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Impatience to Consume and Population Growth in a Simple Agrarian Economy

By

Eirik S. Amundsen¹ and Anders Skonhøft²

Abstract

This paper studies the relationship between population size and the rate of time preference (RTP) in pre-capitalist subsistence agricultural communities. The RTP is reflected in the community's propensity to invest in and maintain new arable land that may be considered as an inherent characteristic of the considered community. Using a Malthusian framework, we show how communities with a low RTP end up with a high steady-state subsistence population compared to communities with a high RTP. Furthermore, unsustainable "optimum population" sizes are identified where consumption per capita has a maximal value. Finally, the paper shows that the population growth rate may have no bearing on the resulting subsistence steady-state population size. A population with a higher growth rate only reaches the subsistence steady-state population size faster and have a lower maximal consumption per capita along the path to the subsistence level.

JEL-classification code: O12, Q12

Keywords: Population growth, Malthusian model, Rate of time preference

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1.Introduction

In this paper we consider population growth in a simple agrarian economy (i.e., a pre-capitalist subsistence agricultural community), where the main focus is on the relationship between impatience to consume (rate of time preference, RTP) and population size. The economy considered is of the very simple type; there is no accumulation of human and man-made physical capital, and there is no technical progress induced by population growth (Boserup, 1965; Pryor and Maurer, 1982), or otherwise. Nor is there any exchange with the world around; what is consumed is therefore exactly what is produced, and the production includes only agricultural products. Labour is the only factor of production together with land. There is a constraint on the amount of land available for agricultural production, but labour can be used in converting undeveloped land (e.g., forest and wilderness land) into agricultural land so that more land, at a later stage, can be used in food production. The labour force and population are generally growing contingent upon food production. Therefore, population growth is considered both as a cause and a consequence of changes in the economy.

The model to be formulated, thus, falls within the Malthusian framework where the population growth is determined by available resources. However, contrary to the standard Malthusian framework, arable land is not a fixed factor of production. The main contribution of this paper is the analysis on how impatience to consume and propensity to invest in productive land resources can play a significant part in affecting population growth as well as the size of the population.

Factors affecting population growth in simple agrarian economies are many and varied. They include natural productive conditions (e.g., soil fertility, precipitation, topography, degree of wilderness formation), availability of other natural resources (e.g., firewood, hunting game, and water), variations in natural conditions (e.g., El Niño phenomena), technological level and mode of production, existence and proneness of diseases. Additionally, cultural and institutional factors play important roles. While cultural aspects related to population growth are clear and direct in modern societies (e.g., preferences with respect to family size and birth control) such factors are also present in pre-capitalist subsistence agricultural economies. Indeed, Malthus himself, discussing historical population growth, included «moral restraint» as a check on population size in addition to “vice and misery” (e.g., disease, war, poverty), defining “moral restraint” as “the restraint from marriage which is not followed by irregular gratifications” (Malthus, Second Essay, 1830). Furthermore, an earlier study of the human

evolution by Carr-Saunders (1922) points to a whole range of factors that may vary among indigenous people in influencing population growth (e.g., premature sex relations, infanticide, abortion, and prolonged abstention from intercourse on the part of the married, in accordance with prescriptive tribal usage or taboo). See also Field (1923). Additionally, it is important to observe that while such factors may determine the pace at which a population evolves towards the subsistence level population, they may not necessarily determine the *size* of a subsistence level population. Contrary to this, there are two additional cultural features that *will* influence the size of subsistence level population; the impatience to consume and the propensity to invest in new arable land.

Evidence about inter-temporal consumption preferences of pre-capitalist subsistence communities is, however, somewhat meagre and scattered. An example of extreme impatience to consume may be taken from the Sirino population mostly living as hunters and gatherers. Holmberg (1950) reports that food consumption for this population group is enormous when there is food available (e.g., it is not uncommon for four people to eat a peccary weighting 27 kg. at a sitting). Normally they would not conserve food for future use and would typically go hungry for days when there is no food around. A similar example is reported for the so-called “Bushmen” of South West Africa (Haswell, 1960; Clark and Haswell, 1964). Otherwise, productive effort in more mature subsistence agricultural communities seem to vary a lot. Burgess and Musa (1950) report an effort of around 3 hours/day in agricultural activities for remote Malay communities, Martin (1956) reports 4 hours/day in Calabar in Southern Nigeria, Refisch (1960) reports 5 hours/day in the village of Warwar in Cameroun and Gourou (1968-69) reports 6 hours/day for married men and 8.5 for married women for the city of Zandé in the North East of Congo. More recent studies show that the RTP in rural communities varies even though it is generally high. For example, Pearce and Markandya (1988) argue that this is the case for people living in semi-arid regions in Africa. Likewise, Pender (1996) find high discount rates for rural India, while Holden, Shiferaw and Wik (1998) find very high but varying RTPs for rural households in Indonesia, Zambia and Ethiopia.

While the relationship between impatience to consume as represented by the RTP and population size has been acknowledged in the literature (Zimmermann, 1989; and Boucekkinne, et al. 2017), it is often dealt with in a more indirect way in models including endogenous growth with technological progress. Otherwise, we are not aware of any publications studying how impatience to consume and propensity to invest in productive land resources may explain

population growth in simple agrarian communities. Hence, in what follows we aim to highlight this relationship by formulating an analytic model studying the relationship between impatience to consume and the propensity to invest in new arable land. The size of arable land and available labour determine food production and the size of the population that can be sustained in the long run.

