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**INSTITUTE OF ECONOMICS, ACADEMIA SINICA**  
**TAIWAN**

# **A Two-sector Model of Endogenous Growth with Leisure Externalities\***

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## **Abstract**

This paper considers leisure externalities in a Lucas (1988) type model in which physical and human capital are necessary inputs in both sectors. In spite of a non-concave utility, the balanced growth path is always unique in our model which guarantees global stability for comparative-static exercises. We analyze and quantify the effects of preferences toward leisure on labor supply and welfare. We find that small differences in preferences toward leisure can explain a substantial fraction of differences in hours worked between Americans and Europeans. Quantitative results indicate that these differences also explain why Europeans grow less and consume less, but still prefer their lifestyle to that of the United States.

**Keywords:** leisure externalities, two-sector model, labor supply, economic growth.

JEL Classification: O41, E24.

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## 1. Introduction

Leisure, along with consumption, plays an important role in economic life. A household usually distributes time among different activities, including leisure, work, and investment in human capital. When people take leisure or consume, their behavior influences others. Recently, there has been a growing emphasis on studying consumption externalities.<sup>1</sup> The basic idea of consumption externalities is that the average consumption in a society can influence the returns to other people's consumption. Consumption externalities may in principle impact individual decisions about consumption, savings, capital accumulation, working hours, and ultimately welfare and the rate of economic growth. Externalities may also lead to indeterminate equilibrium paths, breaking the linkage between competitive equilibrium and Pareto optimality. As a result, government intervention might be called for to help internalize these externalities.

Leisure is a key variable in theories of real business cycles; a large fraction of output variation over business cycles can be accounted for by fluctuations in hours worked (e.g., Hansen and Wright, 1992). Leisure is equally important in theories of taxation because taxes on labor income affect an individual's time allocation between productive and non-productive activities. In endogenous growth theories, leisure and labor choices may even affect economic growth in the long run. Oddly, the analysis of leisure externalities has received little attention even though leisure is an important economic variable, and leisure externalities surely exist.

Weder (2004) pointed out that the externalities from leisure could be the outcome of coordination spillovers in communal leisure activities. Jenkins and Osberg (2003) presented evidence of the synchronization of working hours by spouses using the British Household Panel Survey. Their results indicated that propensities to engage in associative activities depend on the availability of suitable leisure companions outside the household. Hamermesh (2002) and Hunt (1998) found similar results using United States and German data, respectively. In the past leisure was the symbol of social status. That concept can be traced back to Veblen's (1899) *Theory of the Leisure Class*. The conspicuous abstention from labor was an assertion of superior status at Veblen's era, but this situation gradually changed after the industrial revolution. In Gershuny's (2005) empirical study, relatively long hours of work are a characteristic of the best-placed individuals in society. Today, "busyness", not leisure, is the "badge of honor." In a word, the accepted standard of leisure in the community to which a person belongs helps determine his individual standard of living (Weder, 2004).

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<sup>1</sup> See, for example, Galí (1994), Ljungqvist and Uhlig (2000), Dupor and Liu (2003), Alonso-Carrera, et al. (2004), Liu and Turnovsky (2005) and Chen and Hsu (2007).

Understanding preferences over leisure activities is particularly important in order to account for observed differentials in hours worked between Americans and Europeans. Evidence suggests a large difference in hours worked between people in the USA and in Europe. Two existing explanations were offered to explain this difference. Prescott (2004) blames the higher effective marginal tax rate on labor income in European countries, while Alesina, et al. (2006) focus on unions and regulations in European countries. In addition to differences in taxes and labor institutions, differences in preferences toward leisure may also be a cause. This paper studies the effect of leisure externalities on labor supply, time allocation and economic growth in an endogenous growth model.<sup>2</sup> We study how the tradeoff between leisure and labor determines the accumulation of human capital<sup>3</sup> in a two-sector endogenous growth model as opposed to the one-sector neoclassical growth model of Prescott (2004) and the reduced form model of Alesina, et al. (2006).

Specifically, we extend the Lucas (1988) model to include both leisure and a leisure externality in preferences. We restrict our attention to a particular type of preferences: the utility is separable in consumption and leisure as assumed in Benhabib and Perli (1994) and Ladrón-de-Guevara, et al. (1997, Section 4.2). In this formulation, the marginal rate of substitution between consumption and leisure is not homothetic along a *Balanced Growth Path* (BGP). Leisure externalities influence competitive equilibrium in the long run. A Lucas (1988) two-sector model with variable leisure was studied by Benhabib and Perli (1994) and Ladrón-de-Guevara, et al. (1997, 1999) who do not consider physical capital to be an input in the education technology. Previous studies have documented that expenditure in material goods and physical investment accounts for a substantial fraction of education spending (e.g., Hall, 1992). We employ a general two-sector model in which physical capital and human capital are both necessary inputs in the two sectors. A model of this type was analyzed earlier by Bond, et al. (1996), Mino (1996), Mulligan and Sala-i-Martin (1993) and Stokey and Rebelo (1995). The choice of two inputs in each sector is important for two reasons. First, it assures a unique BGP and guarantees global stability. Second, technical progress in the goods sector is no longer neutral

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<sup>2</sup> The fact that one person's leisure increases the returns to other people's leisure was noted in the reduced-form model with a leisure externality by Alesina, et al. (2006, Section 5.1). Our model explores the same idea in a general equilibrium framework.

<sup>3</sup> According to Abramowitz and David (2000), the contribution of human capital to economic growth has doubled since 1890.

for, but is instead beneficial to, economic growth. We regard this outcome to be more plausible.

Our main findings are briefly summarized as follows. First, there exists a unique BGP even though utility is no longer concave in leisure. This result is in sharp contrast to what was obtained in Ladrón-de-Guevara, et al. (1999) in a similar model with leisure in the utility function. Ladrón-de-Guevara, et al. (1999) found multiple BGPs and concluded that global stability does not hold in a Lucas (1988) two-sector model when capital is not an input in the education technology.<sup>4</sup> When we add physical capital in the education technology, that technology is no longer linear in the level of human capital; it is strictly concave and this concavity offsets the curvature of the utility function and delivers a unique BGP. A unique BGP is important in order to guarantee global stability when conducting comparative-static analysis.

We also explore the effects of technology changes and differences in preferences toward leisure on labor supply, economic growth and welfare. A key result is that technological progress in the goods sector now enhances economic growth. This result is in contrast to that in an otherwise similar model without physical capital in the education sector. In our general two-sector model, physical capital and human capital are complementary inputs in the production of education. Productivity growth in the good sector is equivalent to a human capital-saving improvement. It reduces the level of leisure in the economy and releases labor from the goods sector to the education sector, thereby enhancing economic growth.

Finally, we analyze and quantify the effects of household differences in the size of the leisure externality in order to shed light on hours worked in America and Europe. For Europe, we view these differences in part as a positive leisure externality and the implied *keeping up with the Joneses effect*, and partly as a slightly larger weight on the preference for leisure in order to highlight the culture of leisure in European societies. For the U.S., we impose a negative leisure externality and the implied *running away from the Joneses effect*, and also a slightly smaller weight on the preference for leisure in order to characterize the workaholic American labor market. We find that small differences in the degree of leisure externalities and the weight of preference for leisure can account for a large fraction of differences in hours worked between Americans and Europeans. The difference in labor supply leads to less human capital formation and lower long-run economic growth in Europe which lowers welfare through consumption. Yet, a higher level of leisure in Europe results in higher welfare. Our quantitative results indicate that the

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<sup>4</sup> Using similar two-sector Lucas (1988) models with leisure, Benhabib and Perli (1994) also obtained multiple BGPs.

positive effect dominates the negative effect. As a result, even though Europeans work less and consume less, they seem to be happier with their arrangements than they would be with the ones prevailing in the United States.

Adding average leisure in the utility function of a dynamic general equilibrium model is a feature in the work of Weder (2004), Pintea (2006) and Gómez (2006). Weder (2004) investigated conspicuous leisure and found that leisure externalities reduce the reliance on the degree of other market imperfections, thereby making local indeterminacy empirically more plausible. In a one-sector neoclassical growth model with leisure externalities, Pintea (2006) found that positive leisure externalities led to over-consumption and too low leisure in equilibrium, and had significant consequences on optimal tax levels of labor income and on welfare. Our paper differs from these two in the emphasis it puts on endogenous growth. Finally, Gómez (2006) analyzed the effects of both consumption and leisure externalities on economic growth and welfare in a two-sector endogenous growth model. He studied optimal consumption and labor income taxes in order for the decentralized equilibrium path to replicate the optimal growth path. Our paper is also different from Gómez (2006) because the leisure externality in the Gómez (2006) model does not produce any effect on economic growth in the long run.

A roadmap for this paper is as follows. A model of two-sector endogenous growth with leisure and leisure externalities in utility is studied in Section 2. In Section 3 we characterize the BGP and examine comparative statics. Section 4 provides some quantitative assessment regarding the effects of leisure externalities on labor supply, economic growth and welfare. Finally, concluding remarks are offered in Section 5.

