*} > 0$, $\xi = A_1 u^{*\alpha_1}(s^*h^*)^{1-\alpha_1}$, and $\Theta = \frac{\alpha_1\theta(1-\phi_2)\Xi}{\alpha_1\theta(1-\phi_2)\Xi - \alpha_2(1-\phi_1)\Lambda_c}$. Note that it is easy from (16) and (17) to derive that $s^* \lesseqgtr u^*$, if $\alpha_1 \gtreqless \alpha_2$. Thus, by focusing on the growth effect of ϕ_1, it is easy to infer that $\frac{\partial \gamma^*}{\partial \phi_1} \gtrless 0$, if $\frac{u^*}{s^*} \gtrless \frac{\theta}{1+\theta}$. By substituting $\xi = A_1 u^{*\alpha_1}(s^*h^*)^{1-\alpha_1}$ into the growth effect of ϕ_2, we can obtain that $\frac{\partial \gamma^*}{\partial \phi_2} \gtrless 0$, if $\frac{u^*}{s^*} \lessgtr \Theta$. In particular, we can further obtain that $\frac{\partial \Theta}{\partial \beta} = \frac{\alpha_1\alpha_2\theta(1-\phi_1)(1-\phi_2)\tau_e}{\left[\alpha_1\theta(1-\phi_2)\Xi - \alpha_2(1-\phi_1)\Lambda_c\right]^2} > 0.$, implying that the pollution parameter β plays an important role in terms of affecting the growth effect of social comparisons in the clean-good consumption ϕ_2. To make our point more striking, we first assume that there is no pollution issue (by setting $\beta = 0$) and $\frac{u_0^*}{s_0^*} > \frac{\alpha_1\theta(1-\phi_2)}{\alpha_1\theta(1-\phi_2) - \alpha_2(1-\phi_1)}$ such that the negative sectoral reallocation effect is strong enough to result in a decrease in the balanced growth, i.e., $\frac{\partial \gamma^*}{\partial \phi_2} < 0$. Next, we introduce the pollution issue into the model (by setting $\beta > 0$). Because $\frac{\alpha_1\theta(1-\phi_2)}{\alpha_1\theta(1-\phi_2)-\alpha_2(1-\phi_1)\Lambda_c} < \Theta(= \frac{\alpha_1\theta(1-\phi_2)\Xi}{\alpha_1\theta(1-\phi_2)\Xi-\alpha_2(1-\phi_1)\Lambda_c})$ and $\frac{\partial\Theta}{\partial\beta} > 0$, we can easily find a critical value of β, denoted by $\overline{\beta}$, which is large enough where $\overline{\beta} > \frac{1}{\tau_e}\left\{1-(\frac{u_0^*}{u_0^*-s_0^*})(\frac{\alpha_2(1-\phi_1)\Lambda_c}{\alpha_1\theta(1-\phi_2)})\right\}$ such that the negative demand-side sectoral reallocation effect is dominated by the positive supply-side employment effect. Under such a situation, greater social aspirations in the clean-good consumption ϕ_2 turn out to increase, rather than decrease, the balanced growth rate, i.e., $\frac{\partial\gamma^*}{\partial\phi_2} > 0$. This case clearly indicates the importance of environmental concern in the growth effect of consumption externalities.

In addition, the effects of the emission tax are given by:

$$\frac{\partial h^*}{\partial\tau_e} = -\frac{\beta s^* h^*}{\Delta\Xi x^*}\{\rho+\xi\} < 0,$$

$$\frac{\partial u^*}{\partial\tau_e} = -\frac{\beta u^*(1-u^*)(1+\theta)(\rho+\xi)}{\Delta\Xi x^*} < 0,$$

$$\frac{\partial s^*}{\partial\tau_e} = -\frac{s^*(1-s^*)(1+\theta)\beta(\rho+\xi)}{\Delta\Xi x^*} < 0,$$

$$\frac{\partial\gamma^*}{\partial\tau_e} = \frac{\theta\alpha_2^2(1-\alpha_1)(1-\phi_1)^2 x^* u^*}{\alpha_1\Delta\left[(1-\phi_2)(1-u^*)\Xi\right]^2}(s^*-\overline{s}) \gtrless 0, \text{ if } s^* \gtrless \overline{s},$$

