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Environmental income in economic growth of a large open economy for the era of eco-urbanization

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Abstract

Purpose – The purpose of this paper is to show that the environmental income drives economic growth of a large open country.
Design/methodology/approach – The authors detect that the relative environmental income has double effect of "conspicuous consumption" on the international renewable resource stock changes when a new social norm shapes to environmental-friendly behaviors by using normal macroeconomic approaches.
Findings – Every unit of extra demand for renewable resource consumption increases the net premium of domestic capital asset. Even if the technology spillovers are inefficient to the substitution of capital to labor force in a real business cycle, the relative income with scale effect increases drives savings to investment. In this case, the renewable resource consumption promotes both the reproduction to a higher level and saving the potential cost of environmental improvement. Even if without scale effects, the loss of technology inefficient can be compensated by net positive consumption externality for economic growth in a sustainable manner.
Research limitations/implications – It implies how to earn the environment income determines the future pathway of China's rural conversion to the era of eco-urbanization.
Originality/value – We test the tax incidence to demonstrate an experimental taxation for environmental improvement ultimately burdens on international consumption side.

Keywords Consumption externalities, Large open economy, Relative income, Renewable resource, Time preference, Eco-urbanization

Paper type Research paper

1. Introduction

Utility is happiness (Tian and Yang, 2006). Hedonic utility is the happiness obtained from consumption. However, the feelings of happiness vary over time, and the evolution of individual's consumption preference is eventually dominated by "relative terms"

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(Rayo and Becker, 2007). The hypothesis of relative income proposes the individual's consumption and saving to some extent depending upon other's income level (Clark *et al.*, 2008). Such kinds of envy, greed and "keep up with Joneses" reflect the phenomena of Easterlin paradox in that people did not feel happiness when his/her income increases as the same as other companions, but will feel happiness when the increase is more than others (Easterlin *et al.*, 2010). Hence, individual's choice of positional goods like private car or big house is somehow depending upon the choice of neighborhood in their community (Gorman, 1953; Lintott, 2005). According to the Hirsch (2005) hypothesis, irrational consumption for showing up social status can ultimately lead to overconsumption with generating negative consumption externalities, consequently declining natural resource stocks in an unsustainable manner (Brekke *et al.*, 2003; Liu and Turnovsky, 2005; Nguyen-Van and Pham, 2013).

In recent decades, discussions about the overconsumption of resource drag attention to responses to climate changes and environment degradation for human well-being and future generations (Vedeld *et al.*, 2007; Cavendish and Campbell, 2008; Angelsen *et al.*, 2014). Too much relevant international strategies, target environmental conservation such as the greenhouse gases (GHG) emission caps on large economies for global environmental justices and equality issues.

However, even if all resources can be recycled by much advanced technology, technology investment so far costs the efficiency of capital accumulation to increase the resource-based energy-efficiency. The subjective discount rate of consumption utility must be strictly greater than the speed of renewable resource stock growth to increasing capital stock under the premise that renewable resource stock has an inertial tendency of changes over time. In this case, the technology progress alters the trade-offs between throughputs and capital accumulation to change the premium of every unit of intertemporal renewable recourse consumption.

Efforts of the green growth model take the environmental elements into the neoclassical macroeconomic model (Brock and Taylor, 2010; Berthe and Elie, 2015; Schumacher, 2015). These emphasize that theoretical capital accumulation are distorted by the individual unsatisfaction of environmental amenities and social status (Ghosh and Wendner, 2015; Johansson-Stenman and Sterner, 2015). However, the mechanism of the interaction between the stock changes of renewable resource and capital accumulation in a large open economy is still poorly understood by involving these arguments. Thus, we boldly question on that because those international schemes neglect the essentials of the rule of demand for human development.

This research shows a theoretical mechanism that the environmental income drives the economic growth of a large open economy. We argue the relative environmental income holding a part of relative income. When all extra hedonic utility obtained from renewable resource consumption, a discount rate catches the relationship between the saving and the relative environmental income. When all resources are renewable in a long enough time, a reproduction level determines the crowding-out effects of renewable resource consumptions to savings. The more resources can be reproduced, the higher per capita capital stock returns back to reproduction and nation's wealth. When people care about the growth of renewable resource stock, all extra intertemporal utilities are also obtained from earning the interests by holding per capita capital stock for higher returns. The more renewable resources are reproduced, the higher relative environmental income is earned and the larger positive environmental externalities conciliate the negative externalities of overconsumption with increasing technology in the process of capital accumulation. Thus, the growth of both renewable resource stock and technology drives a sustainable manner.

We demonstrate that the environmental income is the earning from relatively savings from the potential cost of consumption on environmental quality improvement on the pathway of economic growth. In China's case, it determines the future pathway of rural conversion to the era of eco-urbanization (Wang, Deng, Wang and Chen, 2017; Wang, Chen, Zheng and Deng, 2018; Wang and Deng, 2017). By examining environmental impacts with population growth, we discuss the uncertain effectiveness of time preference changes for sustainable growth, and showing that the relative savings from the cost of environmental impacts are critical to capital accumulation over time. Because the personal income is influenced by the expectation of future income, interest rate, aging, other people's earnings and saving schemes, *a simili* uncertain impact factors with risks. We test an experimentally environmental tax incidence, and find that the cost of environmental inequality ultimately burdens on international consumers. Thus, every increased unit of environmental income earning from future savings for lowering the environmental inequality is the earning of that savings faster transferred from present reproduction than renewable resources consumption.

We show this theoretical mechanism in economics practices and find the principle of double effect on overconsumption to promote economic efficiency with technology progress and to lower environmental inequality with more environmental-friendly behaviors. Hence, we theoretically proved the miracle of China's economic growth with decreasing environmental effects. A policy implication indicates that a social norm of environmental-friendly behaviors shapes the consumption preference to the double effect on the relative income redistribution. This will shape the pattern of rural conversion to the eco-urbanization progress in the case of China's development.

2. Relative income and renewable resource growth rate

"Conspicuous consumption" has the "demonstration effect" from the perspective of sociology (Veblen, 1900). Because every unit of saving is proposed for future consumption an increase of present income determines the expectation of future income, current consumption amount, interest rate, aging, other people's earnings and saving schemes, *a simili* uncertain impact factors with risks (Zellner and Zilberman, 2011). While income decreases, due to the "ratcheting effect," consumer behaviors tend to follow the "inertia" to keeping a level of consumption (Muellbauer, 1988). It means that the preference of marginal consumption converted to saving is much more relying on the current consumption behavior rather than the current income in the short run. Hence, a decrease of income has a less impact on current consumption than an increase of income does. Consequently, the saving rate has an uncertain relationship with the increase of per capita personal income *per se* at the individual level. Because others' overconsumption behaviors have the "demonstration effect" and have indirect impacts on total saving at the social production level, whatever personal income increases or decreases. These changes in relative real income have significant impacts on total savings when nominal income increases in the mid-and-long run (Friedman and Savage, 1948; Friedman, 1957; Ng and Wang, 1993; McBride, 2001; Aguiar and Bils, 2015; Alvarez-Cuadrado and Van Long, 2011a, b).