## 2. The Model

This section builds the basic analytical framework. This framework draws on the Lucas (1988) two-sector model, extended to a general technology by Bond, et al. (1996) and Mino (1996), and augmented to include leisure by Benhabib and Perli (1994), and Ladrón-de-Guevara, et al. (1997, 1999).

The representative agent is endowed with  $L$  units of time;  $l$  units are allocated to leisure and the remaining  $L-l$  units to working. She obtains utility from consumption and leisure. In addition, her utility is affected by  $\bar{l}$ , the average leisure level in society. An agent's lifetime utility is represented as follows.

$$U = \int_0^{\infty} u(c, l, \bar{l}) e^{-\rho t} dt, \quad \text{where } u(c, l, \bar{l}) = \ln c + \psi \frac{(\bar{l}^\gamma)^{1-\sigma} - 1}{1-\sigma}, \quad \gamma(1-\sigma) < \sigma, \sigma > 0, \quad (\text{P})$$

where  $c$  is consumption and  $\rho > 0$  is the time preference rate.

Following Benhabib and Perli (1994) and Ladrón-de-Guevara (1997, Section 4.2), we use a form of felicity that is separable in consumption and leisure with a unit *intertemporal elasticity of substitution* (hereafter, IES) for consumption that is different from the IES of leisure.<sup>5</sup> In this type of utility, the marginal rate of substitution between consumption and leisure is not homothetic along a BGP. Leisure externalities may then influence competitive equilibrium in the long run. The parameter  $\psi$  is the intensity of leisure preferences relative to consumption with  $\psi > 0$  because leisure is in general a normal good. The larger  $\psi$ , the higher the utility is from an additional unit of leisure. Also  $\sigma > 0$  is the reciprocal of the IES of leisure. The parameter  $\gamma$  denotes the degree of leisure externalities. To assure that felicity is concave in pure leisure time, we impose  $(1+\gamma)(1-\sigma) < 1$  and thus,  $\gamma(1-\sigma) < \sigma$ . Thus, it is required that the degree of leisure externalities be not too large.

An agent's utility is positively influenced by the average leisure level in an economy if  $\gamma > 0$ , and negatively affected if  $\gamma < 0$ . Following existing studies on the consumption externality (Dupor and Liu, 2003), we may call the individual leisure *admiring* if  $u_3(c, l, \bar{l}) > 0$  or equivalently  $\gamma > 0$ , and leisure *jealous* if  $\gamma < 0$ . Alesina, et al. (2006) referred to the case  $u_3(c, l, \bar{l}) > 0$  as a *social multiplier*. An agent's marginal utility of leisure may be affected by the leisure externality. The leisure externality can be described as *keeping up with the Joneses* if  $u_{23}(c, l, \bar{l}) > 0$  or equivalently  $\gamma(1-\sigma) > 0$  (e.g., Gali, 1994) or as *running away from the Joneses* if  $\gamma(1-\sigma) < 0$  (e.g., Dupor and Liu, 2003).

The economy is composed of two production sectors: the goods sector  $x$  and the education sector  $y$ . The two sectors have general technologies which use both physical capital and human capital as inputs, as in Bond, et al. (1996), Mino (1996), Mulligan and Sala-i-Martin (1993) and Stokey and Rebelo (1995). For simplicity, the Cobb-Douglas form is employed for each one:  $x = A(sk)^\alpha [(L-l)uh]^{1-\alpha}$  and  $y = B[(1-s)k]^\beta [(L-l)(1-u)h]^{1-\beta}$ , in which  $k$  is physical capital

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<sup>5</sup> As in Ladrón-de-Guevara (1999, p. 613), only two forms of felicity are consistent with a BGP in our two-sector endogenous growth model. The general form of our separable felicity is  $u(c, l, \bar{l}) = \ln c + f(l, \bar{l})$  as noted in Ladrón-de-Guevara (1997, Section 4.2). As a constant IES is necessary in order to be consistent with a BGP, we use the parametric form of the felicity from leisure assumed in Benhabib and Perli (1994). An alternative felicity is the non-separable form of  $\frac{[c^\theta f(l, \bar{l})]^{1-\sigma} - 1}{1-\sigma}$ , with the special case of  $\frac{[c^\theta (l\bar{l})^\psi]^{1-\sigma} - 1}{1-\sigma}$  used in Lucas (1990) which imposes the same IES for consumption and leisure. In that formulation, the marginal rate of substitution is homothetic in consumption and leisure, and hence leisure externalities do not affect the allocation in the long run.

and  $h$  is human capital with given initial values  $k(0)$  and  $h(0)$ . The variables  $s$  and  $u$  denote the share of physical capital and human capital, respectively, allocated to the goods sector. Both technologies are assumed to exhibit constant returns to scale in order to be consistent with perpetual growth. The parameter  $\alpha \in (0,1)$  is the share of physical capital in the goods sector, and  $\beta \in (0,1)$  is the share of physical capital in the educational sector;  $A$  and  $B$  are the technology coefficients, or factor productivities, in the goods and the educational sector, respectively.

The Lucas (1988) two-sector model with leisure in utility was studied by Benhabib and Perli (1994) and Ladrón-de-Guevara, et al. (1997, 1999) neither of whom allows the education technology to use physical capital as an input. We employ a general two-sector model in which both the goods sector and education technology need physical capital as an input. As we will see below, the choice of two inputs in the Lucas two sector model is important in two aspects. First, this choice guarantees a unique globally stable BGP which is useful when conducting comparative-static analyses. Second, technical progress in the goods sector is beneficial to economic growth instead of neutral as asserted in earlier literature.

While the goods output is used either for consumption or for the formation of physical capital, the education output can only serve the accumulation of human capital. For simplicity, we assume there is no depreciation for physical and human capital. Their laws of motion are as follows.

$$\dot{k} = A(sk)^\alpha [(L-l)uh]^{1-\alpha} - c, \quad k(0) \text{ given}, \quad (1a)$$

$$\dot{h} = B[(1-s)k]^\beta [(L-l)(1-u)h]^{1-\beta}, \quad h(0) \text{ given}. \quad (1b)$$

Equations (P), (1a) and (1b) are the basic framework in this model. Our model reduces to Benhabib and Perli (1994) and Ladrón-de-Guevara, et al. (1999) if  $\beta=\gamma=0$  and to Bond, et al. (1996) and Mino (1996) if  $\psi=\gamma=0$ .

## 2.1 Optimization

The representative agent's optimization problem is to maximize the lifetime utility (P) by choosing between consumption, leisure, and investment in the goods and the education sectors, all of which are subject to the constraints in (1a)-(1b) and the given initial stocks of physical and human capital,  $k(0)$  and  $h(0)$ . Let  $\mu$  and  $\lambda$  be the co-state variable associated with  $k$  and  $h$ , respectively. Thus,  $\mu$  is the shadow price of capital in terms of consumption, while  $\lambda$  is the shadow price of human capital in terms of consumption. The necessary conditions are

$$\frac{1}{c} = \mu, \quad (2a)$$

$$\psi l^{-\sigma} \bar{l}^{\gamma(1-\sigma)} = (1-\alpha)\mu \frac{x}{L-l} + (1-\beta)\lambda \frac{y}{L-l}, \quad (2b)$$

$$\mu \alpha \frac{x}{s} = \lambda \beta \frac{y}{1-s}, \quad (2c)$$

$$\mu(1-\alpha) \frac{x}{u} = \lambda(1-\beta) \frac{y}{1-u}, \quad (2d)$$

$$\dot{\mu} = \mu\rho - \mu\alpha \frac{x}{k} - \lambda\beta \frac{y}{k}, \quad (2e)$$

$$\dot{\lambda} = \lambda\rho - \mu(1-\alpha) \frac{x}{h} - \lambda(1-\beta) \frac{y}{h}, \quad (2f)$$

along with the transversality conditions,

$$\lim_{t \rightarrow \infty} e^{-\rho t} \mu(t)k(t) = 0, \quad (2g)$$

$$\lim_{t \rightarrow \infty} e^{-\rho t} \lambda(t)h(t) = 0. \quad (2h)$$

While (2a) equates the marginal utility of consumption to the shadow price of capital, (2b) equates the marginal utility of leisure to the marginal cost of leisure when labor is reduced by one unit, that is, the marginal utilities derived from forgone goods and from forgone educational output. Equations (2c) and (2d) allocate factors optimally between the two sectors: (2c) equates the marginal products of capital, and (2d) equates the marginal products of human capital. Finally, (2e) and (2f) are Euler equations, and (2g) and (2h) are the two usual transversality or “no Ponzi game” conditions on physical and human capital.

Dividing (2c) by (2d) yields

$$s = \frac{\alpha(1-\beta)u}{\beta(1-\alpha)+u(\alpha-\beta)} \equiv s(u), \text{ where } s'(u) = \frac{\alpha\beta(1-\alpha)(1-\beta)}{[\beta(1-\alpha)+u(\alpha-\beta)]^2} > 0. \quad (3)$$

Intuitively, physical and human capitals are complements in production. As human capital inputs increase in the goods sector, physical capital must increase in that sector, too.

## 2.2 Equilibrium

The equilibrium, with  $l(t) = \bar{l}(t)$ , defines time paths of  $\{k(t), h(t), c(t), l(t), s(t), u(t), \lambda(t), \mu(t)\}$  which satisfy equations (1a), (1b) and (2a)-(2f). We will simplify the equilibrium conditions by transforming them into a three-dimensional dynamical system. We briefly sketch the transformation.