Technically, a hypothetical well-informed social planner is introduced to determine the optimal allocation of labour in food production and labour used for converting undeveloped land into agricultural land. Referring to Nerlove and Raut (1997), the present analysis falls within the reduced-form endogenous population models as the population growth is contingent upon consumption, or food per capita, and hence, the fertility behaviour is not modelled explicitly. However, in contrast to the reduced-form models presented in Nerlove and Raut, the following analysis is formulated in an optimising framework over time where the size of the population is determined dependent upon the RTP. We start in section 2 by presenting the model and the basic assumptions. Section 3 derives and characterises the optimality conditions. Section 4 introduces simplifying assumptions with respect to production functions and investment behaviour while section 5 illustrates some important aspects of the population growth numerically. Section 6 concludes the paper.

2. The model

As stated, we consider an economy where the human population growth depends on the living conditions in a Malthusian manner, and where the population and land-use are interrelated through two production activities. Firstly, land and labour are used in production of agricultural goods determining the current flow of consumption. Secondly, labour is used in converting uncultivated land into arable land, i.e., investment in new land. Therefore, at every point of time the total population, P , is partly allocated as labour in food production, N , and partly as labour in land clearing and land maintenance, L . Omitting time subscript, we thus have the population constraint:

$$(1) P = N + L.$$

Food production, C , depends on the amount of agricultural land, A , together with labour use. In absence of any technological progress, the time-invariant production function is given as:

$$(2) C = C(A, N),$$

with $\frac{\partial C}{\partial A} = C_A > 0$, $C_N > 0$, $C_{AA} \leq 0$, $C_{NN} \leq 0$, $C(0, N) = C(A, 0) = 0$ and $(C_{AA}C_{NN} - (C_{AN})^2) > 0$. The labour force allocated to land clearing³ and maintenance yields a gross addition to agricultural land, $G(L)$, while land depreciation (wilderness land formation), assumed to be a function of the size of agricultural land, $F(A)$, works in the opposite direction. Hence, the change of agricultural land is given as:

$$(3) dA/dt = G(L) - F(A),$$

with $G' > 0$, $G'' \leq 0$, $F' > 0$, and $F'' \geq 0$. Additionally, we have $G(0) = F(0) = 0$.

Population growth is assumed to be a function of consumption per capita, and is positive above a certain subsistence level, given by the constant k . Hence, the population growth rate is expressed as:

$$(4) \frac{dP/dt}{P} = Z\left(\frac{C(A, N)}{P}\right),$$

$$\text{with } Z \begin{cases} > 0 \text{ as } \frac{C}{P} > k \\ = 0 \text{ as } \frac{C}{P} = k. \\ < 0 \text{ as } \frac{C}{P} < k \end{cases}$$

This formulation, therefore, comprises the ‘unchecked’ Malthusian case with $Z' > 0$ for all values of per capita consumption (see, e.g., Brander and Taylor, 1998). However, this general formulation may also comprise humped population growth with $Z' > 0$ for ‘low’ consumption per capita levels and $Z' < 0$ for ‘high’ values (see, e.g., Kremer 1993).

³ Since we are interested in questions relating to population size and the extensive margin of agricultural land, we do not explicitly consider any maximum on the total available land that potentially may be transformed to arable land. Hence, the size of agricultural land is determined endogenously and unconstrained in the model.

3. Optimal investment policy and the steady-state

It is assumed that the agricultural community acts as if a social planner seeks to maximise the net present value utility of food consumption per capita by allocating labour to agricultural production and to land clearing, i.e.

$$(5) \text{ Max } \int_0^{\infty} U \left(\frac{C(A,N)}{P} \right) e^{-\delta t} dt,$$

subject to equations (2), (3) and (4), and given initial values of the population size and the amount of arable land. The utility function is assumed to be increasing, $U' > 0$, and strictly concave, $U'' < 0$. The time preference rate, RTP, is denoted δ and is assumed to be constant through time. As discussed above, the size of the time preference is considered to be an inherent characteristic of the community considered (e.g., a part of the cultural heritage).

The current-value Hamiltonian of this problem is:

$$J = U \left(\frac{C(A,P-L)}{P} \right) + \lambda(G(L) - F(A)) + \mu PZ \left(\frac{C(A,P-L)}{P} \right),$$

with λ and μ as the shadow prices of agricultural land and population, respectively. The necessary conditions for maximum are:

$$(6) \frac{\partial J}{\partial L} = - \left(\frac{U'}{P} + \mu Z' \right) C_N + \lambda G' = 0 ; L > 0 ,$$

$$(7) \frac{dJ}{dA} - \delta \lambda = \left(\frac{U'}{P} + \mu Z' \right) C_A - \lambda (F' + \delta) = - \frac{d\lambda}{dt}$$

and

$$(8) \frac{dJ}{dP} - \delta \mu = \left(\frac{U'}{P} + \mu Z' \right) \left(C_N - \frac{C}{P} \right) - \mu (\delta - Z) = - \frac{d\mu}{dt}.$$

Control condition (6) states that the marginal gain from allocating an additional unit of labour to food production should be equal to the marginal opportunity cost of doing so. An additional unit of labour applied directly in food production increases consumption by an amount equal to the marginal product, C_N . This amount is multiplied by the utility value per capita of an extra consumption unit. This value reflects both the direct utility effect of the existing population,

U'/P , and the indirect utility effect, $\mu Z'$, that an additional consumption unit yields in terms of the utility value of a change in the population size that may follow from increased consumption. The last term may be interpreted as the indirect utility of allocating an additional unit of labour to land acquisition/recovery.

Portfolio condition (7) steers the optimal expansion of agricultural land. The first term on the right-hand side expresses the marginal per capita consumption utility following from more agricultural land. The second term comprises the cost of expanding agricultural land. First, there is an element expressing the cost in terms of the increased physical depreciation given by, F' . Second, there is the RTP (δ) expressing the opportunity cost of abstaining from the current consumption that one otherwise might have without the investment. Both these marginal costs are evaluated by the shadow price of agricultural land. Hence, condition (7) states that agricultural land at every point of time should change such that the difference between the marginal utility per capita gain and the cost should be equal to the negative of the change of the corresponding shadow price. Following Dorfman (1969) the negative of the change of the shadow price, or co-state variable, expresses the rate of economic depreciation of the actual physical capital (i.e., agricultural land) and corresponds to the negative of the change in the marginal stock value.