2.1 Relative environmental income

The environmental income, E, and non-environmental income, I, constitute two parts of personal income on the average household income per capita (Sjaastad, *et al.*, 2005). Denoted the relative non-environmental income, $\Delta I = I - \overline{I}$, is the difference of the non-environmental income per capita from the average level, $\overline{I}$, in a community; and the relative environmental income, $\Delta E = E - \overline{E}$, is the difference of the environmental income per capita from the average level, $\overline{E}$, in a community. There is a function of the total relative income with respect to relative non-environmental income and relative environmental income over time in the following equation:

$$R_t = R_t(\Delta I, \Delta E). \tag{1}$$

The individual consumption c is the average household consumption per capita in an implicit function c_t with respect to the previous level of individual consumption $c_{(t-1)}$ due to the "inertia effect," which is determined by the level of renewable resource consumption at a ratio γ_t, the level of leisure cost at a ratio in total life time l_t and the level of individual relative income R_t at time t in the following equation:

$$c = c_t\left(\gamma_t, l_t, R_t, \mathrm{c}_{t-1}\right). \tag{2}$$

Denoted the intertemporal utility function (3) is an aggregated utility function of consumption with the argument of individual consumption function (Lucas, 1976; Sargent, 1982) premised by Stiglitz (1974)[1]:

$$\int_0^\infty U_t\left(\gamma_t, l_t, R_t, c_{t-1}, k_t, m_t\right) e^{-\rho t} dt, \tag{3}$$

where[2]:

$$U'\left(\gamma_t\right) > 0;\ U'(R_t) > 0;\ U'(l_t) > 0;\ U'(k_t) > 0;\ U'(m_t) > 0;$$
$$U'(c_{t-1}) > 0;\ U''(c_t) < 0;\ \text{and}\ \lim_{c\to 0} U'(c) = \infty,\ c > 0.$$

To maximize intertemporal utility, ρ is a discount rate in a continuous time utility function subject to the following constraints:

$$\dot{k} = F_t(k_t, K_t, L_t, M_t) - c_t, \tag{4}$$

$$\dot{m} = g_{m_t} m_t - \gamma_t c_t, \tag{5}$$

$$c_t = \frac{\sum_{i=1}^{n} c_{it}}{N_t}, \tag{6}$$

$$m_t = M_t / N_t, \tag{7}$$

$$\mathrm{TI}_t = y_t = r_t k_t + \eta_t m_t + w_t \geqslant i_t + x_t + c_t + s_t y_t, \tag{8}$$

$$E_t = \eta_t m_t, \tag{9}$$

$$x_t = x\left(c_{t-1}, \gamma_t, l_t, R_t\right), \tag{10}$$

where K_t is the level of total real capital stock at time t; M_t the level of total renewable resource stock at time t; N_t the total population at time t; $L_t = (1-l_t)N_t$ denotes the total labor supply at time t; and l_t denotes a ratio of leisure hours; k_t the per capita real capital stock at time t; m_t the per capita renewable resource stock at time t; g_{m_t} the growth rate of per capita renewable resource stock at time t; c_t the per capita consumption at time t; TI_t the total individual budget constraint at time t; η_t the interest of per capita renewable resource stock at time t; r_t the interest of per capita real capital stock at time t; w_t the per capita wage at time t; s_t the per capita saving rate at time t; y_t the per capita social production level at time t; i_t the per capita consumption of capital at time t; x_t the per capita consumption of renewable resource at time t; E_t the per capita environmental income of renewable resource at time t.

Solve *∂H/∂k, ∂H/∂c, ∂H/∂m* and *∂H/∂γ* of the Hamiltonian function (11) to separately derive $\dot{\theta}_1/\theta_1$ and $\dot{\theta}_2/\theta_2$ in the following equations:

$$H = U+\theta_1[F(k,K,L,M)-c]+\theta_2\left[(1+g_m)m-\gamma c\right], \tag{11}$$

$$\frac{\dot{\theta}_1}{\theta_1} = \rho-F_k-U_k/\left(U_c-\frac{U_\gamma \gamma}{c}\right), \tag{12}$$

$$\frac{\dot{\theta}_2}{\theta_2} = \rho-g_m-\frac{U_m}{U_\gamma}c. \tag{13}$$

Equations (12)–(13) show the utility changes of both consumption and the relative environmental income having impacts on the speed of capital accumulation. The advanced technology is predeterminate of recycling natural resource for all resources to be renewable. The relative changes of consumption utility U_m/U_γ at the γ ratio of renewable resource consumption and the growth rate of renewable resource stock g_m ultimately drive the speed of stock changes $\dot{\theta}_2/\theta$ by given a discount rate of consumption utility ρ.

2.2 A growth rate of renewable resource per capita

A specific production function (14) is employed to further reveal the growth rate changes in renewable resource stock per capita in a process of capital accumulation (Barro, 1988; Jones, 1995). The format of per capita growth rate (15) is derived by calculation in Appendix 1, which shows the growth rate of throughputs endogenously determined by the growth rate of technology and the growth rate of renewable resource stock:

$$Y = (\mathrm{AM})^{1-\alpha}(\mathrm{KL})^{\alpha}, \tag{14}$$

$$g_y = (1-\alpha)(g_A+g_m). \tag{15}$$

When employing a specific utility function $\mathrm{U}(c_t) = ([(1+l_t+\gamma_t+R_t)c_{t-1}]^{(1-\sigma)}-1)/(1-\sigma)$ in a quadratic form with respect to the individual consumption, here $l_t \in [0, 1]$, $\gamma_t \in [0, 1]$, $R_t \in [0, 1]$ and $(l_t + \gamma_t + R_t) \in [0, 1]$, the expectation value of utility will be ultimately determined by the time preference σ in the following equation:

$$E(U) = \frac{-U'(c_{t-1})}{U''(c_{t-1})c_{t-1}} = \frac{-\left(1+l_t+\gamma_t+R_t\right)^{1-\sigma}c_{t-1}^{-\sigma}}{-\sigma(1+l_t+\gamma+R_t)^{1-\sigma}c_{t-1}^{-\sigma}} = \frac{1}{\sigma}. \tag{16}$$

Updated Euler equations present the changes in per capita capital stock and renewable resource stock in an evolutionary process in Equations (17)–(18):

$$\dot{k} = (sA-\delta)k-c_{t-1}\left(1+l_t+\gamma_t+R_t\right), \tag{17}$$

$$\dot{m} = \left(\frac{g_y}{1-\alpha}-g_A\right)m_t-\gamma_t c_t, \tag{18}$$

$$H = U(c)+\lambda_1[(sA-\delta)k-c(1+l+\gamma+R)]+\lambda_2\left[\left(\frac{g_y}{1-\alpha}-g_A\right)m-\gamma c\right]. \tag{19}$$

Rewrite the Hamiltonian function (19) and solve *∂H/∂k, ∂H/∂c, ∂H/∂m, ∂H/∂γ, ∂H/∂l* and *∂H/∂R* to reach a set of optimal solutions of $\dot{\lambda}_1/\lambda_1$ and $\dot{\lambda}_2/\lambda_2$ *condicio necessaria* about a given discount rate of consumption utility ρ, a saving rate s, a constant growth rate of technology A at time t, a fixed capital depreciation rate δ and a growth rate of renewable resource stock g_{m_t} on the optimal path at steady states (omitted calculations are easily conducted by readers):

$$\frac{\dot{\lambda}_1}{\lambda_1} = \rho - sA + \delta, \tag{20}$$

$$\frac{\dot{\lambda}_2}{\lambda_2} = \rho - g_{m_t}. \tag{21}$$

Equations (20)–(21) show that the growth rate of renewable resource stock per capita determines the divergence from the optimal path given by a discount rate. Hausman (1979) discussed that the resource-based energy-efficiency costs the efficiency of capital accumulation mainly caused by failures investments on technology crowding out the investment to reproduction. It implies a higher possibility of the increased cost of efficiency conversion from technology improvement to resource saving, so that the Jevons's paradox occurs when the more resource efficiency improved, the more resources consumed (Alcott, 2005). It points out that the speed of resource consumption determines the capital loss throughout the improvement of technology.

3. Steady states

Stiglitz (1974, 1998) has stressed that the steady states should be reconsidered due to a mixed "natural growth rate"; *ad hoc* to reveal natural-resource-driven capital accumulation should have examined economic behaviors from the demand side under certain predeterminations, such as some certain institutions, judicatures or social status. By ambitious and passionate innovation of advanced technology for exploiting natural resource in a mid-and-long term, the growth rate of capital stock is a dominator of the tendency of the controlled optimal path in a dynamic economic system, and the growth rate of natural resource stock is an indicator of the consumption of final demand to drive social production and investment (Dechert and Nishimura, 2012).