First, (2a) implies  $\frac{\dot{c}}{c} = -\frac{\dot{\mu}}{\mu}$ , while (2c) and (2d) imply, respectively,

$$y = \frac{\alpha}{\beta} \frac{\mu}{\lambda} \frac{1-s}{s} x, \quad (4a)$$

$$x = \frac{1-\beta}{1-\alpha} \frac{\lambda}{\mu} \frac{u}{(1-u)} y. \quad (4b)$$

If we substitute these three relationships into (2e), (1b), (2f) and (1a), we obtain

$$\frac{\dot{c}}{c} = -\frac{\dot{\mu}}{\mu} = \alpha A \left[ \frac{sk}{(L-l)uh} \right]^{\alpha-1} - \rho, \quad (5a)$$

$$\frac{\dot{h}}{h} = \frac{\alpha}{\beta} A \frac{\mu}{\lambda} (1-s) \left( \frac{u}{s} \right)^{1-\alpha} \left( \frac{k}{h} \right)^{\alpha} (L-l)^{1-\alpha}. \quad (5b)$$

$$\frac{\dot{\lambda}}{\lambda} = \rho - (1-\alpha) A \frac{\mu}{\lambda} \left( \frac{sk}{uh} \right)^{\alpha} (L-l)^{1-\alpha}, \quad (5c)$$

$$\frac{\dot{k}}{k} = A s^{\alpha} \left( \frac{k}{h} \right)^{\alpha-1} [(L-l)u]^{\alpha-1} \frac{c}{k}. \quad (5d)$$

Following Bond, et al (1996), we define  $m \equiv c/k$ ,  $q \equiv h/k$  and  $p \equiv \lambda/\mu$ . Then, (5a)-(5d) yield

$$\frac{\dot{m}}{m} = -\rho + m + A s^{\alpha} u^{1-\alpha} q^{1-\alpha} (L-l)^{1-\alpha} \left( \frac{\alpha}{s} - 1 \right), \quad (6a)$$

$$\frac{\dot{q}}{q} = A s^{\alpha} u^{1-\alpha} q^{-\alpha} (L-l)^{1-\alpha} \left( \frac{\alpha}{\beta} \frac{1}{p} \frac{1-s}{s} - q \right) + m, \quad (6b)$$

$$\frac{\dot{p}}{p} = A s^{\alpha} u^{-\alpha} q^{-\alpha} (L-l)^{1-\alpha} \left[ \alpha q \frac{u}{s} - (1-\alpha) \frac{1}{p} \right]. \quad (6c)$$

Thus, (6a)-(6c) is a three-dimensional dynamical system if  $l$ ,  $u$  and  $s$  are all functions of  $m$ ,  $q$  and  $p$ . To derive these functions, use (2c) and (3) to obtain

$L-l = \left[ \left( \frac{B}{A} \right)^{\frac{1}{\alpha-\beta}} \left( \frac{\alpha}{\beta} \right)^{\frac{-\beta}{\alpha-\beta}} \left( \frac{1-\beta}{1-\alpha} \right)^{\frac{(1-\beta)}{\alpha-\beta}} \left( \frac{s}{u} \right)^{-1} p^{\frac{1}{\alpha-\beta}} q \right]^{-1}$ . This, along with (2a)-(2b), (2d), and (4a)-(4b), leads to

$$l = \left[ \frac{1-\alpha}{\psi} \left( \frac{\alpha}{\beta} \right)^{\frac{-\alpha\beta}{\alpha-\beta}} \left( \frac{1-\alpha}{1-\beta} \right)^{\frac{-\alpha(1-\beta)}{\alpha-\beta}} A^{\frac{-\beta}{\alpha-\beta}} B^{\frac{\alpha}{\alpha-\beta}} \frac{1}{m} q p^{\frac{\alpha}{\alpha-\beta}} \right]^{\frac{-1}{\sigma-\gamma(1-\sigma)}} \equiv l(m, p, q). \quad (7a)$$

Moreover, (2d) and (3) and (7a) yield

$$u = \frac{\alpha(1-\beta)}{\alpha-\beta} \left( \frac{1-\alpha}{1-\beta} \right)^{\frac{1-\beta}{\alpha-\beta}} \left( \frac{\alpha}{\beta} \right)^{\frac{\beta}{\alpha-\beta}} \left( \frac{B}{A} \right)^{\frac{-1}{\alpha-\beta}} [L-l(m, q, p)]^{-1} q^{-1} p^{\frac{-1}{\alpha-\beta}} + \frac{\beta(1-\alpha)}{\beta-\alpha} \equiv u(m, p, q). \quad (7b)$$

Finally,  $s$  depends on  $u$  alone by eq. (3); eq. (7) then says that  $s=s(m, q, p)$ .

### 2.3 The balanced growth path

In a *Balanced Growth Path* (BGP),  $\dot{m} = \dot{q} = \dot{p} = 0$  and thus the state variables  $m$ ,  $q$  and  $p$  are constant. Along that path the fractions  $l$ ,  $u$  and  $s$  are also constant, while  $c$ ,  $k$  and  $h$  grow at the same rate, as do  $\mu$  and  $\lambda$ .

To determine the BGP, first, we use (6b), along with (7a), (6c), (2a), (2b), (2d) and (3), to obtain

$$p = p(u) = \left[ \frac{\alpha}{\rho(1-\beta)} \right]^{\frac{(\alpha-\beta)}{1-\alpha}} \left( \frac{\alpha}{\beta} \right)^{\beta} \left( \frac{1-\alpha}{1-\beta} \right)^{1-\beta} A^{\frac{1-\beta}{1-\alpha}} B^{-1} (u-\beta)^{\frac{(\alpha-\beta)}{1-\alpha}}. \quad (8a)$$

Next, we substitute (8a) and (3) into (6c) and obtain

$$q = q(u) = (1-\alpha) \left( \frac{1-\beta}{A} \right)^{\frac{1-\beta}{1-\alpha}} \left( \frac{\alpha}{\rho} \right)^{\frac{\beta-\alpha}{1-\alpha}} \left( \frac{\beta}{\alpha} \right)^{\beta} \left( \frac{1-\beta}{1-\alpha} \right)^{1-\beta} \frac{B}{\beta(1-\alpha)+u(\alpha-\beta)} \left( \frac{1}{u-\beta} \right)^{\frac{\alpha-\beta}{1-\alpha}}. \quad (8b)$$

Finally, if we substitute (8b) and (3) into (6a), we obtain

$$m = m(u) = \frac{\rho[(1-\alpha)+u(\alpha-\beta)]}{\beta(1-\alpha)+u(\alpha-\beta)}. \quad (8c)$$

It is obvious that once we determine the unique  $u$  in a BGP, we can obtain a unique state vector  $(m, q, p)$  from (8c), (8b) and (8a), respectively. Before we determine  $u$ , we note that consumption, physical capital or human capital should be nonnegative, and so should the shadow prices of physical and human capital. Thus,  $m, q$  and  $p$  must be nonnegative in a BGP.

To determine  $u$  in BGP, we substitute (8a)-(8c) into (7b) and obtain a relationship only in  $u$ . Denote  $M \equiv \{L - [(\frac{1}{1-\alpha})^{1+\beta} \rho^{\frac{1-\alpha+\beta}{1-\alpha}} (\frac{1}{1-\beta})^{1-\beta} (\frac{\alpha}{\beta})^\beta (A\alpha)^{\frac{-\beta}{1-\alpha}} \frac{\psi}{B}]^{\frac{1}{\sigma-\gamma(1-\sigma)}}\}$ . We obtain the following result.<sup>6</sup>

**Proposition 1.** *Under (i)  $(\alpha A)^{\frac{\beta}{1-\alpha}} B(1-\alpha)(\frac{1-\beta}{1-\alpha})^{1-\beta} (\frac{\beta}{\alpha})^\beta \rho^{\frac{-(1-\alpha+\beta)}{1-\alpha}} M > 1$ , (ii)  $\alpha > \beta$  and  $\beta/(1-\beta) > (\alpha-\beta)$ , and (iii)  $u \geq \beta$ , there exists a unique BGP.*

In proposition 1, while condition (iii) guarantees  $p \geq 0$  in a BGP, and Condition (ii) assures the existence of a BGP. Finally, Condition (iii) ensures the uniqueness. As there exists a unique  $u^*$  in a BGP, we can use that value of  $u^*$  to solve for the unique values of  $m^*, q^*$  and  $p^*$  in a BGP.

We must point out that our BGP is unique even though the felicity in our model is non-concave due to a leisure externality. This result is in a sharp contrast to that obtained by Benhabib and Perli (1994) and Ladrón-de-Guevara, et al. (1997, 1999). These authors found multiple BGPs in a Lucas-type (1988) two-sector endogenous growth model with consumption and pure leisure time. In spite of using a utility function of a similar type, our model possesses a unique BGP.