Portfolio condition (8) yields the optimal expansion of the population. An additional individual will increase agricultural production by C_N , but will on the other hand consume an amount given by C/P . The net effect, evaluated at its average utility value, is thus $(C_N - C/P)$, which may be either positive or negative⁴. The second term, $-\mu(\delta - Z)$, is the opportunity cost of an additional individual that expresses the value of consumption foregone. Condition (8) thus states that the optimal net gain (loss) of an additional individual should be equal to the reduction (increase) in the shadow value of the population, μ .

The second order conditions demand that the Hamiltonian should be jointly concave in the control and state variables (Mangasarian's theorem). Furthermore, the solution will be unique

⁴ Hence, if the whole population is applied in food production, the marginal product would be less than the average product (corresponding to consumption per capita) and this expression would be negative. This follows from the assumption that the production function is homogenous of a degree less than 1. However, only a part of the population is applied directly in food production so the marginal product may very well be larger than average consumption and will accordingly give a positive expression.

when the Hamiltonian is strictly concave in the control and state variables which is secured through the concave utility function, the concave food production function, the concave land clearing function and the convex land depreciation function.

Eqs. (6) – (8) together with Eqs. (3) and (4) represent a system of five equations with one control variable, two state variables and two shadow prices. It is well-known that the dynamics of a system with two state variables and one control variable may be complicated both when the system is unilinear in the control, as here, and also when it is linear (see., e.g., Clark, 1990, Ch.10 and Mesterton-Gibbons, 1996). In section 5 we study a simplified version of the dynamics where the investment fraction is kept fixed. However, to find the steady-state, or golden rule, condition of the above model is straightforward. It is given by Eq. (6) together with:

$$(7') \quad \left(\frac{U'}{P} + \mu Z'\right)C_A = \lambda(F' + \delta),$$

$$(8') \quad \left(\frac{U'}{P} + \mu Z'\right)\left(C_N - \frac{C}{P}\right) = \mu\delta,$$

$$(3') \quad G(L) - F(A) = 0$$

and

$$(4') \quad Z\left(\frac{C}{P} = k\right) = 0.$$

Thus, these equations determine P^* , N^* , L^* and A^* together with the shadow prices λ^* and μ^* (where superscript ‘*’ indicates the optimized steady-state values). Condition (4’) states that the equilibrium food consumption per capita will be fixed at $C^*/P^* = k$ while condition (8’) indicates that the steady-state shadow price of the population size, μ^* , actually may be negative. If negative, it means that an additional individual to the population may contribute negatively to the present value per capita consumption. The reason for this is that the population evolves through the average consumption path while not being controlled directly (e.g., no birth control, or no effort aimed to reduce mortality). Accordingly, the population expands until average consumption reaches the existence minimum.

When combining (6) and (7’) we obtain:

$$(9) \quad C_N/C_A = G'/(F' + \delta).$$

This condition states that land and labour should be allocated such that its marginal rate of technical substitution in food production and arable land becomes equal to the relative cost of providing these resources in food production while taking RTP into account. Notice that this condition does not include any expression of the welfare preferences (i.e., utility) of the considered economy. Hence, at least for linear land clearing and land degradation functions, and thus constant values of G' and F' , we find that a higher value of δ implies a higher steady-state labour - land food production ratio.

In order to analyse these relationships further, we combine (4'), (3') and (9) and find after some small rearrangements:

$$(10) \frac{\delta C_N}{G'} dA^* = (k - C_N) dP^*.$$

Clearly, if $k > C_N$; that is, the steady-state consumption per capita is higher than the marginal labour productivity in food production, there is a positive relationship between the steady-state population size and the amount of agricultural land. This means that parameter changes that lead to a larger population size (say, through a lower value of δ), also will lead to more agricultural land (on the extensive margin). It is interesting to note that the condition for this rather intuitive relationship between population size and agricultural land is that the net contribution of the marginal worker in food production is negative. That is, consumption per capita at the extensive margin, $C^*/P^* = k$, should exceed the marginal contribution of labour in food production, C_N . Notice also that if $k > C_N$ together with $Z' > 0$ from Eq. (8') (i.e., the unchecked case of population growth), then the population shadow price μ^* is negative, as was noted as a possibility above. Somewhat more generally it turns out that μ^* is non-positive if $Z' > 0$ and $L/P < (1 - C_N N/C)$; that is, if the investment fraction (i.e., the labour - population fraction) is less than one minus the output elasticity of labour in food production.

4. Impatience and population size

In order to analyse the effects of changes in the economic environment further, and especially to look at the relationship between population size and RTP, more structure is needed in the model. For that reason, we apply Cobb-Douglas functional forms in food production and land clearing, i.e., $C = q_1 A^\alpha N^\beta$ and $G(L) = q_2 L^\gamma$, with q_1, q_2, α, β and γ as productivity parameters.

Due to the second order conditions and the concavity of the Hamiltonian, we must have $(\alpha + \beta) \leq 1$ and $\gamma \leq 1$. Furthermore, we assume that cultivated land depreciates linearly, $F(A) = fA$, where f is a constant decay rate. Combining (3') and (10) we then find the land clearing labour fraction in our economy as:

$$(11) \frac{L^*}{P^*} = \frac{\alpha f \gamma}{\beta(\delta+f) + \alpha f \gamma}.$$

Under these conditions, the steady-state land clearing investment fraction depends only on the given parameters of the model. However, notice that the productivity parameters, q_1 and q_2 , are not included. Condition (11) indicates that a higher δ and, hence, a larger impatience to consume, will lead to a lower investment fraction (land per individual). The highest investment fraction in this economy, thus, takes place when $\delta = 0$. In this special case it is also observed that the land decay rate, f , no longer plays any role.