At the steady states, both growth rates of capital accumulation and renewable resource stock interactively have impacts on the marginal utility of consumption in the following equations, so the relationships between capital stock and resource stock can be argued when all resources are renewable:

$$U_c = \lambda_1 + \gamma\lambda_2, \tag{22}$$

$$U_R = c_R(\lambda_1 + \gamma\lambda_2), \tag{23}$$

$$U_l = c_l(\lambda_1 + \gamma\lambda_2), \tag{24}$$

$$U_\gamma = c_\gamma(\lambda_1 + \gamma\lambda_2) + c\lambda_2. \tag{25}$$

P1. The marginal changes of renewable resource stock must slower than the proportional changes of renewable resource consumption utility in the share of total expenditure, $\lambda_2 < (U_\gamma / c)$, when $U'(\gamma_t) > 0, U'(c_{t-1}) > 0, U''(c_t) < 0$ and $\lim_{c \to 0} U'(c) = \infty$, $c > 0$ and $c_\gamma > 0$.

Proof of *P1*:

$$\exists\Phi = \lambda_2 - \frac{U_\gamma}{c} = \lambda_2 - \frac{\lambda_1 c_\gamma + \lambda_2 c + \lambda_2 \gamma c_\gamma}{c} = -\frac{(\lambda_2\gamma + \lambda_1)}{c},$$

from (25); when (22) is held, and $U'(c_{t-1}) > 0$,

$$\Phi = \lambda_2 - \frac{U_\gamma}{c} = -\frac{(\lambda_2\gamma + \lambda_1)}{c} < 0,$$

so that $\lambda_2 < (U_\lambda/c)$ is proved. ■

P2. Renewable resource stock will not reduce on the optimal path of sustainable development when an inertial tendency of renewable resource consumption is holding over time, $\dot{m}_t > \dot{m}_{t-1}$; and the speed of capital accumulation is faster than the speed of renewable resource stock accumulation, $\left(\left(\dot{\lambda}_1/\lambda_1\right) - \left(\dot{\lambda}_2/\lambda_2\right)\right) > 0$; and the growth rate of technology A at time t is beyond the expected depreciation rate of capital stock δ over the saving rate s for an investment in the next time period, $A > \delta/s$. Otherwise, renewable resource stock will decrease.

Proof of *P2.* $\exists g_m = \dot{m}/m$, rewrite (21):

$$\frac{\dot{\lambda}_2}{\lambda_2} = \rho - g_m = \rho - \frac{\dot{m}}{m},$$

and tidy it to reach $\dot{m}_t = m_t\left(\rho - \left(\dot{\lambda}_2/\lambda_2\right)\right)$ and itinerate to one period of the previous level on the optimal path, then we have $\dot{m}_{t-1} = m_{t-1}\left(\rho - \left(\dot{\lambda}_2/\lambda_2\right)\right)$ with plugging a reformatted (20) $\rho = \dot{\lambda}_1/\lambda_1 + sA - \delta$ to reach:

$$m_t - m_{t-1} = (\dot{m}_t - \dot{m}_{t-1})/\left(\frac{\dot{\lambda}_1}{\lambda_1} - \frac{\dot{\lambda}_2}{\lambda_2} + sA - \delta\right) > 0,$$

when $\dot{m}_t > \dot{m}_{t-1}$, if $\left(\dot{\lambda}_1/\lambda_1\right) - \left(\dot{\lambda}_2/\lambda_2\right) > 0$, and only if $A > \delta/s$ when $s > 0$.

Corollary 1. $\rho > \dot{\lambda}_2/\lambda_2$, the subjective discount rate of consumption utility must be strictly greater than the convergence speed of renewable resource stock accumulation only if increasing capital accumulation $\dot{\lambda}_1/\lambda_1 = \rho - sA + \delta$ is held on the optimal path when $m_t > m_{t-1}$ under the premise of renewable resource stock has an inertial tendency of changes over time, $\dot{m}_t > \dot{m}_{t-1}$.

Proof of Corollary 1. Recall:

$$m_t - m_{t-1} = (\dot{m}_t - \dot{m}_{t-1})/\left(\frac{\dot{\lambda}_1}{\lambda_1} - \frac{\dot{\lambda}_2}{\lambda_2} + sA - \delta\right) > 0,$$

by plugging (20) to reach:

$$m_t - m_{t-1} = (\dot{m}_t - \dot{m}_{t-1})/\left(\rho - \frac{\dot{\lambda}_2}{\lambda_2}\right) > 0,$$

if $m_t > m_{t-1}$ is held, then, $\rho > \left(\dot{\lambda}_2/\lambda_2\right)$ is proved when $\dot{m}_t > \dot{m}_{t-1}$:

Corollary 2. Sustainable development cannot be sustained without successive social production if $\rho \in (0, 1)$.

Proof of Corollary 2. If $\rho \in (0, 1)$, $\rho > (\dot{\lambda}_2/\lambda_2)$ can be held only if $(\dot{\lambda}_2/\lambda_2) \in (-\infty, 1)$, so that $m_t > m_{t-1}$ is held when $\dot{m}_t > m_{t-1}$ only if $(|\dot{\lambda}_2/\lambda_2|) > \rho$; otherwise $m_t > m_{t-1}$ by supposed $\rho \neq (\dot{\lambda}_2/\lambda_2)$ and $m_t \neq m_{t-1}$; under the premise of $(\dot{\lambda}_2/\lambda_2) \in (-\infty, 1)$ to consider (21) $(\dot{\lambda}_2/\lambda_2) = \rho - g_{m_t} < 1$, then reach $g_m = \rho - (\dot{\lambda}_2/\lambda_2)$, if $(|\dot{\lambda}_2/\lambda_2|) > \rho > 0$, and when $g_m < 0$ which is equivalent to $m_t < m_{t-1}$, and disobeys the premise of $m_t > m_{t-1}$, so that Corollary 2 is proved. ■

There are two main arguments about the subjective discount rate of consumption utility. First in Corollary 1, the cost of environmental degradation induces the uncertain gap between the subjective discount rate and the individual discount rate (Weitzman, 1994). Because the former is a calculated value of intergenerational discrepancies on valued economic entities which have strong relationships with a real interest of individual's consumption preference and a practical discounted utility elasticity over time. In other words, it is a leverage to evaluate the time preference of any consumption over generations, whereas the individual's discount rate is usually varied from social discount rate due to the discrepancies between public cost and private benefit. Weitzman (1994) argued that private discount rate should be higher than social discount rate due to an increase of the cost of environmental degradation. Shapiro (2005) further argued that the "permanent income hypothesis" (Friedman and Savage, 1948; Friedman, 1957) for emphasizing anticipated income in a life-cycle consumption fails to be explained by a quasi-hyperbolic discount rate of time preference. It simply means that people prefer consuming more for obtaining hedonic utility rather than following on rational behaviors, so that the optimal steady states consequently will deviate from the saddle path.

Second in Corollary 2, we show that only the successive social production can sustain the sustainable development because the rational decision of investment to risk aversion is primary. Financial crises and chaos at asset market also fail to be well-explained by either Cash-in-advance (Lucas and Stokey, 1985) or money-in-utility (Calvo, 1983) due to "liquidity trap" or "irrational hedging." Arrow *et al.* (2013, 2014) pointed out that a decreasing discount rate (decreasing absolute risk aversion) should be adopted by current central planning and project evaluation of benefit cost in every country, *ad hoc*, in those large open economies with a large population. It clearly presents that the projection of the environmental effects on reducing the GHG emission should be increased, and can be inferred that large countries should invest more on climate change adaptation, R&D for cleaner production and renewable energy to lower environmental impacts on future generation. However, the low efficiency of technology investment toward those huge uncertain fields is just like throwing the money to the "black hole." Thereby, we boldly question on the strategy of GHG emission caps to these large economies. Even though that will not a superior solution for environmental quality improvement and climate change adaptation, some inefficiencies of technology investment can be compromised to approaching intergenerational and environmental equality. In the next session, we further argue with the aging effect of labor production to show the sustainable development fails to be sustained without a certain level of social reproduction of renewable resources dynamically.

