Response to Reviewer Comments

Point 1: In the first place, it seems to me that the scholars do not "extend the classic endogenous growth model".

Response 1: Thank you for your comments. This study does extend the classic endogenous growth model (Lucas, 1988; Mankiw et al., 1992) by including leisure in the assessment of production and examines the role of leisure in determining labor productivity both theoretically and empirically.

In this paper, we use Lucas (1988) production function and treat education time as exogenous (Mankiw *et al.*, 1992)[1], and we specify the production function as follows:

$$Y=AK^{\beta}(uH)^{1-\beta} \tag{1}$$

where K is aggregate capital, H is human capital, β is the output elasticity of physical capital, u is education time (total time volume is normalized to 1), and A represents the technical level. When considering the positive effects of leisure time, the accumulation path for A is

$$A=\bar{A}K^{\alpha}l^{1-\alpha} \tag{2}$$

where $\bar{A}$ is the parameter of the technical level and l denotes leisure time. α indicates the elasticity of K to A, and $1-\alpha$ indicates the elasticity of l to A.

Equation (2) shows that technical accumulation combines two processes: the process of "learning by doing" (K^{α}) and the process of "learning through leisure" ($l^{1-\alpha}$)[2], as we call it. The former process has been clearly elaborated by Romer (1986). The latter implies that "creative" leisure produces technological externalities for society. In other words, if activities performed during leisure time are enjoyable and constructive, they benefit individuals' and their counterparts' physical strength, willpower, and creativity. Although the effect of an individual's participation in such leisure on the whole economy may be too weak to notice, the accumulated aggregate effect can be a huge and "unexpected" knowledge accumulation that generates further positive externalities and increases the overall level of technology in the economy (Romer, 1990).

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[1] By treating human capital as an endogenous variable (Lucas, 1988), we can measure an endogenous accumulating path of human capital. This treatment does not affect the main conclusion about the optimal path of labor productivity in our study. For simplicity, we do not pursue this issue here.

[2] $1-\alpha$ is the technological elasticity of leisure time. Leisure time has a decreasing marginal return to the technological level, i.e., $0<1-\alpha<1$. However, there are two situations in which $1-\alpha<0$. First, if leisure time has not been constructively used (i.e., there are sharp increases in such leisure activities as crime, drug use, and illegal sex activities), the formation of new knowledge and creativity will be inhibited (Fogel, 2000). Second, when the income of laborers in low-income countries increases, the substitute effects of leisure time may offset the positive effect of "learning by leisure." In these two cases, $1-\alpha< 0$.

Point 2: learning by doing (not sure how that characteristic was attributed to the capital input), on-the-job upgradation of skills to meet with new technological demands, and so on. Thus, I am not sure of the meaning of separating out the hours spent therein in a formula like 365.24 – u – l.

Response 2: Arrow (1962) and Sheshinski (1967) put forward and strengthened the effect of Learning by doing. They suggested that because the larger the amount of investment in physical capital, the richer the new technological ideas are, the more abundant the basis for exploring, experimenting and accumulating experience can be provided for leaning by doing. Therefore, the technological progress caused by the leaning by doing has a positive correlation with the amount of investment in physical capital. Romer (1986) pointed that with the increase of investment in physical capital, the difficulty of learning by doing increases accordingly. Individuals need to invest more human capital and physical capital to accumulate and create new technological ideas. Therefore, learning by doing has a positive correlation with human capital investment.

Based on this, we proposed the equation (2) as follows:

$$A=\bar{A}K^{\alpha}l^{1-\alpha} \tag{2}$$

Equation (2) shows that technical accumulation combines two processes: the process of "learning by doing" (K^{α}) and the process of "learning through leisure" ($l^{1-\alpha}$)[3], as we call it. The former process has been clearly elaborated by Romer (1986). The latter implies that "creative" leisure produces technological externalities for society.

Moreover, the significance of efficiency lies not only in the ratio of capital to output, but also in the input of working hours. In this study, we want to investigate how to achieve high output with less work time input, and whether activities in leisure time can promote economic efficiency and economic development. Thus, we use per capita per hour GDP to measure labor productivity, just as follows:

$$GDPpp=\frac{\text{per capita GDP}}{\text{average annual worked hours}} \tag{6}$$

Furthermore, this study differs from most previous studies (Gould *et al.*, 2008; Kirchmeyer, 1992; Melamed *et al.*, 1995; Nimrod, 2007; Pagano *et al.*, 2006; Spreitzer and Snyder, 1974; Xie *et al.*, 2018) by considering leisure at the time level instead of taking leisure as activities. Leisure time, is the time when the individual does not work (Robinson and Godbey, 1998). Ramsay and Francis (2009) suggested that leisure time

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should be calculated by subtracting work time, school time from the total available time. we calculated leisure time by subtracting average worked hours and schooling hours from total hours in a year (see formula 7).

l=365×24-(average annual schooling hours)-(average annual worked hours) (7)

Based on the formula 7, we know the "average annual worked hours" can be calculated as follows:

average annual worked hours = 365×24-(average annual schooling hours)- l

$$= 365*24 - u - l.$$

Thus, the labor productivity is

$$GDPpp = \frac{\text{per capita GDP}}{\text{average annual worked hours}} = \frac{\text{GDP}}{(365*24-u-l) * L}$$

Point 3: I could not grasp how leisure and the flow of capital services multiplicatively determined the "technical level" in equation (2). In equation (3), u and l are additively separable.

Response 3: Equation (2) shows that technical accumulation combines two processes: the process of "learning by doing" (K^{α}) and the process of "learning through leisure" ($l^{1-\alpha}$), as we call it. The former process has been clearly elaborated by Romer (1986). The latter implies that "creative" leisure produces technological externalities for society. In other words, if activities performed during leisure time are enjoyable and constructive, they benefit individuals' and their counterparts' physical strength, willpower, and creativity. Although the effect of an individual's participation in such leisure on the whole economy may be too weak to notice, the accumulated aggregate effect can be a huge and "unexpected" knowledge accumulation that generates further positive externalities and increases the overall level of technology in the economy (Romer, 1990).

In this study, we want to investigate how to achieve high output with less work time input, and whether activities in leisure time can promote economic efficiency and economic development. Due to the leisure time can be calculated by subtracting work time, school time from the total available time (Ramsay and Francis, 2009), thus we calculated leisure time by subtracting average worked hours and schooling hours from total hours in a year (see formula 7).

Assuming that human capital accumulation follows an exponential path (Mankiw *et al.*, 1992), after introducing leisure time into the model, the new path takes the following form:

$$H=e^{\psi_1 u+\psi_2(\varepsilon l)}L \quad (3)$$

where L represents the untrained labor force and ψ_1 denotes the magnitude of education time (u)'s effect on the formation of human capital ($dlnH/du=\psi_1$). Similarly, ψ_2 denotes the magnitude of leisure time's (l) effect on the formation of human capital ($dlnH/dl=\psi_2$), which is termed the "advancing through leisure" effect. In other words, various instructive leisure activities will increase individuals' self-fulfillment and self-

realization, creativity, exploration, and productivity (Barnett, 2006; Csikszentmihalyi, 1975; Nimrod, 2007). Note that ε, as a parameter, denotes the proportion of leisure time involved in the formation of human capital, $0 < \varepsilon < 1$.

Point 4: A development of the theme would lead to sociological elements. As the paper stands, I believe 'psychology' would be a more appropriate word in the subtitle.

Response 4: Thank you for your comments. Maybe this study also involves some psychological points of view, but we think it is more sociological.