Using Eqs. (3'), (4) and (11), steady-state consumption may be expressed as

$$(12) C^* = q_1 \left(\frac{q_2}{f}\right)^\alpha \left[\frac{\alpha f \gamma}{\beta(\delta+f) + \alpha f \gamma}\right]^{\gamma\alpha} \left[\frac{\beta(\delta+f)}{\beta(\delta+f) + \alpha f \gamma}\right]^\beta P^{*(\gamma\alpha + \beta)}.$$

Dividing by the population size and using the steady-state condition $\left(\frac{C^*}{P^*}\right) = k$, we next find the steady-state population size as:

$$(13) P^{*(1 - (\gamma\alpha + \beta))} = \frac{q_1}{k} \left(\frac{q_2}{f}\right)^\alpha \left[\frac{\alpha f \gamma}{\beta(\delta+f) + \alpha f \gamma}\right]^{\gamma\alpha} \left[\frac{\beta(\delta+f)}{\beta(\delta+f) + \alpha f \gamma}\right]^\beta.$$

With constant return to scale in food production and decreasing effect in land clearing, or *vice versa*, or decreasing return to scale in both these activities, we find that a higher per capita subsistence level, k , definitely means a lower steady-state population size. On the other hand, higher productivity in food production and land clearing work in the opposite direction.

Differentiating Eq. (13) implicitly yields:

$$(14) \frac{\partial P^*}{\partial \delta} = \frac{\beta \delta L^*}{(1 - \gamma\alpha - \beta)(\delta + f)f}.$$

Therefore, with $(\gamma\alpha + \beta) < 1$ we find $\partial P^*/\partial\delta < 0$, as illustrated in Figure 1. It also turns out that the condition $(\gamma\alpha + \beta) < 1$ is a sufficient condition for $k > C_N$, and, hence, that the population shadow price μ^* is non-positive. Intuitively a higher value of δ leading to a lower population size in this case makes sense since an impatient population (large value of δ) is less inclined to invest in agricultural land. Figure 1 also demonstrates the negative population effect of a larger natural decay of arable land. Furthermore, it is straightforward to demonstrate that the population size is increasing in the food production productivity, q_1 , and also in land clearing productivity, q_2 .

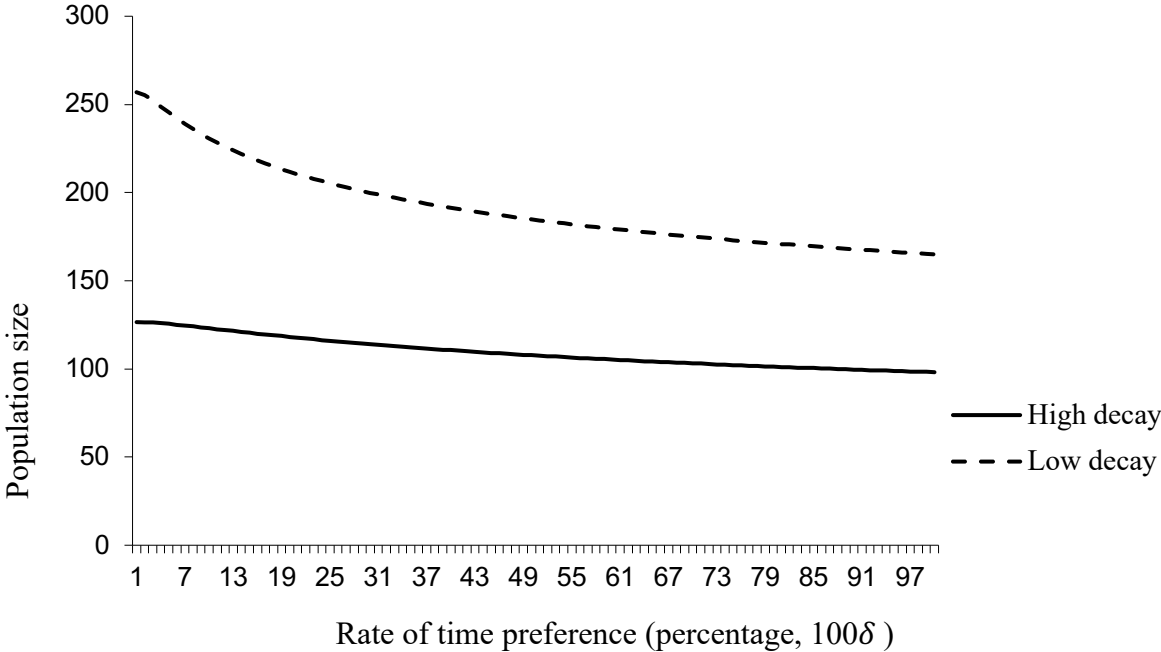


Fig. 1. Steady-state population size as a function of RTP (δ) and decay rate.

Parameter values: Decay rate, high: $f=0.1$. Decay rate, low: $f=0.05$

5. Population development – a numerical illustration

In the following numerical illustration, we assume that the RTP is reflected in the way the community allocates people working with land clearing versus direct food production. Hence, a community with a small value of RTP allocates a larger proportion of the population in land

clearing and development of agricultural land. We assume that this proportion is an inherent trait of the considered community and is fixed as the population evolves over time. The correspondence between the particular labour allocation and the RTP is given by the steady-state condition (11) and is assumed to hold outside steady-state as well. Therefore, the particular investment behaviour used in the numerical illustration does not correspond exactly to the optimal population development as determined by the optimality conditions (6)-(8). However, with the fixed proportion given by the parameters of (11), the resulting steady-state population size will be the same as in the optimal model. In order to illustrate population growth under the above simplification, we apply a discrete time version of the model given by:

$$(15) C_t = q_1 A_t^\alpha N_t^\beta,$$

$$(16) A_{t+1} = A_t + q_2 L_t^\gamma - f A_t,$$

$$(17) \frac{P_{t+1} - P_t}{P_t} = b \frac{C_t}{P_t} - a,$$

and

$$(1) P_t = L_t + N_t.$$

Additionally, we have:

$$(11) \frac{L_t}{P_t} = \frac{\alpha f \gamma}{\beta(\delta+f) + \alpha f \gamma}.$$