4. Dynamics of consumption preference and population aging

Debates on the consumption decision focus on time preference allocated intertemporal utility in the dynamic optimal control theory of macroeconomics, because the population aging has uncertainty on capital accumulation on allocated intergenerational social utility. The aging effect is the major challenge of time preference with changing in the substitution of asset capital to human capital. The life-cycle consumption theory depicts the expenditure prone to following a hump shape because people will spend less when they are getting old which is the aging effect (Gourinchas and Parker, 2002). On the contrary of the Malthusian hypothesis, Lucas (1993) studied the contributions of human capital to the miracles of economic growth in several Asian countries, and emphasized the population growth with knowledge spillover effects shaped the growth path. Because the substitution effect of human capital on asset capital is higher than the inhibiting effect of population growth on technology. Kremer (1993) addressed the contribution of human capital to endogenously economic growth in that with holding a large initial population is prone to have faster economic growth rates. Moreover, Cropper and Griffiths (1994) presented an empirical study that the population growth control failed to mitigate deforestation. Hence, we further question that a higher social production is the main cause of environment degradation.

The preference of economic behavior is much more important than the number of human beings because their efforts ultimately determine happiness, self-improvement and technology innovation, and all of which will reduce the discounted future utility (Becker *et al.*, 1990; Becker and Mulligan, 1997). Thus, it is highly possible that the Environment Kuznets Curve (EKC) has a downward sloping curve when it passed by a turning point of the environmental impacts and the income per capita.

A specific production function (26) introduces an argument of renewable resource stock m with a substitution elasticity of labor production β and a substitution elasticity of capital production α. Divided by labor L at both sides of (26) reaches a production function in the format of per capita (27), and Equation (28) presents the growth rate of social production having relationships with the population aging effect of n. See calculation in Appendix 1:

$$Y' = (\mathrm{AM})^{1-\alpha} K^{\alpha} L^{\beta}, \tag{26}$$

$$y' = f(k) = (Am)^{1-\alpha} k^{\alpha} L^{\beta}, \tag{27}$$

$$g_{y'} = (1-\alpha)(g_A + g_m) + \alpha g_k + \beta n, \quad g_L = n. \tag{28}$$

Bansal and Yaron (2004) proved the growth rate of consumption and its expectation value being predeterminate to the convergence of risk premium due to time preference. Here, it assumes that a proportion i of consumption spent for reducing environmental impacts dynamically weaken capital accumulation over time (or saying a per capita risk payment rate), so that to reach an updated Euler equation of capital accumulation (29); and an updated Euler equation of renewable resource stock under the tidied premise (30):

$$k\cdot = sf(k) - (n+\delta)k - ic_t, \tag{29}$$

$$\dot{m} = g_m m_t - \mu c_t, \tag{30}$$

when:

$$g_k = \frac{\dot{k}}{k} = \frac{s}{\alpha} f'(k) - (n+\delta) - \frac{ic_t}{k},$$

and:

$$g_m = \frac{\dot{m}}{m} = \frac{g_y}{1-\alpha} - \frac{\alpha}{1-\alpha}\left[\frac{s}{\alpha} f'(k) - (n+\delta) - c_t\right] - \frac{\beta_n}{1-\alpha} - g_A.$$

When every unit of renewable resource can be allocated by per capita spending on each kind of final demands, the intertemporal representative individual utility function can be rewritten to an implicit form (31). Where in (31), μ_t presents a predeterminate proportion of renewable resource consumption at time *t*, and being determined by the ratio of renewable resource consumption γ_t, the ratio of leisure hours in total life time l_t, and the relative income R_t at time *t* in a function of $\mu_t = \psi(\gamma_t, l_t, R_t)$, $\mu'(\gamma_t) > 0$, $\mu'(R_t) > 0$, $\mu'(l_t) > 0$. Rewrite the *H* in (32), where the renewable resource stock is determined by the capital accumulation, labor production and innovation on the controlled optimal path in (33):

$$U_t = U_t(c_t, \mu_t)U'(c_t) > 0;\ U''(c_t) < 0;\ \text{and}\ \lim_{c\to 0} U'(c) = \infty, c > 0, \tag{31}$$

$$H = U_{c_t} + \lambda_1[sf(k) - (n+\delta)k - ic_t] + \lambda_2(g_{m_t} m_t - \mu c_t). \tag{32}$$

By solving $\partial H/\partial c$, $\partial H/\partial k$, $\partial H/\partial m$ and $\partial H/\partial \mu$, let $\phi_t = g_{m_t}$ to reach the following equation:

$$\phi_t = \rho - \frac{U''(\mu)}{U'(\mu)}\dot{\mu} = \frac{1}{1-\alpha}\left[g_y - \alpha g_k - (1-\alpha)g_A - \beta_n\right]. \tag{33}$$

Positive externalities of environmental impacts are crucial. Grossman and Krueger (1996) discussed an inverted-U shape of the relationship between per capita the cost of environmental degradation and economic income with aiming to stand for less policy intervention to environment governance. However, they also claimed that "there is nothing automatic about the relationship between economic growth and the environment." Some individual consumption preferences highly likely enable the overconsumption of any kind of resource. Daly (1974) stressed that "a steady-state economy is defined by constant stocks of physical wealth (artifacts) and a constant population." It means that capital at a certain level of economic scale represents a level of stock of physical resources with surviving a certain amount of population via social production. Economic growth thus cannot totally break away from the environment, whereas these control variables used to be overlooked by a "reduced form" in empirical studies. Hedonic utility obtained from resources consumption such as the benefit from natural tourism in forest, wetland and snow mountain does exist and having huge impacts on environmental governance. Hence, it is credible that to limit social production for reducing total environmental impacts is not a wise solution. Even with the aging effect of population increases, the economic growth enables to harmonize environmental quality in a higher level of social reproduction when the relative income derives a higher level of consumption toward a conspicuous environmental-friendly manner.

The cross-term consumption decisions have impacts on relative income redistribution, and reallocate the aggregated utility over the life cycle. Guest and McDonald (2001, 2010) emphasized that a small open economy with a relatively lower per capita income is prone to catching-up with those developed large open economies with a relatively higher per capita income when the discounting time is considered to influence the future consumption utility by throughputs and innovation. It disobeys that Uzawa (1968) stated that poor country may have more patience to sustain a lower economic growth and a lower technology progress over time. In addition, except China, countries with a lower per capita income and a higher saving rate fail to keep a higher economic growth rate. This means that the economic growth *ex proprio vigore* fails to fully explain the economic performance of a nation. The evidence of case studies in behavioral economics shows an increasing dissatisfaction to underline the capital accumulation and overlook the real production and resource flows (Ljungqvist and Uhlig, 2000; Frey and Stutzer, 2002). Thereby, we examine the divergences of the subjective discount rate of consumption utility from the growth rate of renewable resource stock. The former is lower than the later if the EKC does have a turning point and vice versa:

P3. When $\dot{\mu} > 0$ and $U'(\mu) > 0$:

(1) If the EKC does have a turning point, there is:

$$\rho < \frac{1}{1-\alpha}\left[g_y - \alpha g_k - (1-\alpha)g_A - \beta_n\right],$$

(2) If the EKC does not have a turning point, there is:

$$\rho > \frac{1}{1-\alpha}\left[g_y - \alpha g_k - (1-\alpha)g_A - \beta_n\right].$$

Proof of *P3.* Recall $U(\mu)$, if the EKC has a turning point, when $U''(\mu) < 0$, $\dot{\mu} > 0$ and $U'(\mu) > 0$, so that $\left(U''(\mu)/U'(\mu)\right)\dot{\mu} < 0$, $\rho - \phi_t < 0$, and because (33) is held, then it is proved; if the EKC does not have a turning point, when $U''(\mu) > 0$, $\dot{\mu} > 0$ and $U'(\mu) > 0$, so that $\left(U''(\mu)/U'(\mu)\right)\dot{\mu} > 0$, $\rho - \phi_t > 0$, and because (33) is held, then it is proved. ■

5. Environmental tax and scale effect on a large open economy

We test the gap between the distorted time preference and the growth rate of renewable resources consumption, by applying *a simili* experimental fiscal policy as either taxation or subsidy for environmental quality improvement (Sibert, 1990; Daly, 1992).