where $\overline{s} = \frac{(1+\theta)[\alpha_1(1-\phi_2)(1-u^*)\Xi+\alpha_2(1-\phi_1)(1-\alpha_1 u^*)]}{\alpha_2\theta(1-\phi_1)(1-\alpha_1)}$. Moreover, we can easily obtain $\frac{\partial\overline{s}}{\partial\phi_1} = \frac{\alpha_1(1+\theta)(1-\phi_2)(1-u^*)\Xi}{\alpha_2\theta(1-\alpha_1)(1-\phi_1)^2} > 0$ and $\frac{\partial\overline{s}}{\partial\phi_2} = -\frac{\alpha_1(1+\theta)\Xi(1-u^*)}{\alpha_2\theta(1-\phi_1)(1-\alpha_1)} < 0$. This implies that if s^* is higher (i.e., the clean good is more capital-intensive or the dirty good is more labor-intensive), the growth effect of the pollution tax is more likely to be positive. ∎

Robustness Examination of the Generalized Model Setting on Pollution

If the production processes of both dirty and clean goods generate pollution, the by-products of the two goods are given by:

$Z_1 = \beta_1 y_1$ and $Z_2 = \beta_2 y_2$; with $0 < \beta_1, \beta_2 < 1$ and $\beta_1 > \beta_2$,

where β_1 and β_2 are the emission per unit of output associated with dirty and clean goods and $\beta_1 > \beta_2$ because the production of clean goods generates fewer emissions. Thus, the total amount of pollution is:

$$Z = Z_1 + Z_2 = \beta_1 y_1 + \beta_2 y_2,$$

and, accordingly, the government budget constraint is $T = \tau_e(\beta y_1 + \beta_2 y_2)$.

Based on this modification, the factor price equalization yields:

$$r = \Xi_1\alpha_1\widetilde{A}_1(uk)^{\alpha_1-1}(sh)^{1-\alpha_1} = \alpha_2\Xi_2 P\widetilde{A}_2\left[(1-u)k\right]^{\alpha_2-1}\left[(1-s)h\right]^{1-\alpha_2},$$

$$w = (1-\alpha_1)\Xi_1\widetilde{A}_1(uk)^{\alpha_1}(sh)^{-\alpha_1} = (1-\alpha_2)\Xi_2 P\widetilde{A}_2\left[(1-u)k\right]^{\alpha_2}\left[(1-s)h\right]^{-\alpha_2}.$$

where $\Xi_1 = 1 - \tau_e\beta_1$ and $\Xi_2 = 1 - \tau_e\beta_2$ Thus, in the steady-state BGP equilibrium the competitive equilibrium is satisfied:

$$(1-\phi_1)x\Lambda_h h^{\alpha_1+\theta} = (1-\alpha_1)\Xi_1 A_1 u^{\alpha_1}s^{-\alpha_1},$$

$$(1-\phi_2)(1-s)(1-\alpha_1)\Xi_1 A_1 u^{\alpha_1}s^{-\alpha_1}h^{1-\alpha_1} = (1-\alpha_2)\Xi_2(1-\phi_1)x,$$

$$(1-\phi_2)(1-u)\alpha_1\Xi_1 A_1 u^{\alpha_1-1}(sh)^{1-\alpha_1} = (1-\phi_1)\alpha_2\Xi_2 x,$$

$$\rho - A_1 u^{\alpha_1-1}(sh)^{1-\alpha_1}(\alpha_1\Xi_1 - u) = x,$$

which pin down h, u, s, and x. With these variables, we can obtain the effects of social comparisons in consumption ϕ_1 and ϕ_2:

$$\frac{\partial\gamma^*}{\partial\phi_1} = \frac{x(1-\alpha_1)\alpha_1\Xi_1\xi\left[(1+\theta)u^*-\theta s^*\right]}{(1-\phi_1)\widetilde{\Delta}u^*} \gtrless 0$$

$$\frac{\partial\gamma^*}{\partial\phi_2} = \frac{-(1-\alpha_1)\alpha_1\Xi_1}{(1-\phi_2)\widetilde{\Delta}u^*}\left[\theta(u^*-s^*)x^* - (1-u^*)\xi\right] \gtrless 0$$