Notice that Eq. (17) corresponds to the unchecked Malthusian population development with the subsistence per capita consumption level given by $(C_t/P_t) = (a/b)$. Hence, the steady-state per capita consumption for the simplified model equalizes the subsistence per capita level in the general model, i.e., $(a/b) = k$. The above system can be reduced to the following two unilinear first order difference equations in P_t and A_t

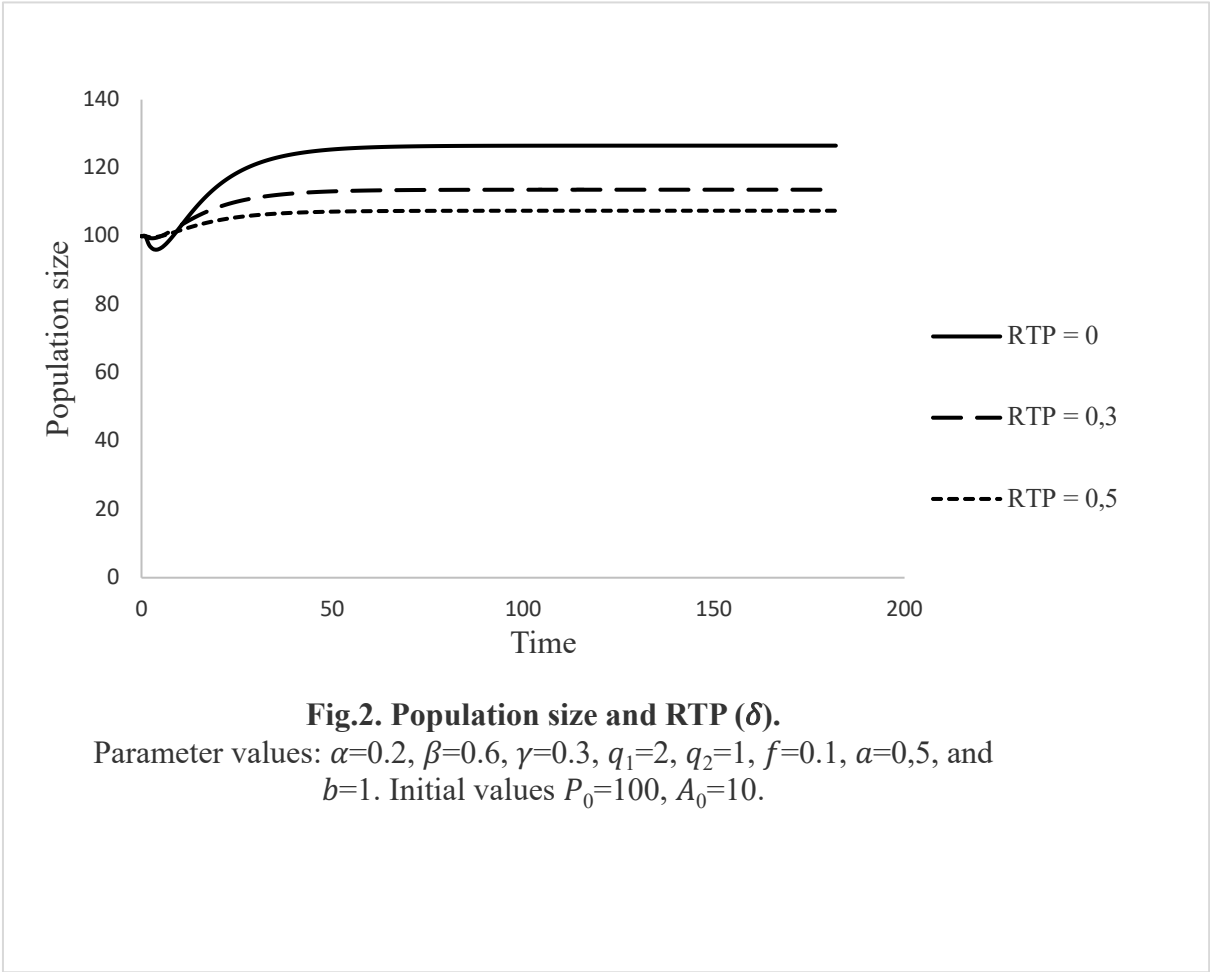
$$(18) P_{t+1} = b q_1 A_t^\alpha (P_t(1 - \xi))^\beta + P_t(1 - a)$$

and

$$(19) A_{t+1} = (1 - f)A_t + q_2(\xi P_t)^\gamma,$$

and where $\xi = \frac{\alpha f \gamma}{\beta(\delta+f) + \alpha f \gamma}$.

It can be confirmed that the system leads to a stable steady-state solution which is independent of the initial values of the population size and the size of the agricultural land. The solution is illustrated in Figure 2 where it is shown how a low, a medium and a high value of δ influences population growth. In all these three cases it is assumed similar initial values for the population and the size of agricultural land (i.e., three populations of the same size settling in a comparable area). A community with a low value of δ will start by investing more in agricultural land than a community with a higher impatience to consume. In the beginning it will therefore experience a lower per capita consumption and therefore also a slower population growth than the community with the higher value of δ . Figure 2 illustrates that this may actually result in a reduction of the population, before it starts to grow. As time passes, however, the investment starts to pay off and the per capita consumption of the less impatient population exceeds that of the per capita consumption of the more impatient population, as can be seen in Figure 3. Hence, it grows more until it, as expected, settles at a higher steady-state level.