By employing a specific consumption utility function (34), the relative environmental income is predeterminate to the renewable resource consumption μ, e.g.:

$$U(c_t) = \frac{\left(\mu_t c_{t-1}\right)^{1-\sigma} - 1}{1-\sigma}, \tag{34}$$

where $\mu_t = (1 + l_t + \gamma_t + R_t)$, and $c_t = \mu_t c_{t-1}$.

Rewrite (33) to reach:

$$\frac{\dot{\mu}}{\mu} = -\frac{U'(\mu)}{U''(\mu)\mu}(\phi_t - \rho).$$

The expectation value of renewable resource consumption utility is allocated by intertemporal preference (35), so that the growth rate of renewable resource consumption can be presented by (36):

$$E(U(c_t)) = -\frac{U'(c_t)}{U''(c_t)c_t} = \frac{1}{\sigma}, \tag{35}$$

and:

$$E\left(U\left(\mu_t\right)\right) = -\frac{U'\left(\mu_t\right)}{U''\left(\mu_t\right)\mu_t} = \frac{1}{\sigma},$$

$$g_\mu = \frac{\dot{\mu}}{\mu} = \frac{1}{\sigma}(\phi_t - \rho). \tag{36}$$

Rewrite (36) to have an equation with arguing the per capita consumption utility time preference $\sigma = (\phi_t - \rho)/g_\mu$. Let $\tau = (\rho - \phi_t)$ present the gap between time preference and practical growth of renewable resource consumption. The intertemporal consumption utility time preference is determined by this taxation rate and the growth of renewable resource consumption (37). In that, the consumption time preference is endogenous (Gong, 2006):

$$\sigma = \frac{-\tau}{g_{\mu}}, \left(g_{\mu} \neq 0\right). \tag{37}$$

5.1 *With scale effect*

The "scale effect" in the endogenous growth model mainly relies on knowledge spillover. Basu and Weil (1998) pointed out that knowledge spillover cross-countries even with no cost which brings about the technology growth contributed to capital accumulation globally. Segerstrom (1998) stated that both Romer and Lucas addressed innovation increasing the economy scale, and these scale effects have significant impacts on economic growth (Jones, 1999). The Mundell–Fleming model gives an extreme simplified model to describe saving is perfectly equivalent to investment (Laibson, 1997; Mendoza, 1991); however, it is not true in a real business cycle (Cannell, 1999). In a real business cycle, the intertemporal consumption time preference clearly distinguishes between savings and investment, so that the relative income determines the trade-offs between consumptions and savings.

Some inefficient technology investment crowd out wages to shrinking the consumption, and mitigate a constant labor force with increasing resource consumption and income inequality. However, because the relative income is higher, the economic scale effect can save their people to a higher living standard even if a nation suffers from income inequality severely. In this case, the "income inequality is not harmful for growth" (Li and Zou, 1998).

For a large open economy in global trade, the real exchange interest presents the relative value of a nation and has impacts on the premium changes of domestic assets. When all resources are renewable, the premium of domestic asset should have presented the renewable resource consumption with regard to the capital inflows, so that an internal debt-elastic interest rate (Schmitt-Grohé and Uribe, 2003; Uribe and Schmitt-Grohé, 2016) can be modified to (38)–(40), where the interest rate i equals to a per capita risk payment rate i^* plus the premium rate of renewable resource consumption $p(\mu_t)$ at time t:

$$i_t = i^* + p\left(\mu_t\right), \tag{38}$$

$$\dot{i}_t = i^* + p\left(\mu_t\right) + p'\left(\mu_t\right)\mu_t, \tag{39}$$

$$U(c_t) = \left[1 + i^* + p\left(\mu_t\right) + p'\left(\mu_t\right)\mu_t\right] E_t(U(c_t))(c_{t+1}, \ldots). \tag{40}$$

P4. The relative capital income and premium of every unit of asset deterministically affect every unit of renewable resource consumption:

$$\mu_t = \frac{-\left(i_t - i^*\right)}{p'\left(\mu_t\right)}.$$

This is the ratio between the detrend of interest rate and the marginal premium of renewable resource consumption.

Proof of *P4*. See detailed steps of Hamiltonian in Appendix 2.

Corollary 3. The detrend of the premium elasticity of renewable resource consumption is smaller than the marginal change of renewable resource consumption when the detrend of the marginal premium of renewable resource consumption is positive and vice versa:

(1) $\varepsilon_{p(\mu_{t+1})}/\varepsilon_{p(\mu_t)} < \mu_t/\mu_{t+1}$, when $p'(\mu_{t+1})/p'(\mu_t) > 0$; and

(2) $\varepsilon_{p(\mu_{t+1})}/\varepsilon_{p(\mu_t)} > \mu_t/\mu_{t+1}$, when $p'(\mu_{t+1})/p'(\mu_t) < 0$.

Proof of Corollary 3. Recall *P3*(1) if the EKC has a turning point, when $\dot{\mu} > 0$, there has $\mu_{t+1} - \mu_t > 0$ or $\mu_{t+1}/\mu_t > 1$, and $\mu_t \neq 0$. See detailed steps in Appendix 3.

Corollary 3 states that the premium $p(\mu_t)$ changes determine the elasticity of renewable resource consumption against the "inertia effects" of consumption. In particular, the relative income drives that relative consumption changes across oversea countries that have huge impacts on global trading valuable raw materials, vacation tours and insurance with the consumption preference changes over time (Alpizar *et al.*, 2005). These relative consumption changes dynamically influence the changes of relative income.

The free trade is not free because these relative income differences have huge impacts on overseas relative purchasing power parity of an open economy in a real business cycle. Obstfeld and Rogoff (2000) found that the terms of trade and exchange rate are more consistent than pricing system over time. Lane (2001) pointed out the exchange rate as a premium of capital inflows reflecting the relative speed of domestic capital accumulation. It illustrates that the relative resource flows present relative changes in capital stock, so that the international financial market should have signaled the relative resource stock changes on the right track. However, some innovations of financial derivative products highly likely distort asset pricing. For instance, the quantitative easing easily affects the inflation rate to distort the price of capital stock, consequently arouses uncertain price signal to either asset market or international commodity market.

5.2 Without scale effect

The relative renewable consumption becomes more important to capital accumulation when we test the total scale effect of technology innovation transferred to individual utility. By learning from the studies of tax incidence (Turnovsky, 1982; Asea and Turnovsky, 1998), we examine the growth of renewable resource consumption in a real business cycle with a taxation distortion of relative environmental income. Recall Equation (8), let w_t as an average wage of labor force:

$$\mathrm{TI}_t = y_t = r_t k_t + \eta_t m_t + w_t \geqslant (1+\tau)(c_t + i_t + x_t) + s_t y_t + \tau y_t. \tag{41}$$

Denoted $p(\mu_t)$ is a function of μ_t. $c(p(\mu_t))$ is an implicitly composite function of μ_t. Recall Equations (38)–(40), the deviation of a per capita risk payment rate i^* at time t is caused by $p(\mu_t)$. If μ_t presents all final demands of renewable resource consumption at time t, there has $i^* = [y^*(1-s^*-\tau^*)/(1+\tau^*)] - c^* - x^*$ when there is an optimal taxation rate of environmental degradation on the saddle path. In addition, a lump sum of this taxation is proposed to be set on every unit of renewable resource exploration without any burdens on capital earning at an initiative level. Equation (39) can be rewritten to (42) with holding the updated Euler Equations (43)–(44):

$$\dot{i} = [y(1-s-\tau)/(1+\tau)] - c_t - x_t + p(\mu_t) + p'(\mu_t)\mu_t, \tag{42}$$

$$\dot{k} = sf(k) - (n+\delta)k - c_t(1+\tau+i), \tag{43}$$

$$\dot{m} = g_m m_t - \mu c_t(1+\tau). \tag{44}$$

Rewrite H, and recall Equation (28) $y = f(k) = (Am)^{1-\alpha}k^{\alpha}L^{\beta}$ to solve $\partial H/\partial c$, $\partial H/\partial i$, $\partial H/\partial k$, $\partial H/\partial m$, $\partial H/\partial L$, $\partial H/\partial \mu$, $\partial H/\partial s$, $\partial H/\partial x$ and $\partial H/\partial \tau$ to reach v_1, v_2 and v_3 in (45). Tidy them up to get an equation of c_t, then calculate $\partial c/\partial s$ in (46) which the consumption externalities are caught by $(1+\tau)(U_s/U_x)$:

$$v_1 = U_x; v_2 = U_x/(1+\tau)-U_s/y; v_3 = [U_c-U_x-(1+\tau+i)v_2]/(1+\tau)\mu, \tag{45}$$

$$\frac{\partial c}{\partial s} = -\frac{1}{(i^*+p(\mu_t))\left(1-(1+\tau)\frac{U_s}{U_x}/y\right)}y, \text{ if } \lim_{U_x\to U_c}\frac{U_c}{U_x} = 1, U_x \neq 0. \tag{46}$$

P5. Spillover effects of consumption externality generated from saving or consuming every unit of renewable resource for social production determine the convergence of capital accumulation on the controlled optimal path to increase the total social production level if all individual utility is transferable from renewable resource consumption (46).