The reason for this difference in results is that earlier studies assumed that human capital is the only input in the education sector. This corresponds to  $\beta=0$  in our model. In that situation, education technology is linear in the level of human capital. Indeed, if  $\beta=0$  in our model, the BGP relationship is so nonlinear that it is no longer monotone in  $u$ . As a result, there are possibly multiple BGPs in our model. When  $\beta \neq 0$ , however, education technology is strictly concave in the level of human capital. The strict concavity of the education technology in the level of human capital offsets the non-concavity of the utility function and delivers a unique BGP. Uniqueness is important for our analysis as it assures global stability in the comparative-static analysis that follows.

### 3 Characterizing balanced growth paths

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<sup>6</sup> See the proof in Appendix 1.

In this section we characterize the BGP by examining its comparative-static properties when structural parameters change.<sup>7</sup> We start with the analysis of long-run effects on aggregate labor supply, and on the labor allocation among the two sectors, followed by the long-run effects on the overall economic growth rate. While we are more interested in the effects of changes in the degree of leisure externalities ( $\gamma$ ) and the intensity of leisure preference relative to consumption ( $\psi$ ), we will also analyze the impact of technical change in both sectors ( $A, B$ ).

### 3.1 Effects on leisure and labor allocation

We start with the long-run effects on leisure and the labor allocation between the sectors. Eq. (8a)-(8c) allow us to calculate the effects of changes in structural parameters on aggregate labor supply as follows (See Appendix 2 for derivation).

$$\frac{dl}{dA} = \frac{\partial l}{\partial A} + \frac{\partial l}{\partial u} \frac{\partial u}{\partial A} \leq 0 \text{ if } \beta \geq 0, \quad \frac{dl}{dB} = \frac{\partial l}{\partial B} + \frac{\partial l}{\partial u} \frac{\partial u}{\partial B} < 0, \quad \frac{dl}{d\psi} = \frac{\partial l}{\partial \psi} + \frac{\partial l}{\partial u} \frac{\partial u}{\partial \psi} > 0, \quad \frac{dl}{d\gamma} = \frac{\partial l}{\partial \gamma} + \frac{\partial l}{\partial u} \frac{\partial u}{\partial \gamma} \begin{matrix} \geq 0 \\ \leq 0 \end{matrix} \text{ if } \sigma \begin{matrix} \leq 1 \\ \geq 1 \end{matrix}. \quad (9)$$

$\begin{matrix} (-) & (-)(-) \\ (-) & (-)(-) \\ (+) & (-)(+) \\ (+) & (-)(-) \end{matrix}$

Intuitively, a higher productivity in the education sector ( $B$ ) increases the supply of labor and the fraction of the human capital allocated to the education sector because the education sector is relatively more human-capital intensive.

On the other hand, a higher productivity in the goods sector ( $A$ ) has no effect on labor supply or on the human capital shares of the two sectors when the education sector does not require physical capital ( $\beta=0$ ). If the education sector does require physical capital ( $\beta>0$ ), higher productivity in the goods sector ( $A$ ) increases labor supply and also the fraction of the human capital allocated to the education sector. This is because higher productivity in the goods sector represents a human capital-saving improvement and thus labor is relocated to the education sector.

A higher intensity of leisure preference relative to consumption ( $\psi$ ) increases the marginal utility of leisure; leisure goes up and labor supply goes down. Since leisure and consumption are complements, it is necessary to allocate a larger fraction of labor supply to the goods sector in order to produce a sufficient amount of consumption goods.

Next, we analyze the effect of changes in the intensity of the leisure externality,  $\gamma$ . It is worth noticing that  $\gamma$  could be either positive or negative. When  $\gamma>0$ , the agent admires leisure enjoyed by others, and the average level of leisure is a complement to each agent's leisure. In this case there is a social multiplier, as in Alesina, et al. (2006). Alternatively, when  $\gamma<0$ , the agent feels

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<sup>7</sup> To ensure there is only one equilibrium path toward the unique BGP when doing comparative statics, we need the BGP to be a saddle. We discuss in Appendix 1 conditions that guarantee the saddle property.

jealous about other's leisure and the average level of leisure in society becomes a substitute for individual leisure.

It follows from this argument that an increase in  $\gamma$  will either increase our admiration toward other people's leisure plans or reduce the jealousy we feel about them. Depending on whether the initial value of  $\gamma$  is positive or negative, the impact of changes in  $\gamma$  can be stated in Table 1.

Table 1 Meanings for changes in the degree of leisure externalities

	$\gamma > 0$	$\gamma = 0$	$\gamma < 0$
$d\gamma > 0$	Admiration goes up.	Admiration effect created.	Jealousy reduced.
$d\gamma < 0$	Admiration reduced.	Jealousy created.	Jealousy goes up.

The effect of a larger intensity of leisure externality ( $d\gamma > 0$ ) depends on how the agent's marginal utility of leisure,  $l^{-\sigma} \bar{l}^{\gamma(1-\sigma)}$ , is affected by the leisure externality. In particular, the sign of  $\gamma(1-\sigma)$  controls whether the agent will increase or decrease her leisure level. Thus, the crucial determinant of the effect of a larger intensity of leisure externality is whether  $\gamma(1-\sigma) > 0$  which signals a *keeping up with the Joneses effect*, or  $\gamma(1-\sigma) < 0$  which signals a *running away from the Joneses effect*.

First, suppose  $\gamma(1-\sigma) > 0$ . In this case,  $(1-\sigma)d\gamma > 0$  means a stronger "keeping up with the Joneses" effect which leads to higher leisure. This result may be understood as follows. For a given level of leisure, the marginal utility of leisure increases in the leisure externality which leads the agent to choose a higher level of leisure. As labor supply drops, it is necessary to allocate a larger fraction of labor in order to produce a sufficient amount of goods. Alternatively, suppose  $\gamma(1-\sigma) < 0$ . In this case,  $(1-\sigma)d\gamma < 0$  means a higher "running away from the Joneses" effect, which leads to lower leisure by reversing the earlier causal chain. As labor supply goes up, the agent will allocate a smaller fraction of labor in order to produce a sufficient amount of goods.

A "keeping up with the Joneses" effect occurs when people enjoy having fun together. For example, people like to go to movies, concerts and basketball games together. Usually, a gathering or a chat with bosom friends can sweep away the fatigue and tediousness in daily life and make it easier for us to perform our duty, and go back to work again. Alternatively, a "running away from the Joneses effect" is a sign of "leisure competition." Having more leisure is a sign of "status", that is of an individual's capability to lead a more comfortable and decent life without working hard, just as others of higher status do. In this kind of environment, the individual will

choose a higher level of leisure when other people in the society have low levels of leisure.

These results are summarized as follows.

**Proposition 2** *In the long run, the labor supply is:*

- (i) *an increasing function of total factor productivity in both the goods and education sectors;*
- (ii) *a decreasing function of the intensity of leisure in preferences;*
- (iii) *a decreasing function of the strength of the “keeping up with the Joneses” effect and an increasing function of the strength of the “running away from the Joneses” effect.*

To further investigate the effects of changes in the intensity of leisure relative to consumption and the degree of leisure externalities, we describe their effects on the allocation of the labor supply to the goods sector (total time devoted to work),  $(L-l)u$ , and to the educational sector (total time used in education),  $(L-l)(1-u)$ . In Appendix 3, we have obtained the following results.

A higher intensity of leisure reduces the labor allocation to the education sector as a result of a lower labor supply in the economy and of a smaller fraction of labor supply allocated to the education sector. However, a higher intensity of leisure has an ambiguous effect on the labor allocation to the goods sector because a larger fraction of labor supply allocated to the goods sector offsets the decrease of aggregate labor supply.

When there is a higher “keeping up with the Joneses” effect, labor supply to the education sector drops because both aggregate labor supply and the fraction of labor allocated to the education sector go down. The opposite outcome occurs if there is a higher “running away from the Joneses” effect as well.

Finally, the fraction of labor allocated to the good sector is ambiguous. Under a higher “keeping up with the Joneses” effect, aggregate labor supply shrinks, but the fraction of labor supply allocated to the goods sector goes up. The net effect is ambiguous in this case and, for entirely symmetric reasons, when we deal with a higher “running away from the Joneses” effect as well.

### **3.2 Impacts on long-run growth**

Next, we describe the impact of changing parameters on long-run economic growth. Along a BGP, the growth rate of output is equal to the growth rate of consumption, the growth rate of physical capital as well as the growth rate of human capital.

The balanced economic growth rate in (5a), denoted as  $\phi$ , can be read from equations (7a) and (8a). We rewrite it as follows.<sup>8</sup>

$$\phi = \frac{\rho(1-\beta)}{u-\beta} - \rho, \quad \text{where} \quad \frac{d\phi}{du} = \frac{-\rho(1-\beta)}{(u-\beta)^2} < 0. \quad (10a)$$

It is easy to see that the long-run economic growth rate is decreasing in the fraction of labor supply allocated to the goods sector  $u$  and thus, increasing in the fraction of labor supply allocated to the education sector  $1-u$ . Intuitively, the long-run economic growth rate is dictated by the formation of human capital and thus, other things being equal, a larger fraction of labor supply allocated to the education sector increases human capital formation.