An important feature of the model is that the initial sizes of the population and agricultural land are not decisive for the long run population size. Therefore, if the population is very small relative to the size of the initial agricultural land, the population will grow over time before it reaches the long run subsistence level. And on the contrary, if the initial population is very large relative to the initial size of agricultural land, the population will decline over time before the long run subsistence level is reached. In both these cases, the long run steady-state population size will be similar provided that there are no differences in δ .

Next, Figure 3 illustrates consumption per capita levels along the path towards the steady-state population size. As can be seen, various maximum levels of consumption per capita may be identified depending on the size of δ . These levels may be taken to correspond to “optimum populations” in the sense of Edwin Cannan (1894) and later writers, since average consumption is the highest possible. With $\delta = 0$, the optimum population in this sense would be equal to 99 instead of 126 for the subsistence level population (Figure 2) and for the case of $\delta = 0,5$ it would be 101 instead of 106. However, in the model considered, such levels of optimum population size cannot be sustained unless some harsh checking mechanisms set in at this point to prevent the population size and the size of agricultural land to increase further. Rather, with unchecked population growth, the population size and the size of agricultural land will, as noted, continue to grow until the subsistence consumption per capita level is attained, resulting in similar consumption per capita levels, but different long run population sizes (Figure 2).

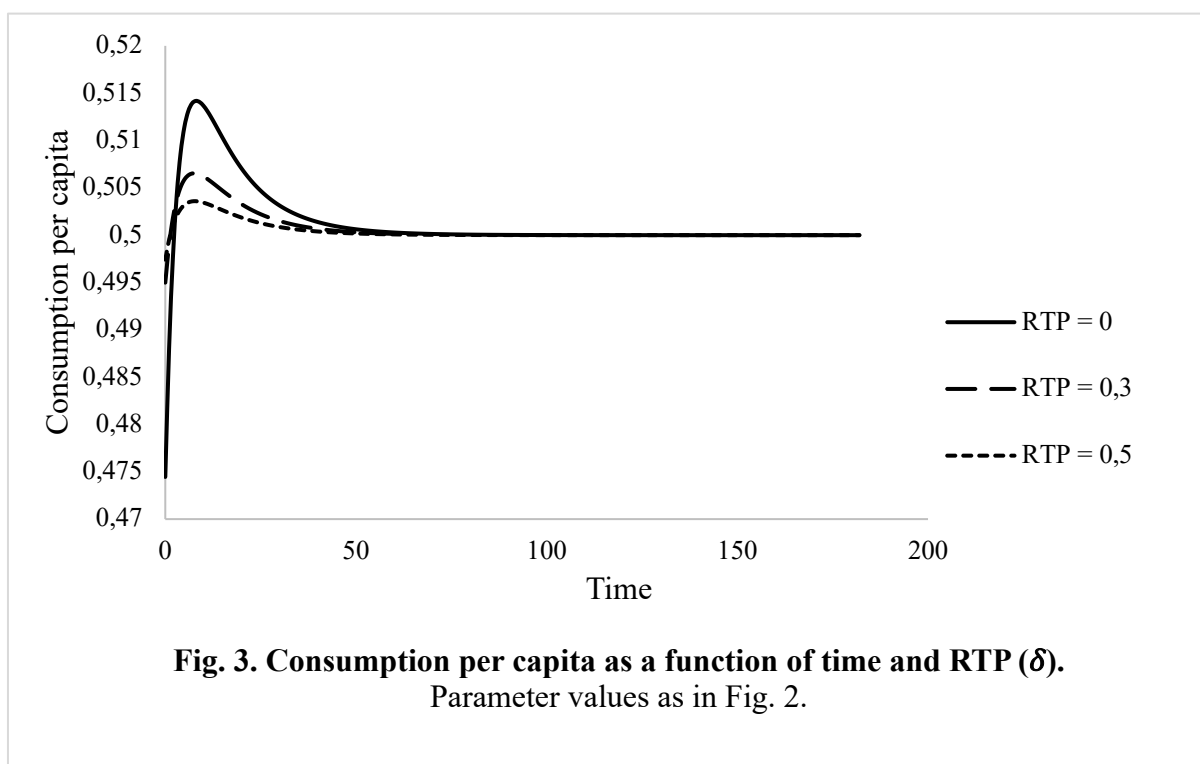
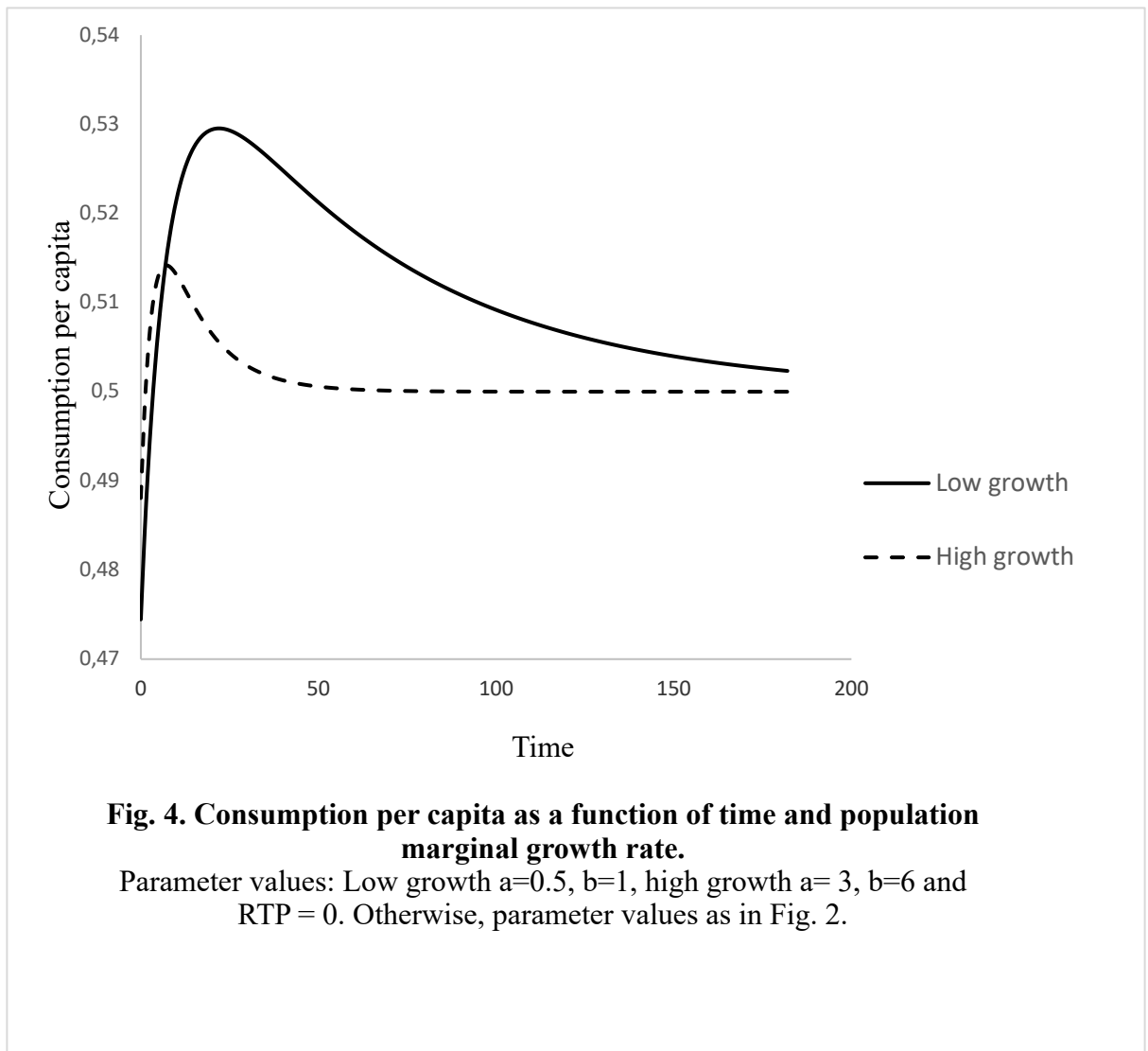