Proof of *P5*. See detailed steps of Hamiltonian in Appendix 4.

Corollary 4. An increase of every unit of the premium of renewable resource increases the current consumption, and decreases the saving for future consumption of renewable resource when the spillover effect is consistent.

Proof of Corollary 4. If $p'(\mu_t) > 0$, $i^* + p(\mu_t)\uparrow$, when $(1+\tau)(U_s/U_x)/y$ is consistent:

$$\frac{1}{(i^*+p(\mu_t))\left(1-(1+\tau)\frac{U_s}{U_x}/y\right)}\downarrow,$$

then $\partial c/\partial s\uparrow$ is proved. ■

Corollary 5. An increase of consumption externality obtained from saving over consuming renewable resource decreases the current consumption, and increases the saving for future consumption of renewable resource when the premium of renewable resource is consistent.

Proof of Corollary 5. If $(1+\tau)(U_s/U_x)\uparrow$, when $i^* + p(\mu_t)$ is consistent:

$$\frac{1}{(i^*+p(\mu_t))\left(1-(1+\tau)\frac{U_s}{U_x}/y\right)}\uparrow,$$

then $\partial c/\partial s\downarrow$ is proved. ■

Corollary 6. An increase of environmental taxation decreases the current consumption, and increases the saving for future consumption of renewable resource through both asset pricing and spillover effect of an open economy when relative utility obtained from saving over consuming renewable resource is consistent.

Proof of Corollary 6. Recall Equation (37), $\tau = -\sigma g_{\mu}$, $(g_{\mu}\neq 0)$, if $\tau\uparrow, g_{\mu}\downarrow$ when σ is given, $p'(\mu_t) < 0$, $i^* + p(\mu_t)\downarrow$, when U_S/U_x is consistent:

$$\frac{1}{(i^*+p(\mu_t))\left(1-(1+\tau)\frac{U_s}{U_x}/y\right)}\uparrow,$$

then $\partial c/\partial s\downarrow$ is proved. ■

Because capital income is the earning from the returns on saving or investment, either a close economy or an open economy is driven by saving rises when multiplier effects are small due to low substitution effects between capital and labor. It brings a question on what is the saving and how to evaluate it. For instance, Hamilton and Clemens (1999) studied that the savings of developing countries are much lower than developed countries in resource exploration, human capital and environmental degradation. Karlan *et al.* (2017) evaluated that the savings-led microfinance programs have a positive effect on improving the lives of the poor in African countries. However, preferences and behaviors lead to some financial crises to have a huge uncertainty of global capital accumulation and an international inequality of wage changes in the long run (Dinopoulos and Thompson, 1999). People from developed countries much more care about clean water and air than those from developing countries with relative lower income. Hence, by learning from the past, the fiscal policy to increase capital inflow is much better than the monetary policy to those large open economies (Sachs, 1996).

The taxation rate on those potential environmental degradation should have redistributed social welfare to improve equality issues. Nguyen-Van and Pham (2013) approached to some similar results as Schumacher (2015) did that both consumption and environmental qualities get improved under the assumption of Leontief social utility function, so that the investment on public infrastructures has no distortions on the economic growth of a nation. However, in a real business cycle, the tax incidence is a headache in public finance to have some uncertain burdens on various economic components under predetermined conditions:

P6. Environmental taxation ultimately burdens on the international consumption side when international resource consumption utility is taken into the model of a large open economy without a scale effect (49)[3].

Proof of *P6*. Recall $U_\mu = v_3(1+\tau)(c_t+\mu c_\mu)+[c_\mu - p'(\mu_t) - p''(\mu_t)]v_1$, $v_3 = \{U_c - U_x - (1+\tau+i)[U_x/(1+\tau) - U_s/y]\}/(1+\tau)\mu$, $\tau = -\sigma g_\mu$, $(g_\mu \neq 0)$ and $x_t = x(c_{t-1}, \gamma_t, l_t, R_t)$. Set $D(\mu) = U_\mu + [p'(\mu_t) + p''(\mu_t)]U_x$ to reach $\tilde{u}_\mu = D(\mu)/\mu$. Let $B(\tau) = U_c - [U_x(1+\tau+i)/(1+\tau)] + [U_s(1+\tau+i)/y]$ and calculating μ in (47) to reach $\dot{\mu}/\mu$ the implicit proportion of marginal changes in renewable resource consumption in (48):

$$\mu = \frac{B(\tau) - U_x}{D(\mu) - B(\tau)c_\mu} c_t, \tag{47}$$

$$\frac{\dot{\mu}}{\mu} = g_\mu = -\frac{\tilde{u}_\mu}{\tilde{u}_\mu - B(\tau)\left(c_\mu + c_{\mu\mu}\right)} = \frac{1}{\sigma}(-\tau), \tag{48}$$

$$\frac{\partial \tilde{u}_\mu}{\partial \tau} = \tilde{u}_\mu + \left(c_\mu + c_{\mu\mu}\right)\left[B'(\tau)\tau + B(\tau)\right]. \tag{49}$$

Equation (49) shows that the tax incidence of a lump sum of environmental taxation will ultimately burden on the consumption side across various countries without scale effect and population aging effect. Here, every unit of renewable resource consumption is predetermined by the implicit proportion of marginal changes in renewable resource consumption which is shaped by consumption utility changes. Thus, this experimental taxation rate on those potential environmental degradation redistributes global welfare, but burdens on international consumers.

6. Discussion

The relative consumption induced renewable resource stock changes in fact is more significant to reflect the gap between demand and supply than just emphasizing the cost of environmental impacts from the supply side. The relative environmental income from various local environmental amenities are significant driving forces on relative consumption having impact on the growth of international capital accumulation and throughputs; even though great efforts are paid to the evaluation of economic valuation to natural resource and the cost of environmental impacts on soil erosions, water pollution, fishing stock shrinks, vegetation degradation and climatic adaptation (Brennan and Schwartz, 1985; Pimentel *et al.*, 1995; Reddy and Chakravarty, 1999; Balmford *et al.*, 2002; Chari and Kehoe, 2006; Richardson *et al.*, 2007; Drabo, 2011). It leads to public perceptions of fiscal policies on resource allocation and income redistribution becomes more decisive to trace the growth optimal path (Wang and Deng, 2017). Based on that, we examine the relative environmental income and its relevant fiscal policy from the consumption side to discuss savings and relative consumption impact on the dynamics of capital accumulation and renewable resource stock changes.

The relative consumption predetermines the renewable resource stock changes and shapes the evolutionary growth of capital accumulation with the advanced technology. First, if the EKC has a turning point, the subjective discount rate of consumption utility must be smaller than the growth of renewable resource stock; otherwise, renewable resource stock cannot be sustained on the controlled optimal pathway of sustainable development. For a large open economy, the marginal premium of renewable resource consumption crowds out the relative savings and predetermines the future relative consumption. It means that every unit of renewable resource can be transferred to either every unit of relative capital income or every unit of consumption utility with respect to the savings changes over time. That indicates every unit of environmental-friendly investment highly likely earns a higher return because the relative environmental income increases both saving and positive consumption externality that increases future savings.