The effects of changes in structural parameters on economic growth are:

$$\frac{d\phi}{dA} = \frac{d\phi}{du} \frac{du}{dA} \geq 0 \text{ if } \beta \geq 0, \quad \frac{d\phi}{dB} = \frac{d\phi}{du} \frac{du}{dB} > 0, \quad \frac{d\phi}{d\psi} = \frac{d\phi}{du} \frac{du}{d\psi} < 0, \quad \text{and} \quad \frac{d\phi}{d\gamma} = \frac{d\phi}{du} \frac{du}{d\gamma} \begin{matrix} \leq \\ \geq \end{matrix} 0 \text{ if } \sigma \begin{matrix} \leq \\ \geq \end{matrix} 1. \quad (10b)$$

The results are summarized as follows.

**Proposition 3**      *The balanced rate of economic growth is:*

- (iv)      *an increasing function of total factor productivity in both the goods and education sectors;*
- (v)      *a decreasing function of the intensity of leisure in preferences;*
- (vi)      *a decreasing function of the strength of the “keeping up with the Joneses” effect and an increasing function of the strength of the “running away from the Joneses” effect.*

All of these results are intuitively simple to understand as follows. A better technology in the educational sector (higher  $B$ ) increases economic growth because of the resulting human capital formation. The positive growth effect of the progress in the technology of the goods production ( $A$ ) is explained as follows. Technical progress in the goods sector represents a human capital-saving improvement which releases labor from that sector to the human capital sector. This increases human capital formation which in turn enhances both the goods and the educational sector, thereby resulting in a higher economic growth rate in both sectors. This positive growth effect disappears when the education sector uses only human capital ( $\beta=0$ ); then a higher value of  $A$  only has a level effect which does not influence long-term economic growth.

When  $\psi$  is higher, an agent feels happier from a unit of leisure, which means less work, less consumption and slower economic growth. Finally, the effect of changes in the degree of leisure

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<sup>8</sup> See the derivation of (10a) in Appendix 4.

externalities depends on whether there is a “keeping up with the Joneses” effect or a “running away from the Joneses” effect. In the former case, the agent enjoys more leisure and works less. Moreover, the agent also allocates a small fraction of labor in the education sector which results in slower accumulation of human capital. As a result, economic growth is lower. These results are completely reversed under a “running away from the Joneses” effect.

#### **4. Numerical Simulations**

This section quantifies the effects of changes in the two parameters in relation to preferences toward leisure: changes in the intensity of leisure on the preference relative to consumption, and changes in the degree of leisure externalities. We study their quantitative effects on the labor supply, economic growth and welfare. As will be seen, differences in the two parameters shed light on the differences in the hours worked between the US and the European countries like France, Germany and Italy after 1993-1996.

##### **4.1 Calibration**

We calibrate the model in a BGP in order to reproduce key features representative of the U.S. economy in annual frequencies. The time endowment is assumed to be  $L=100$  units. The leisure time is chosen at  $l^*=75$  in consistent with the fraction of time allocated to market at around 25 percent, as pointed out by Prescott (2006). Human capital is as large as physical capital according to Kendrick (1976); accordingly, we choose the ratio of human capital to physical capital at  $q^*=h/k=1$ .

The empirical literature has not come to an agreement about the value of the IES of leisure,  $1/\sigma$ , but the estimation result in Imai and Keane (2004) may shed light on the value of  $\sigma$ . Using a model that allows for the IES of consumption to be different from the IES for labor/leisure, Imai and Keane (2004) took into consideration the value of human capital that people acquire when working. They applied their model to white males from the 1979 cohort of National Longitudinal Survey of Labor Market Experience and found that the IES for labor is 3.82. Prescott (2006) pointed out this labor supply elasticity is equivalent to an IES for leisure of 1.2 if the fraction of productive time allocated to market is 0.25, as it is for the United States. Following this line of wisdom, we set  $\sigma=0.83$ . In order to compare the quantitative results with and without the leisure externality, we start with a parameter value of  $\gamma=0$  in our benchmark model. We then change the value of  $\gamma$  to a small positive number, and a small negative number, in order to investigate the effect of leisure externalities.

We choose the physical capital share in the goods sector at  $\alpha=0.36$ , as in Andolfatto (1996) and Hansen and Imrohorglu (2008). Under Condition L, the physical capital share in the educational sector is less than that in the goods sector; thus, we choose  $\beta=0.3$ . The rate of time preference ( $\rho$ ) is set at 4% as used by Kydland and Prescott (1991).

The remaining parameters of technology and preference are chosen so that our model is consistent with various facts characterizing the US macroeconomy. The fraction of labor allocated to the goods sector ( $u$ ) is chosen to match the  $\phi = 2\%$  long-run economic growth rate in per capita income, and we obtain  $u^*=0.7667$ . From Eq. (7a) we also compute the ratio of the shadow price of human capital to the shadow price of physical capital at  $p^*=1.8824$ . Given this, we use equations (3) and (7e) to compute the fraction of capital allocated to the goods sector and the ratio of consumption to capital at  $s^*=0.8118$  and  $m^*=0.1153$ , respectively. Finally, using (6c), (7c) and (8b), we obtain  $A=0.02203$ ,  $B=0.0096$ , and  $\psi=1.41045$ .

Under these benchmark parameter values, the equilibrium values for labor allocation and economic growth in a BGP are  $L-l^*=25$ ,  $u^*=0.7667$ ,  $s^*=0.8118$ ,  $(L-l^*)u^*=19.1675$ ,  $(L-l^*)(1-u^*)=5.8325$ , and  $\phi = 2\%$ .<sup>9</sup> See Row 1 in Table 2.

[Insert Table 2 here]

## 4.2 Quantitative Results

We start to examine the effects of differences in the degree of the leisure externality ( $\gamma$ ) by deviating from the benchmark value  $\gamma=0$ , and then by changing the intensity of the leisure parameter from its benchmark value  $\psi=1.41045$ .

First, consider an increase in the degree of the leisure externality from  $\gamma=0$  to  $\gamma=0.05>0$ . Then, the agent admires average leisure and, moreover, there is a keeping up with the Joneses effect as  $\gamma(1-\sigma)>0$ . In this situation, the agent will spend more time on leisure and less time on working. Our quantitative results confirm that the level of leisure  $l^*$  in the economy rises and thus, labor supply  $L-l^*$  in the economy drops. See the fine dash line in Panel A, Figure 1. As the labor supply in the economy goes down, the fraction of labor supply allocated to the goods sector  $u^*$  goes up in order to maintain a sufficient amount of goods for consumption (Figure not presented). Due to a substantial increase in the fraction of labor supply allocated to the goods sector at the

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<sup>9</sup> We have shown that the unique BGP is a saddle point under the benchmark parameter values. When the parameter values are changed below, we have also shown that, for these chosen values, the unique BGP satisfies the saddle-path stability.

beginning, labor supply in the goods sector  $(L-l^*)u^*$  is initially higher than the original level; yet, as the labor share allocated to the goods sector decreases monotonically over time, labor supply in the goods sector eventually becomes lower than the original value (Panel B in Figure 1). On the other hand, as the fraction of labor supply to the education sector drops substantially at the beginning, labor supply to the educational sector  $(L-l^*)(1-u^*)$  is initially lower than the original level. Over time, labor supply to the educational sector rises gradually, but, in a BGP, remains lower than the original level (Panel C in Figure 1). The lower labor supply in the education sector resulting from a higher “keeping up with the Joneses” effect also lowers human capital formation. As a result, the economic growth rate is lower ((Panel D in Figure 1).

[Insert Figure 1 here]

Conversely, a decrease in the degree of the leisure externality from  $\gamma=0$  to  $\gamma=-0.05<0$  creates a “running away from the Joneses effect” as  $\gamma(1-\sigma)<0$ . The agent allocates less time to leisure and more time to work. The effects of the previous paragraph reverse themselves: there is more human capital formation and faster economic growth. See Figure 1.

Next we quantify the effects of changes in the intensity of the preference for leisure relative to consumption ( $\psi$ ). Suppose that the intensity of leisure on the preference rises by 5% from the benchmark at  $\psi=1.41$  to  $\psi=1.48$ . As the agent puts more weight on leisure, the flow of leisure goes up and labor supply drops. With no leisure externality, aggregate labor supply would decrease from 25 to 22.91, and the labor supply allocated to the education sector also goes down from 5.83 to 4.59 (Row 4, Figure 2). As a result, the economic growth rate is reduced. If there is a leisure externality with a “keeping up with the Joneses” effect at  $\gamma=0.05$ , labor supply would drop even more to 21.35 and so does the labor supply allocated to the education sector to 3.85, making the economic growth even lower (Row 5, Table 2). Figure 2 illustrates the dynamic paths in response to a change in the intensity of leisure together with a change in the leisure externality.

[Insert Figure 2 here]

Alternatively, suppose that the intensity of leisure decreases by 5% from the benchmark level at  $\psi=1.41$  to  $\psi=1.34$ . Then the changes in the previous paragraph would be reversed. When there is no leisure externality, aggregate labor supply goes up from 25 to 27.29 and the labor supply allocated to the education sector increases to 7.1; thus, the economic growth rate increases (Row 6, Figure 2). If there is a leisure externality with a “running away from the Joneses effect” at  $\gamma=-0.05$ , total labor supply in the economy rises further to 28.93, so do the labor supply allocated to the education sector and the economic growth rate (Row 7, Table 2).