Fig. 3. Consumption per capita as a function of time and RTP (δ).
Parameter values as in Fig. 2.

Finally, Figure 4 illustrates a point discussed in the introduction, namely that various cultural traits that affect the growth rate of a population may have no effect on the long run steady-state population size in a simple agrarian economy. In the model considered, the marginal growth rate as a function of consumption per capita is equal to b in Eq. (17). However, to compare two populations with different growth rates, a corresponding adjustment is made for the parameter a such that the subsistence consumption per capita level is the same for both populations, i.e., $a/b = k$. For both populations, δ is set equal to zero. As can be seen in Figure 4, a higher growth rate will result in a higher consumption per capita level in the short and medium term compared to the case with a lower population marginal growth rate present. However, the consumption per capita will sooner fall off attaining a maximum level less than the maximum consumption per capita level for the population with the lower growth rate. Notice also that the population with the highest growth rate will reach the long run subsistence level population faster.



6. Summary and concluding remarks

The existing literature demonstrates that population growth in subsistence agrarian economies may vary quite a lot with respect to impatience to consume. While both Thomas Malthus and later writers such as John Stuart Mill, Edwin Cannan (1894) and Alexander Carr-Saunders (1922) did substantial contributions to study and describe how cultural aspects may explain population growth in simple agrarian societies, they did not however address possible effects of impatience to consume. As far as we know there is neither any other literature addressing this particular point. The goal of the present paper is to fill in this gap, and where a Malthusian model with unchecked population growth of a Millian type (growth depends on consumption per capita) is formulated. The population is all the time allocated to either food production or to land clearing activities to expand the amount of agricultural land and thus at a later stage

increase food production. There is assumed to be no technical progress. Our analysis is, therefore, not related to the seminal contribution by Ester Boserup (1965, 1981) that highlights the importance of intensification of agricultural production along with population growth that leads to induced innovations of better agricultural methods.

Using both the analytical model as well as a numerical illustration, we find that the larger the impatience to consume, as represented by the marginal rate of time preference (RTP), the smaller the steady-state population size. Hence, the larger the RTP, the lower weight imposed on investments in new arable land. The results also show that the higher the decay rate of agricultural land, the smaller the subsistence steady-state population size. Furthermore, depending on the parameter values of the model, it is possible to identify “optimum population” sizes in the sense that the consumption per capita reaches a maximal value. Such levels are, however, not sustainable in an unchecked Malthusian model as the population continues to grow until the subsistence level is attained. The paper also shows that the parameter describing the population growth rate may have no bearing on the resulting subsistence steady-state population size. (See also Perrings, 1989, on this point). Given the same consumption per capita subsistence level, a population with a higher growth rate only reaches the subsistence steady-state population size earlier. Also, in the model considered, the population with a high growth rate has a lower “optimum population” size than a population with a lower growth rate.

Several related issues not directly captured by the model are worth mentioning. One relates to the causes for why impatience of consumption and the propensity to invest may differ. For instance, a consumption and investment strategy that ensures a large population may be important in its own right. Hence, a large population may give better protection against nearby hostile tribes and also provide better opportunities to organise and carry out large common projects (e.g., fortification and irrigation systems). Also, a high propensity to invest, may be seen as a strategy to create a resource buffer in the face of uncertainty and variability of natural events such as El Niño phenomena and diseases.