$$\frac{\partial h^*}{\partial\phi_1} = \frac{x^*s^*h^*}{(1-\phi_1)\widetilde{\Delta}} > 0$$

$$\frac{\partial h^*}{\partial\phi_2} = \frac{h^*\left\{\rho\alpha_1(u^*-s^*)u^* - \xi\left[\alpha_1\Xi_1(u^*-s^*) - u^*(1-s^*)\right]\right\}}{(1-\phi_2)\widetilde{\Delta}\Omega u^*} \gtrless 0$$

$$\frac{\partial u^*}{\partial\phi_1} = \frac{x^*u^*(1-u^*)(1+\theta)}{(1-\phi_1)\widetilde{\Delta}} > 0$$

$$\frac{\partial u^*}{\partial\phi_2} = -\frac{u^*(1-u^*)}{(1-\phi_2)\widetilde{\Delta}}\left[x^*(1+\theta) - \rho(1-\alpha_1)\right] \gtrless 0$$

$$\frac{\partial s^*}{\partial\phi_1} = \frac{(1+\theta)(1-s^*)x^*s^*}{(1-\phi_1)\widetilde{\Delta}} > 0,$$

$$\frac{\partial s^*}{\partial\phi_2} = -\frac{s^*(1-s^*)}{(1-\phi_2)\widetilde{\Delta}}\left[x^*(1+\theta) - \rho(1-\alpha_1)\right] \gtrless 0$$

where $\widetilde{\Delta} = \rho\Omega + (1+\theta)\xi\left[1-\alpha_1\left(1-\tau_e\beta_1\right)\right] > 0$. These comparative static results confirm those of the baseline model.

Appendix B

In the Appendix, we perform a welfare analysis. The welfare effects of social comparisons in consumption ϕ_1 and ϕ_2 can be derived as follows:

$$\frac{\partial W}{\partial \phi_1} = \frac{1}{\rho}\left\{\frac{-1}{1-\phi_1} + \frac{1}{c_1(0)}\frac{\partial c_1(0)}{\partial \phi_1} + \frac{\Lambda_c}{c_2(0)}\frac{\partial c_2(0)}{\partial \phi_1} - \frac{\Lambda_Z}{Z(0)}\frac{\partial Z(0)}{\partial \phi_1} - \Lambda_h h^{\theta}\frac{\partial h^*}{\partial \phi_1} + \frac{1+\Lambda_c-\Lambda_Z}{\rho}\frac{\partial \gamma^*}{\partial \phi_1}\right\}$$

$$= \frac{1}{\rho}\left\{\begin{array}{l} \dfrac{-1}{1-\phi_1} + \left(\dfrac{1+\Lambda_c-\Lambda_Z}{\rho} - \dfrac{k(0)}{c_1(0)}\right)\dfrac{\partial \gamma^*}{\partial \phi_1} \\ \quad + \left[\dfrac{1-\alpha_1}{s}\left(\dfrac{Z(0)}{\beta c_1(0)} - \Lambda_Z\right) - \dfrac{\Lambda_c(1-\alpha_2)}{1-s}\right]\dfrac{\partial s^*}{\partial \phi_1} \\ + \left[\dfrac{\alpha_1}{u}\left(\dfrac{Z(0)}{\beta c_1(0)} - \Lambda_Z\right) - \dfrac{\alpha_2\Lambda_c}{1-u}\right]\dfrac{\partial u^*}{\partial \phi_1} \\ \quad + \dfrac{1}{h}\left[(1-\alpha_1)\left(\dfrac{Z(0)}{\beta c_1(0)} - \Lambda_Z\right) + \Lambda_c(1-\alpha_2) - \Lambda_h h^{1+\theta}\right]\dfrac{\partial h^*}{\partial \phi_1} \end{array}\right.,$$

$$\frac{\partial W}{\partial \phi_2} = \frac{1}{\rho}\left\{\frac{-1}{1-\phi_2} + \frac{1}{c_1(0)}\frac{\partial c_1(0)}{\partial \phi_2} + \frac{\Lambda_c}{c_2(0)}\frac{\partial c_2(0)}{\partial \phi_2} - \frac{\Lambda_Z}{Z(0)}\frac{\partial Z(0)}{\partial \phi_2} - \Lambda_h h^{\theta}\frac{\partial h^*}{\partial \phi_2} + \frac{1+\Lambda_c-\Lambda_Z}{\rho}\frac{\partial \gamma^*}{\partial \phi_2}\right\}$$