A good example of this type of comparative statistics is to contrast labor supply and economic growth in two similar economies, Europe and the US, which seem to differ in their preference for vacations and other forms of leisure. First, suppose that the two otherwise identical economies differ only in the degree of the leisure externality. Suppose that Europe has a culture of leisure with a “keeping up with the Joneses” effect at  $\gamma=0.05$  and Americans are workaholics with a “running away from the Joneses” effect at  $\gamma=-0.05$ . Then, our quantitative results suggest that Americans supply labor hours are about 13.80% higher than Europeans (c.f. the second column in Rows 2 and 3). Second, suppose that the two otherwise identical economies differ only in the intensity of leisure in preferences. The culture of leisure in Europe is captured by a higher intensity of leisure at  $\psi=1.48$ , whereas the workaholism in the US is represented by a lower intensity of leisure at  $\psi=1.34$ . Then, the labor supply in the US is about 19.09% higher than that in Europe (c.f. the second column in Rows 4 and 6).

Suppose that these two otherwise identical economies differ in both the degree of the leisure externality and the intensity of leisure on the preference. The culture of leisure in Europe is partly captured by keeping up with the Joneses effect at  $\gamma=0.05$  and partly by a higher intensity of leisure at  $\psi=1.48$ , whereas the workaholism in the US is partly represented by a running away from the Joneses effect at  $\gamma=-0.05$  and a lower intensity of leisure at  $\psi=1.34$ . Then, the labor supply in the US is about 35.53% higher than that in Europe (c.f. the second column in Rows 5 and 7). Such a difference in the labor supply accounts for a large fraction of the gap in the hours of work per person between the US and European countries like Germany, France and Italy after 1993-1996 as pointed out in Prescott (2004, Table 1). Thus, differences in preferences toward leisure seem to account for the differences of hours worked between the US and Europe reasonably well.

Finally, when the culture of leisure in Europe is captured  $\gamma=0.05$  and  $\psi=1.48$  and the workaholism in the US is represented by  $\gamma=-0.05$  and  $\psi=1.34$ , our quantitative results also indicate that the labor supply allocation to the education sector in the US is about 2 times higher than that in Europe (c.f. the fifth column of Row 5 and 7). As a result of the difference in the education hours, the economic growth rate in the US is also much higher than that in Europe.

## 5. Concluding Remarks

This paper studies a Lucas (1988) style model with leisure externalities and two sectors, in which both physical and human capital are necessary inputs in each sector. An instantaneous utility that is separable in consumption and leisure permits a leisure externality to influence

allocations along a balanced growth path.

In spite of a non-concave utility, the BGP is always unique in our model. This result is due to the use of a general two-input technology in both sectors. In particular, education no longer enjoys constant returns to scale in labor, and the resulting concavity in the level of human capital offsets the non-concave utility function. The offsetting impact from technology is sufficiently strong to guarantee a unique BGP despite a potentially large leisure externality. A unique BGP is important in conducting comparative-static analysis as it assures global convergence. Moreover, due to a general two sector setup, total factor productivity advances in the goods sector that are normally neutral for economic growth now exert a positive effect on economic growth. We also analyze the long-run effects of differences in preferences toward leisure on the supply of labor and on economic growth.

To shed some light on the role different preferences toward leisure play on the observed disparity in hours worked between Americans and Europeans, we quantify the role different preferences toward leisure have on economic growth and welfare. We represent the European leisure culture in part as a small positive leisure externality with a *keeping up with the Joneses effect* and in part as a slightly higher intensity of leisure in preferences. We also capture the workaholic labor market in the US in part by a small negative leisure externality with a *running away from the Joneses effect*, and partly by a slightly lower intensity of the preference for leisure. We find that small differences in preferences toward leisure can account for a large fraction of the difference in hours worked between Americans and Europeans. Our quantitative results indicate that because of such attitudes, Europeans work less, grow less and consume less, but are happier than they would be on an American balanced growth path.

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## Appendix to “A Two-sector Model of Endogenous Growth with Leisure Externalities”

### Appendix 1 Proof Proposition 1

Proof:

First, condition (ii) is to assure  $p \geq 0$  in a BGP.

Next, to determine  $u$ , if we substitute in (8a)-(8c), we may rewrite (7b) as

$$LHS(u) = RHS(u), \quad (A1a)$$

where  $LHS(u) \equiv \frac{1}{L-l(u)}$ ,

$$RHS(u) \equiv (\alpha A)^{\frac{\beta}{1-\alpha}} (1-\alpha)^{\frac{1-\beta}{1-\alpha}} (1-\beta)^{\frac{\beta}{\alpha}} [\rho(1-\beta)]^{\frac{1-\alpha+\beta}{1-\alpha}} B(u-\beta)^{\frac{1-\alpha+\beta}{1-\alpha}}.$$

The function  $l(u) = l(m(u), p(u), q(u))$  is defined in (7a), and with the use of (8a)-(8c), can be rewritten as

$$l(u) = \{(1-\alpha)^{-2} \rho^{\frac{1-\alpha+\beta}{1-\alpha}} (\frac{1}{1-\beta})^{\frac{1-\alpha-\beta}{1-\alpha}} (\frac{\alpha}{\beta})^{\beta} (\frac{1-\alpha}{1-\beta})^{1-\beta} [A\alpha(u-\beta)]^{\frac{-\beta}{1-\alpha}} \frac{\psi}{B} [1-\alpha+u(\alpha-\beta)]\}^{\frac{1}{\sigma-\gamma(1-\sigma)}}. \quad (A1b)$$

It is obvious that  $RHS(u)$  is increasing in  $u$  even if  $\gamma=0$ .

Moreover,  $RHS(u)$  is decreasing in  $u$  if  $l$  is decreasing in  $u$ . To see this, we use (A1b) to obtain

$$\frac{\partial l}{\partial u} = -\frac{(1-\alpha)[\beta-(\alpha-\beta)(u-\beta)]+\beta u(\alpha-\beta)}{(1-\alpha)(u-\beta)} \frac{1}{(1-\alpha)+u(\alpha-\beta)} \frac{l(u)}{[\sigma-\gamma(1-\sigma)]}, \quad (A1c)$$

where the concavity of the utility function in  $l$  requires  $[\sigma-\gamma(1-\sigma)] > 0$ . Eq. (A1c) is negative if Condition (iii) is met. Then, under Condition (iii),  $LHS(u)$  is decreasing in  $u$ . Moreover, at  $u=0$ ,

$$l(0) = \{(1-\alpha)^{-1} \rho^{\frac{1-\alpha+\beta}{1-\alpha}} (\frac{1}{1-\beta})^{\frac{1-\alpha-\beta}{1-\alpha}} (\frac{\alpha}{\beta})^{\beta} (\frac{1-\alpha}{1-\beta})^{1-\beta} [A\alpha(-\beta)]^{\frac{-\beta}{1-\alpha}} \frac{\psi}{B}\}^{\frac{1}{\sigma-\gamma(1-\sigma)}} < 0$$

and thus  $LHS(0) > 0 > RHS(0)$ . Therefore, a negatively slopping  $LHS(u)$  and a positively slopping  $RHS(u)$  must intersect.

Finally, the intersection is unique if  $LHS(1) < RHS(1)$ . This is true under Condition (i). ■

### Appendix 2 Comparative-static effects on aggregate labor supply/leisure in eq. (9)

Total differentiation to (A1a-A1b) with respect to  $A$ ,  $B$ ,  $\psi$  and  $\gamma$  yields

$$\frac{du}{dA} = \frac{-\beta}{A} \frac{l+(L-l)[\sigma-\gamma(1-\sigma)]}{(L-l)[\sigma-\gamma(1-\sigma)]} \frac{(u-\beta)}{T(u)}, \quad (A2a)$$

$$\frac{du}{dB} = -\frac{l+(L-l)[\sigma-\gamma(1-\sigma)]}{B(L-l)[\sigma-\gamma(1-\sigma)]} \frac{(1-\alpha)(u-\beta)}{T(u)}, \quad (A2b)$$

$$\frac{du}{d\psi} = \frac{l}{\psi(L-l)[\sigma-\gamma(1-\sigma)]} \frac{(1-\alpha)(u-\beta)}{T(u)}, \quad (A2c)$$

$$\frac{du}{d\gamma} = \frac{l}{L-l} \frac{(1-\sigma)\ln l}{[\sigma-\gamma(1-\sigma)]} \frac{(1-\alpha)(u-\beta)}{T(u)}, \quad (A2d)$$

where  $T(u) = 1 - \alpha + \beta + \frac{\{(1-\alpha)[\beta - (u-\beta)(\alpha-\beta)] + \beta[u(\alpha-\beta)]\}}{(L-l)[1-\alpha+u(\alpha-\beta)]} \frac{l(u)}{\sigma-\gamma(1-\sigma)} > 0$  under condition L.