Furthermore, there is an interesting discussion in Holden, Shiferaw and Wik (1998 p. 106) on the causality of RTP and consumption level, i.e., whether a high RTP induces a low

consumption level or the other way around. The authors argue that poverty leads to a high RTP⁵, but recognise that the question of causality is inconclusive. In our model, such a relationship would imply changing levels of RTP as the consumption per capita changes along with the population growth development.

An issue not taken up here relates to the question of inequality and the existence of feudal elites that may capture all surpluses (Darity 1980 p. 145), and how this may affect population growth and long run population size. On this point, it is interesting to observe that John Stuart Mill (1848) arrives at the following conclusion: “An unjust distribution of wealth does not even aggravate the evil (i.e., the subsistence level) but, at most, causes it to be somewhat earlier felt.”⁶ Hence, according to Mill, an unjust distribution of consumption does not affect the end result of population development, i.e., a steady-state subsistence level population.

⁵ On this question, see also Pender and Walker (1990) and Pender, (1996, p. 259), and more recently Bartos et al. (2018).

⁶Quotation referred to in Zimmermann (1989).

Literature

- Bartos, V., Bauer, M., Chytilova, J. and Lively, I. (2018) 'Effects of Poverty on Impatience: Preferences or Inattentions? Rationality and Competition' CERGE-EI Working Papers wp623, The Centre for Economic Research and Graduate Education, Economic Institute, Prague.
- Boserup, E. (1965) *The conditions of agricultural growth: The economics of agrarian change under population pressure*, London: Allen and Unwin.
- Boserup, E. (1981) *Population and technology*, Oxford: Blackwell.
- Boucekkine, R., Martinez, B. and Ruitz-Tamarit, J. R. (2017), 'Optimal Population Growth as an Endogenous Discounting Problem: The Ramsey Case', HAL, halshs-01579155.
- Brander, J. and Taylor, M.S. (1998) 'The simple economics of Easter Island: A Ricardo-Malthus model of renewable resource use', *American Economic Review*, 88, pp. 119-138
- Burgess, R.C. and Musa, L. B. A. (1950) *A Report on the State of Health, the Diet and the Economic Conditions of Groups of People in the Lower Income Levels in Malaya*, Institute for Medical Research Report No.: 13, Federation of Malaya.
- Cannan, E. (1894) *A History of the Theories of Production and Distribution*, Oxford: Clarendon Press.
- Carr-Saunders, A.M. (1922), *The Population Problem: A study in Human Evolution*, Oxford: Clarendon Press.
- Clark, C. and Haswell, M. (1964): *The Economics of Subsistence Agriculture*, London: MacMillan, St. Martin's Press.
- Clark, C. (1990), *Mathematical Bioeconomics: The Optimal Management of Renewable Resources*, (2. Ed.), Wiley.
- Darity, W.A. Jr. (1980) 'The Boserup theory of agricultural growth: A model for anthropological economics', *Journal of Development Economics*, 7, pp. 137-157.
- Dorfman, R. (1969) 'An Economic Interpretation of Optimal Control Theory', *American Economic Review*, 59(5), pp. 817-831.
- Field, J.A. (1923) 'Review: The Population Problem: A Study in Human Evolution by A.M. Carr-Saunders', *Journal of the American Statistical Association*, 18(144), pp. 1051-1053.
- Gourou, P. (1969) *Annuaire du Collège de France, 1959-60*. Paris.
- Haswell, M. R. (1960) 'Economics and Population in Africa', *The Month*, November.

- Holden, S.T., Shiferaw, B. and Wik, M. (1998) 'Poverty, market imperfections and time preferences: of relevance for environmental policy?' *Environmental and Development Economics*, 3(1), pp. 105-130.
- Holmberg, A.R. (1950) *Nomads of the Long Bow: The Sirino of Eastern Bolivia*, Smithsonian Institution of Social Anthropology, Publication No. 10.
- Kremer, M. (1993) 'Population growth and technological change: One million B.C. to 1990', *Quarterly Journal of Economics*, 108, pp. 681-716.
- Malthus, T.R. (1798) *An Essay on the Principle of Population* (ed. Flew, A.), Pelican Classics, 1970.
- Markandya, A. and Pearce, D. (1988) 'Environmental considerations and the choice of discount rate in developing countries', Working Paper Environmental Department, The World Bank, Washington D.C.
- Martin, A. (1956) *The Oil Palm Economy of the Ibibio Farmer*, Ibadan University Press.
- Mill, J.S. (1848) *Principles of Political Economy*, London: John W. Parker, West Strand.
- Mesterton-Gibson, M. (1996) 'A technique for finding optimal two-species harvesting policies', *Ecological Modeling* 9, pp. 235 -244.
- Nerlove, M. and L. Raut (1997): 'Growth models with endogenous population: A general framework', in Rosenzweig, M. and Stark, O. (eds.): *Handbook of Population and Family Economics*, Amsterdam: Ib. Elsevier.
- Pender, J. L. and Walker, K. (1990) 'Experimental measurement of time preference in rural India', Record Number 19901884025, International Crops Research Institute for the Semi-Arid Tropics, Patancheru, Andhra Pradesh.
- Pender, J. L. (1996) 'Discount rates and credit markets: Theory and evidence from rural India', *Journal of Development Economics*, 50, pp. 257-296.
- Perrings, C. (1989) 'An optimal Path to Extinction? Poverty and resource degradation in the open agrarian economy', *Journal of Development Economics*, 30, pp. 1-24.
- Pryor, F.L., Maurer, S.B. (1982) 'On induced economic change in precapitalist societies', *Journal of Development Economics*, vol. 10, pp. 325-353.
- Refisch, R. (1960), M.A. thesis in Anthropology, University of London (available in Colonial Office Library).
- Zimmermann, K.F. (1989) 'Optimum Population: An introduction' in Zimmermann, K. F. (ed.), *Economic Theory of Optimal Population*, Berlin: Springer-Verlag, pp. 1-16.