$$= \frac{1}{\rho}\left\{\begin{array}{l} \dfrac{-1}{1-\phi_2} + \left(\dfrac{1+\Lambda_c-\Lambda_Z}{\rho} - \dfrac{k(0)}{c_1(0)}\right)\dfrac{\partial \gamma^*}{\partial \phi_2} \\ \quad + \left[\dfrac{1-\alpha_1}{s}\left(\dfrac{Z(0)}{\beta c_1(0)} - \Lambda_Z\right) - \dfrac{\Lambda_c(1-\alpha_2)}{1-s}\right]\dfrac{\partial s^*}{\partial \phi_2} \\ + \left[\dfrac{\alpha_1}{u}\left(\dfrac{Z(0)}{\beta c_1(0)} - \Lambda_Z\right) - \dfrac{\alpha_2\Lambda_c}{1-u}\right]\dfrac{\partial u^*}{\partial \phi_2} \\ \quad + \dfrac{1}{h}\left[(1-\alpha_1)\left(\dfrac{Z(0)}{\beta c_1(0)} - \Lambda_Z\right) + \Lambda_c(1-\alpha_2) - \Lambda_h h^{1+\theta}\right]\dfrac{\partial h^*}{\partial \phi_2} \end{array}\right..$$

Moreover, we can derive from the first and second terms that $\frac{-1}{1-\phi_2} + \frac{1}{c_2(0)}\frac{\partial c_2(0)}{\partial \phi_2} < 0$ if labor supply is fixed ($\Lambda_h = 0$) and environmental concerns are absent ($\Lambda_Z = 0$ and $\beta = 0$).

To derive the Pigovian tax, we compare the social optimum with the competitive equilibrium. From (3) and (26), we obtain $\frac{\dot{\lambda}}{\lambda} = \frac{\dot{\varsigma}}{\varsigma}$. Based on this relation, from (9), (5), and (30), it is easy to derive

$$\tau_e^o = \frac{MRS_{c_1Z}}{1-\phi_2} - \frac{\phi_2}{(1-\phi_2)\beta} - \frac{\left[(\alpha_2\Lambda_c-\alpha_1)u^2 + \alpha_1(1-\alpha_2\Lambda_c)\right]u}{\alpha_1(1-\phi_2)\left[\alpha_2 u\Lambda_c + \alpha_1(1-u)\Lambda_Z\right]},$$

as shown in (31). This pollution tax is sub-optimal and unable to correct the distortion caused by the consumption externality in the clean good ($\phi_2 > 0$). In the social optimum, from (28) and (29), we have the fraction of labor devoted to the dirty-good sector: $s = \frac{(1-\alpha_1)\alpha_2 u}{\alpha_1(1-\alpha_2)+(\alpha_2-\alpha_1)u}$. In the competitive equilibrium under the environmental Pigovian tax, from (10), (3), (4), (27), and (29), we have the fraction of labor devoted to the dirty-good sector: $s = \frac{(1-\alpha_1)\alpha_2 u}{(1-\phi_2)[\alpha_1(1-\alpha_2)+(\alpha_2-\alpha_1)u]}$. Due to the existence of the consumption externality in the clean good, the environmental Pigovian tax cannot optimally allocate labor between the dirty-good and clean-good sector even under the environmental Pigovian tax τ_e^o. A possible optimal solution is to introduce an income tax into the model. Specifically, if we impose a tax, denoted by τ_i, on income ($wh + rk$) and modify the household's budget constraint as $\dot{k} = \tau_i(wh+rk) + T - (c_1 + pc_2)$, by applying a similar procedure, we can obtain the optimal taxation: $\tau_e^o = MRS_{c_1Z} - \frac{[(\alpha_2-\alpha_1)u^2+\alpha_1(1-\alpha_2)]u}{\alpha_1[\alpha_2 u+\alpha_1(1-u)\Lambda_Z]}$ and $\tau_i^o = \phi_2$. Given that ϕ_2 is positive, in addition to the environmental Pigovian tax, a positive income tax is socially desirable for achieving the social optimum.

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