Thus, we obtain

$$\frac{du}{dA} \leq 0 \text{ if } \beta \geq 0, \frac{du}{dB} < 0, \frac{du}{d\psi} > 0, \text{ and } \frac{du}{d\gamma} \begin{matrix} \geq \\ \leq \end{matrix} 0 \text{ if } \sigma \begin{matrix} \leq \\ \geq \end{matrix} 1. \quad (\text{A2e})$$

Moreover, equation (A1b) suggests that  $\frac{\partial l}{\partial A} = -\frac{\beta}{1-\alpha} \frac{l(u)}{A[\sigma-\gamma(1-\sigma)]} \leq 0$  if  $\beta \geq 0$ ,

$$\frac{\partial l}{\partial B} = -\frac{l(u)}{B[\sigma-\gamma(1-\sigma)]} < 0, \quad \frac{\partial l}{\partial \psi} = \frac{l(u)}{\psi[\sigma-\gamma(1-\sigma)]} > 0 \quad \text{and} \quad \frac{\partial l}{\partial \gamma} = \frac{(1-\sigma)}{\sigma-\gamma(1-\sigma)} l(u) \ln l(u) \leq (\geq) 0 \quad \text{if } \sigma \geq (\leq) 1.$$

Using these relationships and those in (A2e), we obtain the following results.

$$\begin{aligned} \frac{\partial l}{\partial A} &= \frac{\partial l}{\partial A} + \frac{\partial l}{\partial u} \frac{\partial u}{\partial A} = \frac{-\beta l}{(1-\alpha)A[\sigma-\gamma(1-\sigma)]} \left\{ 1 + \frac{(\alpha-\beta)(1-\alpha)(u-\beta) - \beta[1-\alpha+u(\alpha-\beta)]}{[1-\alpha+u(\alpha-\beta)]} \frac{l+(L-l)[\sigma-\gamma(1-\sigma)]}{(L-l)[\sigma-\gamma(1-\sigma)]T(u)} \right\} \\ &= \frac{-\beta l}{(1-\alpha)A[\sigma-\gamma(1-\sigma)]} \frac{(1-\alpha)[1-\alpha+u(\alpha-\beta)] + (\alpha-\beta)(1-\alpha)(u-\beta)}{[1-\alpha+u(\alpha-\beta)]T(u)} < 0. \end{aligned} \quad (\text{A2f})$$

$$\begin{aligned} \frac{\partial l}{\partial B} &= \frac{\partial l}{\partial B} + \frac{\partial l}{\partial u} \frac{\partial u}{\partial B} = \frac{-\beta l}{B[\sigma-\gamma(1-\sigma)]} \left\{ 1 + \frac{(\alpha-\beta)(1-\alpha)(u-\beta) - \beta[1-\alpha+u(\alpha-\beta)]}{[1-\alpha+u(\alpha-\beta)]} \frac{l+(L-l)[\sigma-\gamma(1-\sigma)]}{(L-l)[\sigma-\gamma(1-\sigma)]T(u)} \right\} \\ &= \frac{-\beta l}{B[\sigma-\gamma(1-\sigma)]} \frac{(1-\alpha)[1-\alpha+u(\alpha-\beta)] + (\alpha-\beta)(1-\alpha)(u-\beta)}{[1-\alpha+u(\alpha-\beta)]T(u)} < 0. \end{aligned} \quad (\text{A2g})$$

$$\begin{aligned} \frac{\partial l}{\partial \psi} &= \frac{\partial l}{\partial \psi} + \frac{\partial l}{\partial u} \frac{\partial u}{\partial \psi} = \frac{1}{\psi} \frac{l}{[\sigma-\gamma(1-\sigma)]} \left\{ 1 + \frac{(\alpha-\beta)(1-\alpha)(u-\beta) - \beta[1-\alpha+u(\alpha-\beta)]}{[1-\alpha+u(\alpha-\beta)]} \frac{l}{(L-l)[\sigma-\gamma(1-\sigma)]T(u)} \right\} \\ &= \frac{1}{\psi} \frac{l}{[\sigma-\gamma(1-\sigma)]} \frac{(1-\alpha+\beta)}{T(u)} > 0. \end{aligned} \quad (\text{A2h})$$

$$\begin{aligned} \frac{\partial l}{\partial \gamma} &= \frac{\partial l}{\partial \gamma} + \frac{\partial l}{\partial u} \frac{\partial u}{\partial \gamma} = \frac{(1-\sigma)l \ln(l)}{[\sigma-\gamma(1-\sigma)]} \left\{ 1 + \frac{(\alpha-\beta)(1-\alpha)(u-\beta) - \beta[1-\alpha+u(\alpha-\beta)]}{[1-\alpha+u(\alpha-\beta)]} \frac{l}{(L-l)[\sigma-\gamma(1-\sigma)]T(u)} \right\} \\ &= \frac{(1-\sigma)l \ln(l)}{[\sigma-\gamma(1-\sigma)]} \frac{(1-\alpha+\beta)}{T(u)} \begin{matrix} \geq \\ \leq \end{matrix} 0 \text{ if } \sigma \begin{matrix} \leq \\ \geq \end{matrix} 1. \end{aligned} \quad (\text{A2i})$$

### Appendix 3 Effect of changes in the leisure factor on the labor allocation between sectors

From (A2c)-(A2d), (A2e), and (A2h)-(A2i), we obtain

$$\frac{d(L-l)(1-u)}{d\psi} = -(L-l) \frac{du}{d\psi} - (1-u) \frac{dl}{d\psi} < 0, \quad (\text{A3a})$$

$$\frac{d(L-l)u}{d\psi} = (L-l) \frac{du}{d\psi} - u \frac{dl}{d\psi} = [(L-l) - u \frac{\partial l}{\partial u}] \frac{\partial u}{\partial \psi} - u \frac{\partial l}{\partial \psi}, \quad (\text{A3b})$$

$$\frac{d(L-l)(1-u)}{d\gamma} = -(L-l) \frac{du}{d\gamma} - (1-u) \frac{dl}{d\gamma} \begin{matrix} \leq \\ \geq \end{matrix} 0 \text{ if } \sigma \begin{matrix} \leq \\ \geq \end{matrix} 1, \quad (\text{A3c})$$

$$\frac{d(L-l)u}{d\gamma} = (L-l) \frac{du}{d\gamma} - u \frac{dl}{d\gamma} = [(L-l) - u \frac{\partial l}{\partial u}] \frac{\partial u}{\partial \gamma} - u \frac{\partial l}{\partial \gamma}, \text{ if } \sigma \begin{matrix} \leq \\ \geq \end{matrix} 1. \quad (\text{A3d})$$

#### Appendix 4 Derivation of the economic growth rate in the long run

The balanced economic growth rate in (5a), denoted as  $\phi$ , is rewritten as

$$\phi = \frac{\dot{c}}{c} = \alpha A \left[ \frac{sk}{(L-l)uh} \right]^{\alpha-1} - \rho = \alpha A \left( \frac{u}{s} \right)^{1-\alpha} q^{1-\alpha} (L-l)^{1-\alpha} - \rho. \quad (\text{A4a})$$

Substituting in (L-l) in (7a) yields

$$\phi = \alpha A p^{-\frac{(1-\alpha)}{\alpha-\beta}} \left( \frac{B}{A} \right)^{-\frac{(1-\alpha)}{\alpha-\beta}} \left( \frac{\alpha}{\beta} \right)^{-\frac{(1-\alpha)\beta}{\alpha-\beta}} \left( \frac{1-\alpha}{1-\beta} \right)^{-\frac{(1-\beta)(1-\alpha)}{\alpha-\beta}} - \rho, \quad (\text{A4b})$$

with the use of  $p(u)$  in (8a), the balanced economic growth rate is rewritten as follows

$$\phi = \frac{\rho(1-\beta)}{u-\beta} - \rho.$$

In the above expression, the effect of a higher time preference rate hurts economic growth via a  $u$  as verified below.

$$\begin{aligned} \frac{d\phi}{d\rho} &= \frac{1-u}{u-\beta} + \frac{\partial\phi}{\partial u} \frac{\partial u}{\partial\rho} = \frac{1}{u-\beta} \left\{ 1 - u - (1-\beta)(1-\alpha+\beta) \frac{l+(L-l)[\sigma-\gamma(1-\sigma)]}{(L-l)[\sigma-\gamma(1-\sigma)]T(u)} \right\} \\ &= - \frac{\{(u-\beta)(1-\alpha+\beta)(L-l)[\sigma-\gamma(1-\sigma)] + (u-\beta)\beta + (1-\beta)(1-\alpha)\}l + [1-\alpha+u(\alpha-\beta)] + (1-u)(\alpha-\beta)(1-\alpha)(u-\beta)}{(1-\alpha+\beta)(L-l)[\sigma-\gamma(1-\sigma)] + l\{\beta u(\alpha-\beta) + (1-\alpha)[\beta - (\alpha-\beta)(u-\beta)]\}} < 0. \end{aligned}$$