The evidence of scientific research and practical economic performance have showed some successes of returns on ecological investment to the forestry construction of ecological projects in China (Jiang *et al.*, 2014; Wang, Deng, Song, Li and Chen, 2017). By comparing some regions without those projects, some agricultural expansions meet food demands which has significant impacts on tropical forest, but generating very low positive consumption externalities, and increasing uncertainties to local sustainable environment development (Barbier and Burgess, 1997, 2001). In those regions, there is no assured of a foresight turning point on the EKC (Bimonte, 2002; Kijima, Nishide and Ohyama, 2010). On the contrary, a higher level of cleaner production provides more renewable resources to satisfy a higher level of consumption with more positive environmental externalities for benefiting to increase relative environmental income in China's development. Both cleaner production and consumption at a higher level enable to promote economic growth with lowering the environmental effects. To end this discussion, we prefer to quote Veblen (1900, p. 414) that:

> The substitution of hedonism (utility) in the place of industry as the central and substantial fact in the process of production is due not to the acceptance of hedonism simply, but rather to the conjunction of hedonism with an economic situation of which the investment of capital and its management for gain was the most obvious feature.

7. Conclusion

This research shows that the relative environmental income drives economic growth of a large open country. We demonstrate a theoretical mechanism to explain the miracle of China's economic growth with decreasing environmental effects. We show that the renewable resource stock will not reduce in sustainable development when its marginal changes slower than the proportional changes of renewable resource consumption utility in the share of total expenditure, and the growth of technology is beyond the expected depreciation rate of capital stock over the saving rate for an investment in the next time period, $A > \delta/s$, if renewable resource stock has an inertial tendency of changes over time. Hence, a higher-level social production of all renewable resources in fact with scale effect drives economic growth in a sustainable manner.

This research emphasizes that the spillover effect of relative utility transferred from every unit of social production produces the positive consumption externality transferred to future saving or consumption. We introduce that an experimental taxation to show this spillover effect without scale effect determines the convergence of capital accumulation on the controlled optimal path. An increase of this taxation decreases the current consumption, and increases the saving for future consumption of renewable resource through both asset pricing and spillover effect of an open economy when relative utility obtained from saving over consuming renewable resource is consistent. Thus, the tax incidence ultimately burdens on the international consumption side when the relative environmental income drives the international resource consumption and the capital inflows to a large open economy.

This research implies that a social norm of environmental-friendly behaviors shapes the consumption preference to the double effect on the relative income redistribution. When international consumers intended to behave more environmental friendly, the premium of relative renewable resource consumption drives their relative environmental income changes. Only a higher level of social production of renewable resource can lower the cost of this relative consumption transferred to savings. Hence, the increase of domestic savings compensates the loss of relative asset pricing changes. The side effects of relative income growth can be reduced by absorbing the relatively lower pricing capital inflows. In that, the relative environmental income growth contributes to economic growth in the progress of cleaner production because a higher-level saving or ecological investment drives capital accumulation with lowering the negative consumption externalities and the inequality of both income and environmental quality. Therefore, we demonstrate a theoretical mechanism of the miracle in China's development with the double effect on improving economic performance and decreasing environmental effects. A foresight is how to earn the environment income determines the future pathway of China's rural conversion to the era of eco-urbanization.

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Notes

1. Individual utility follows the law of decreasing marginal utility, so that the second derivative of utility function with respect to consumption is negative. Thus, the utility function is premised in a concave convergence with a maximum consumption value (Cass, 1965; Barro, 1974).
2. Suppose "economic man" holds the hedonic preference of consumption during leisure hours to reach a higher level of happiness (Veblen, 1900; Turnovsky, 1982).
3. Turnovsky (2011) addressed that the lag of policy can distort the anticipated outcomes of macroeconomic performance. Dynamic central policies in fact stabilize the optimal level according to the dynamic control theory. Thus, we further detect the impact of environmental tax on the dynamics of renewable resource consumption.

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Appendix 1. Derivation of the relationships among the per capita growth rate of production factors of capital *K*, labor *L* and renewable resource stock *M*.

$$Y = (\mathrm{AM})^{1-\alpha}(\mathrm{KL})^{\alpha}, \tag{A1}$$

$$\frac{Y}{KL} = (\mathrm{AM})^{1-\alpha}(KL)^{\alpha-1} = \left(A\frac{M}{\mathrm{KL}}\right)^{1-\alpha} = (Am)^{1-\alpha}, \tag{A2}$$

$$y = (Am)^{1-\alpha}, \tag{A3}$$

$$\dot{y} = \frac{dy}{dt} = (1-\alpha)A^{-\alpha}\frac{dA}{dt}m^{1-\alpha} + (1-\alpha)m^{-\alpha}\frac{dm}{dt}A^{1-\alpha}, \tag{A4}$$

$$g_y = \frac{\dot{y}}{y} = (1-\alpha)\left(m\frac{dA}{dt} + A\frac{dm}{dt}\right)/Am = (1-\alpha)(g_A + g_m), \tag{A5}$$

$$Y' = (\mathrm{AM})^{1-\alpha}K^{\alpha}L^{\beta}, \tag{A6}$$

$$y' = \frac{Y}{L} = \left(A\frac{M}{L}\right)^{1-\alpha}\left(\frac{K}{L}\right)^{\alpha-1}L^{\beta} = (Am)^{1-\alpha}k^{\alpha}L^{\beta}, \tag{A7}$$

$$\begin{aligned}\dot{y}' = \frac{dy'}{dt} &= (1-\alpha)A^{-\alpha}\frac{dA}{dt}m^{1-\alpha}k^{\alpha}L^{\beta} + (1-\alpha)m^{-\alpha}\frac{dm}{dt}A^{1-\alpha}k^{\alpha}L^{\beta}\\ &\quad + \alpha(Am)^{1-\alpha}k^{\alpha-1}\frac{dk}{dt}L^{\beta} + \beta(Am)^{1-\alpha}k^{\alpha}L^{\beta-1}\frac{dL}{dt},\end{aligned} \tag{A8}$$

$$g_{y'} = \frac{\dot{y}'}{y'} = (1-\alpha)(g_A + g_m) + \alpha g_k + \beta n, \quad g_L = n. \tag{A9}$$

Appendix 2. Proof of *P4*

$$H = U(c_t) + \lambda_1\left[sf(k) - (n+\delta)k - (i + p(\mu_t))c_t\right] + \lambda_2\left[g_{m_t}m_t - \mu_t c_t\right], \tag{A10}$$

$$\text{and solve } \frac{\partial H}{\partial c_t} \text{ to have } U(c_t) = \lambda_1 i + \lambda_1 p(\mu_t) + \lambda_1 p'(\mu_t)\mu_t + \mu_t\lambda_2, \tag{A11}$$

$$i = \frac{U(c_t)}{\lambda_1} - \frac{\mu_t\lambda_2}{\lambda_1} - p(\mu_t) - p'(\mu_t)\mu_t, \tag{A12}$$

$$i_t = i^* + p(\mu_t) = \frac{U(c_t)}{\lambda_1} - \frac{\mu_t\lambda_2}{\lambda_1} - p'(\mu_t)\mu_t, \tag{A13}$$

$$\text{If } U(c_t) = i^*\lambda_1 + \mu_t\lambda_2 \text{ when } p(\mu^*) \text{ is a constant.} \tag{A14}$$

$$\text{Rewrite } i_t = \frac{i^*\lambda_1 + \mu_t\lambda_2}{\lambda_1} - \frac{\mu_t\lambda_2}{\lambda_1} - p'(\mu_t)\mu_t,\ i_t - i^* = -p'(\mu_t)\mu_t \text{ to } \mu_t = \frac{-(i_t - i^*)}{p'(\mu_t)}. \tag{A15}$$