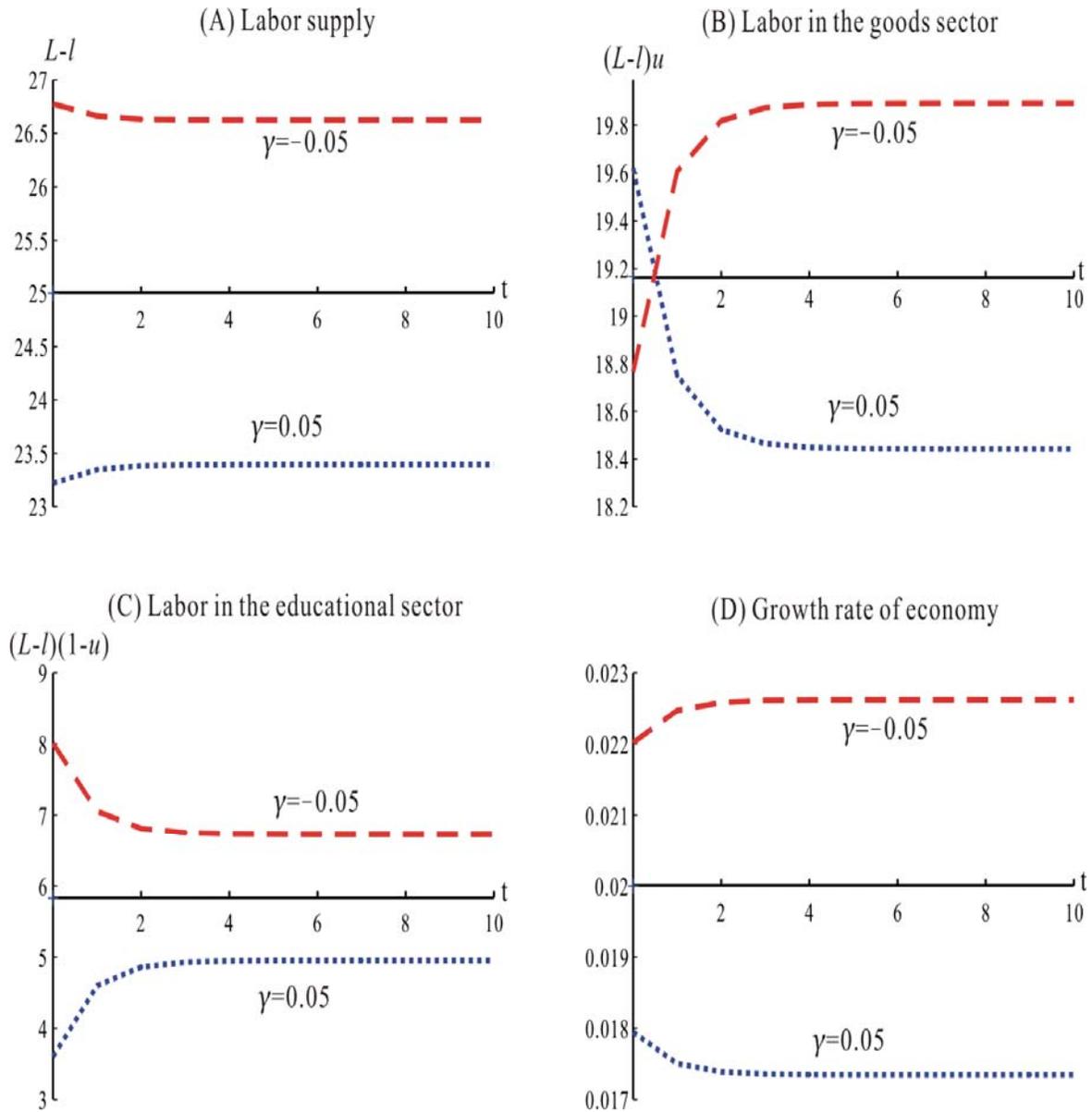


Figure 1 Dynamic paths of labor supply when  $\gamma$  is changed

Note. The intersection of the horizontal and the vertical axis is the initial BGP under the benchmark parameter values ( $\gamma=0$ ,  $\rho=0.04$ ,  $\alpha=0.36$ ,  $\beta=0.3$ ,  $\sigma=0.83$ ,  $L=100$ ,  $A=0.02203$ ,  $B=0.0096$ ,  $\psi=1.41045$ ).

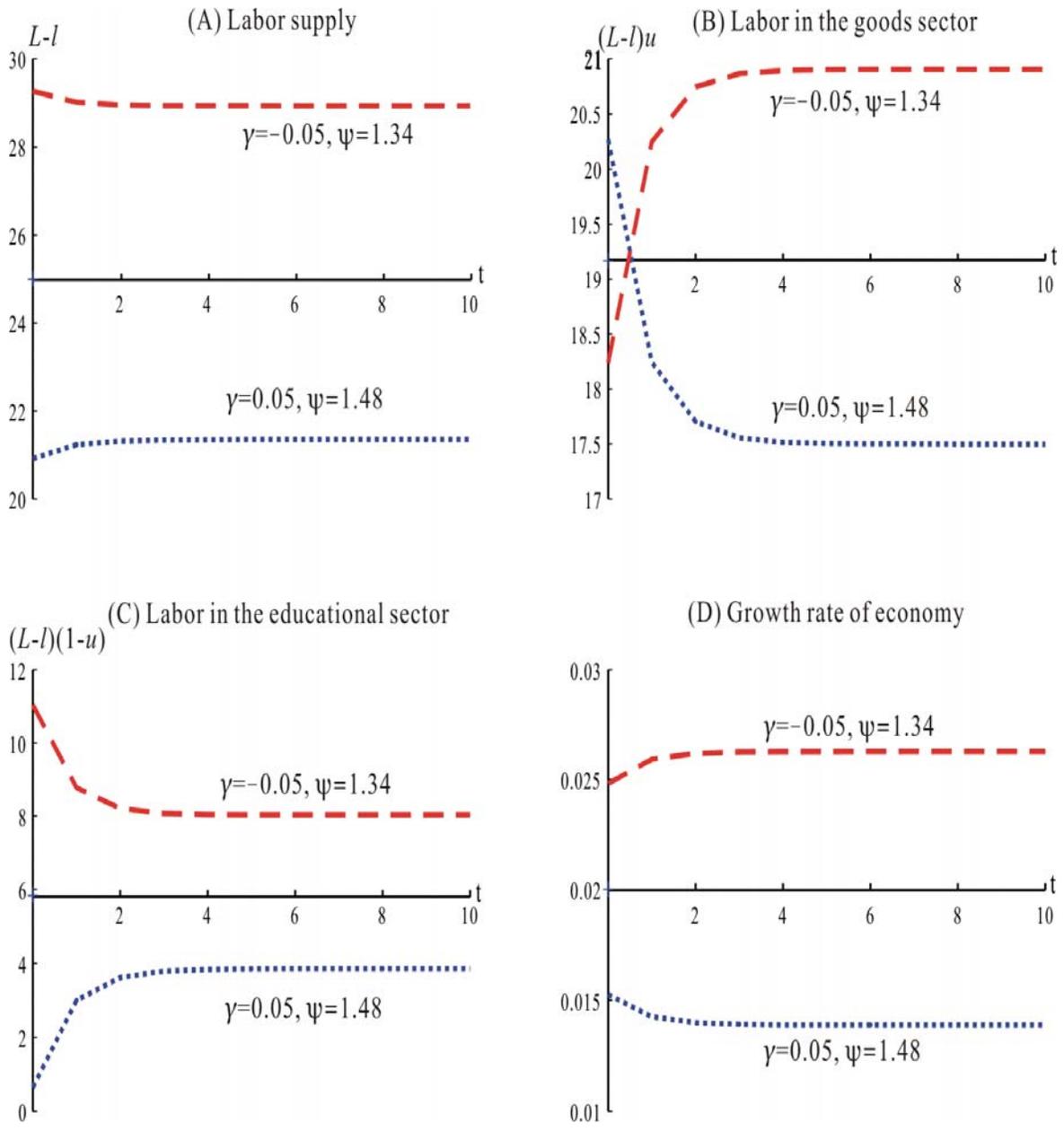


Figure 2 Dynamic paths of labor supply when  $\gamma$  and  $\psi$  are changed

Note. The intersection of the horizontal and the vertical axis is the initial BGP under the benchmark parameter values ( $\gamma=0, \rho=0.04, \alpha=0.36, \beta=0.3, \sigma=0.83, L=100, A=0.02203, B=0.0096, \psi=1.41045$ ).

Table 2 Comparative Static Results

	$\gamma$	$L-l^*$	$u^*$	$(L-l^*)u^*$	$(L-l^*)(1-u^*)$	$\phi^*$
Benchmark	0	25.0000	0.7667	19.1675	5.8325	0.0200
	0.05	23.3949	0.7883	18.4417	4.9532	0.0173
	-0.05	26.6231	0.7471	19.8913	6.7318	0.0226
$\psi=1.48$	0	22.9125	0.7953	18.2213	4.6912	0.0165
	0.05	21.3487	0.8197	17.4990	3.8497	0.0139
$\psi=1.34$	0	27.2860	0.7397	20.1840	7.1020	0.0237
	-0.05	28.9343	0.7225	20.9052	8.0291	0.0263

Note. Benchmark parameters:  $\rho=0.04$ ,  $\alpha=0.36$ ,  $\beta=0.3$ ,  $\sigma=0.83$ ,  $\gamma=0$ ,  $A=0.02203$ ,  $B=0.0096$   
 $\psi=1.41045$ ,  $L=100$ .

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