Appendix 3. Proof of Corollary 3

Recall *P3*(1) if the EKC has a turning point, when $\dot{\mu} > 0$, there has $\mu_{t+1} - \mu_t > 0$ or ($\mu_{t+1}/\mu_t > 1$) and $\mu_t \neq 0$:

$$\text{to reach } \frac{\mu_{t+1}}{\mu_t} = \frac{-(i_{t+1} - i^*)}{p'(\mu_{t+1})} \Big/ \frac{-(i_t - i^*)}{p'(\mu_t)} > 1 \text{ from } P4, \tag{A16}$$

$$\text{If } \frac{p'(\mu_{t+1})}{p'(\mu_t)} > 0,\ \text{so that } \frac{i_{t+1} - i^*}{i_t - i^*} > \frac{p'(\mu_{t+1})}{p'(\mu_t)},\ \text{and because,} \tag{A17}$$

$$\frac{p'(\mu_{t+1})}{p'(\mu_t)} = \frac{(\Delta p(\mu_{t+1})/\Delta\mu_t)(\mu_{t+1}/p(\mu_{t+1}))(p(\mu_{t+1})/\mu_{t+1})}{(\Delta p(\mu_t)/\Delta\mu_{t-1})(\mu_t/p(\mu_{t-1}))(p(\mu_t)/\mu_{t-1})} > 0, \tag{A18}$$

$$\text{Let } \varepsilon_{p(\mu_t)} = \frac{\Delta p(\mu_t)/p(\mu_t)}{\Delta\mu_t/\mu_t} = \frac{\Delta p(\mu_t)}{\Delta\mu_t}\frac{\mu_t}{p(\mu_t)},\ \text{to have} \frac{p'(\mu_{t+1})}{p'(\mu_t)} = \frac{\varepsilon_{p(\mu_{t+1})}}{\varepsilon_{p(\mu_t)}}\frac{p(\mu_{t+1})}{p(\mu_t)}\frac{\mu_t}{\mu_{t+1}}, \tag{A19}$$

$$\text{and itinerate to } i_{t+1} = i^* + p(\mu_{t+1})\ \text{ from } i_t = i^* + p(\mu_t), \tag{A20}$$

$$\text{then, we have } \frac{i_{t+1}-i^*}{i_t-i^*} > \frac{p'(\mu_{t+1})}{p'(\mu_t)} = \frac{\varepsilon_{p(\mu_{t+1})}}{\varepsilon_{p(\mu_t)}}\frac{i_{t+1}-i^*}{i_t-i^*}\frac{\mu_t}{\mu_{t+1}} > 0, \tag{A21}$$

$$\text{and rewrite to } \frac{\varepsilon_{p(\mu_{t+1})}}{\varepsilon_{p(\mu_t)}}\frac{\mu_t}{\mu_{t+1}} < 1,\ \text{and because} \frac{\mu_{t+1}}{\mu_t} > 1, \tag{A22}$$

$$\text{so Corollary 3(1)} \frac{\varepsilon_{p(\mu_{t+1})}}{\varepsilon_{p(\mu_t)}} < \frac{\mu_t}{\mu_{t+1}}\ \text{is proved if } \frac{p'(\mu_{t+1})}{p'(\mu_t)} > 0, \tag{A23}$$

$$\text{If } \frac{p'(\mu_{t+1})}{p'(\mu_t)} < 0,\ \text{there is } \frac{i_{t+1}-i^*}{i_t-i^*} < \frac{p'(\mu_{t+1})}{p'(\mu_t)},\ \text{so that } \frac{\varepsilon_{p(\mu_{t+1})}}{\varepsilon_{p(\mu_t)}}\frac{\mu_t}{\mu_{t+1}} > 1, \tag{A24}$$

$$\text{and because } \frac{\mu_{t+1}}{\mu_t} > 1,\ \text{so Corollary 3(1)} \frac{\varepsilon_{p(\mu_{t+1})}}{\varepsilon_{p(\mu_t)}} < \frac{\mu_t}{\mu_{t+1}}\ \text{is proved if } \frac{p'(\mu_{t+1})}{p'(\mu_t)} > 0, \tag{A25}$$

$$\text{and because } \frac{\mu_{t+1}}{\mu_t} > 1\ \text{, so Corollary 3(2)} \frac{\varepsilon_{p(\mu_{t+1})}}{\varepsilon_{p(\mu_t)}} > \frac{\mu_t}{\mu_{t+1}} \text{is proved if } \frac{p'(\mu_{t+1})}{p'(\mu_t)} < 0. \tag{A26}$$

Appendix 4. Proof of *P5*

Recall Equations (27) and (32) to have $y = f(k) = (Am)^{1-\alpha}k^\alpha L^\beta$, and $\tau = (\rho-\phi_t)$, solve $\partial H/\partial c$, $\partial H/\partial i$, $\partial H/\partial k$, $\partial H/\partial m$, $\partial H/\partial L$, $\partial H/\partial \mu$, $\partial H/\partial s$, $\partial H/\partial x$ and $\partial H/\partial \tau$ from H:

$$H = U(c,\mu,\tau,s,x) + v_1\left\{\left[(Am)^{1-\alpha}k^\alpha L^\beta(1-s-\tau)/(1+\tau)\right] - c_t - x_t + p(\mu_t) + p'(\mu_t)\mu_t\right\}$$

$$+ v_2[sf(k)-(n+\delta)k-(1+\tau+i)c_t] + v_3\left(g_{m_t}m_t - \mu(1+\tau)c_t\right),$$

to reach the following equations:

$$U_c = v_1 + v_2(1+\tau+i) + v_3\mu(1+\tau), \tag{A27}$$

$$U_\mu = v_3(1+\tau)\left(c_t+\mu c_\mu\right) + \left[c_\mu - p'(\mu_t) - p''(\mu_t)\right]v_1, \tag{A28}$$

$$U_\tau = v_1\left[(1+\tau)^{-1} + (1-s-\tau)(1+\tau)^{-2}\right]y_t + v_2c_t + v_3\mu c_t, \tag{A29}$$

$$U_s = \left(v_1/(1+\tau) - v_2\right)y_t, \tag{A30}$$

$$U_x = v_1, \tag{A31}$$

$$\frac{\dot{v}_1}{v_1} = \rho + c_t v_2/v_1, \tag{A32}$$

$$\frac{\dot{v}_2}{v_2} = \rho+n+\delta-\left\{s+\left[\alpha(1-s-\tau)/(1+\tau)\right]v_1/v_2\right\}f'(k), \tag{A33}$$

Proof of *P5*. From:

$$\frac{\dot{v}_3}{v_3} = \tau-\left[(1-\alpha)(1-s-\tau)/(1+\tau)\right]f'(m)v_1/v_3. \tag{A34}$$

$$U_\tau = v_1\left[(1+\tau)^{-1}+(1-s-\tau)(1+\tau)^{-2}\right]y_t+v_2c_t+v_3\mu c_t,$$

and $v_1 = U_x$, $v_2 = U_x/(1+\tau)-U_s/y$, $v_3 = [U_c-U_x-(1+\tau+i)v_2]/(1+\tau)\mu$., solve $\partial c/\partial s$ to have the following equations:

$$c_t = \frac{U_\tau-v_1\left[(1+\tau)^{-1}+(1-s-\tau)(1+\tau)^{-2}\right]y_t}{v_2+v_3\mu}, \tag{A35}$$

$$c_t = \frac{U_\tau-U_x\left[(1+\tau)^{-1}+(1-s-\tau)(1+\tau)^{-2}\right]y_t(1+\tau)}{[U_c-U_x-i]\left[U_x/(1+\tau)-U_s/y\right]}, \tag{A36}$$

$$\frac{\partial c}{\partial s} = \frac{U_x y}{\left[U_c-U_x-i^*-p(\mu_t)\right]\left[U_x-(1+\tau)U_s/y\right]}, \tag{A37}$$

and if U_c can be transferred to U_x by all throughputs, we get:

$$\frac{\partial c}{\partial s} = -\frac{y}{\left[i^*+p(\mu_t)+1-\frac{U_c}{U_x}\right]\left[1-(1+\tau)\frac{U_s}{U_x}/y\right]},$$

$U_x \neq 0$, so that *P5* is proved. ■

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