

“Is There a General Criterion for Dynamic Efficiency ?”

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Is there a general criterion for dynamic efficiency?

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Abstract: This paper analyses an overlapping generations model with absolute bequest motive. It is shown that the widely accepted criterion to verify dynamic efficiency does not apply to this case. In our model the social planner maximizes welfare by choosing a capital stock larger than the golden rule and a real rate of interest smaller than the rate of growth of the economy.

Keywords: Dynamic efficiency; Bequest motive; Overlapping generations; Capital accumulation.

JEL Classification: D99, D69.

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Is there a general criterion for dynamic efficiency?

1. Introduction

A widely accepted way to verify whether a competitive market economy is or is not dynamically efficient is to ask a social planner to look at its balanced growth path and see if she or he can do better. The well established criterion is: an economy is said to be Pareto-inefficient when its capital stock is larger than the level warranted by either the golden or the modified golden rule. That is, when the equilibrium real rate of interest is smaller than the growth rate of the model plus any discount rate of the future (see Blanchard and Fisher, 1989, and Romer, 1996).

This paper deals with this same subject. However, unlike current literature, the analysis focuses on an overlapping generations model populated by individuals with absolute bequest motives, as in Hoover (1988). Contrary to the above criterion it is shown that in this case Pareto optimality requires a steady state stock of capital greater than the one given by the golden rule, i.e., a real rate of return on capital smaller than the economy's growth rate.

The established criterion for dynamic efficiency is derived from models in which welfare depends only upon the levels of *consumption* attained by the living individuals in the steady state, disregarding the level of wealth transferred to future generations. This is the case of the Ramsey-Cass-Koopmans model, and of the altruistic OLG economy designed by Barro (1974), in which finite-lived individuals behave as if they were infinitely lived. It is also a feature of the Diamond (1965) model, where people care only about their own consumption and do not take into account future generations. However the example provided in this paper does take into consideration wealth left as bequests for future generations. Here individuals derive utility from consumption as well as from the absolute magnitude of the bequests they leave, willingly forego consumption in order to transfer capital to future generations, and do not care at all as to the way future generations utilizes these bequests. In this case social planners choose, as mentioned, a stock of capital larger than the golden rule and a real rate of return smaller than the economy growth rate. As a consequence, the paper concludes that the comparison between interest and growth rates is not a criterion general enough to assess dynamic efficiency. It is also necessary to consider how individuals consider the future and treat future generations.

Next section presents the model, solves it for a competitive market economy and exhibits some very simple simulations to prepare for further analyses. Third section derives the Pareto optimality conditions for the model and provides an example of a dynamically efficient competitive market economy in which the equilibrium capital-labor ratio is larger than the level prescribed by the golden rule. Fourth section presents the concluding remarks of the paper.

2. The competitive equilibrium

The present formulation extends Martins (1980, 1995), and Araujo and Martins (1999). It expands the demand side of the Samuelson (1958)-Diamond (1965) overlapping generations model by the inclusion of an absolute bequest motive as in Hoover (1988). The goal is to exemplify an economy in which the widely used current criterion for dynamic efficiency fails. Besides, this formulation follows Diamond (1965) closely, to stimulate comparisons.

Generations overlap. Population growth is η . Individual t lives for two periods, supplies one unit of labor as young, nothing afterwards, and values consumption and bequest plans according to the well behaved utility function $U_t = \beta * \ln C_1(t) + (1 - \beta) * \ln C_2(t) + \delta * \ln W_t$, where C 's are consumptions, W is the bequest left for future generations, $0 < \beta < 1$, and δ are parameters. The greater the importance placed on future generations, the greater the δ . In Diamond $\delta = 0$. The only good may be immediately consumed, saved as capital for next period production, or transferred as bequest. The quantity produced of it at time t per unit of labor is $y_t = A * k_t^\alpha$, where k is the capital-labor ratio and A and $0 < \alpha < 1$ parameters of the Cobb-Douglas technology. At t individual t earns competitive wages equal to w_t , gets $W_t/(1 + \eta)$ units of bequest from a member of generation $t - 1$, and consumes $C_1(t)$ and saves $(1 + \eta) * k_{t+1}$ units of good. In period $t + 1$ she or he earns competitive interests equal to $(1 + \eta) * r_{t+1} * k_{t+1}$, consumes $C_2(t)$ and leaves as bequest W_{t+1} units of the good. To solve for $C_1(t)$, $C_2(t)$, k_{t+1} and W_{t+1} individual t takes w_t , r_{t+1} and W_t as given and maximizes the above utility function subject to (1) and (2):

$$C_1(t) + (1 + \eta) * k_{t+1} = W_t/(1 + \eta) + w_t \quad (1)$$

$$C_2(t) + W_{t+1} = (1 + \eta) * (1 + r_{t+1}) * k_{t+1} \quad (2)$$

With Cobb-Douglas utility and production functions solution is straightforward. First observe that the present value of individual t 's total wealth, discounted at r_{t+1} , is exactly $W_t/(1 + \eta) + w_t$. With the above particular utility function she or he spends a fraction equal to $\beta/(1 + \delta)$ of this discounted total wealth in $C_1(t)$, and fractions of $(1 - \beta)/(1 + \delta)$ and $\delta/(1 + \delta)$ in the present values of second period consumption and bequest, $C_2(t)/(1 + r_{t+1})$ and $W_{t+1}/(1 + r_{t+1})$. So, $\delta * C_2(t) = (1 - \beta) * W_{t+1}$. These data can be substituted into (1) and (2) to obtain (3) and (4) as:

$$(1 + \eta) * (1 + \delta) * k_{t+1} = (1 - \beta + \delta) * [W_t/(1 + \eta) + w_t] \quad (3)$$

$$(1 - \beta + \delta) * W_{t+1}/(1 + \eta) = \delta * (1 + r_{t+1}) * k_{t+1} \quad (4)$$

Expression (4) is also valid for period t . Let us re-write it for t and plug the resulting value of $W_t/(1 + \eta)$ in (3). This implies:

$$(1 + \eta) * (1 + \delta) * k_{t+1} = \delta * k_t + \delta * r_t * k_t + (1 - \beta + \delta) * w_t \quad (5)$$

Now remember that with the above production function we have, $r_t * k_t = \alpha * A * k_t^\alpha$ and $w_t = (1 - \alpha) * A * k_t^\alpha$. By inserting these expressions into (5) the model is immediately solved for the for the competitive equilibrium time path of capital. The solution is:

$$(1 + \eta) * (1 + \delta) * k_{t+1} = \delta * k_t + [(1 - \alpha) * (1 - \beta) + \delta] * A * k_t^\alpha \quad (6)$$

For $\delta = 0$ the dynamics of k_{t+1} is entirely determined by the past behavior of k 's. For $\delta > 0$ it also depends on how people value the future that goes beyond their own life times. Now let $k = k_{t+1} = k_t$, be the competitive steady state capital-labor ratio associated to (6), and

$r = \alpha * A * k^{a-1}$ the correspondent real rate of return. By using these two expressions into (6) we obtain the following two competitive steady state conditions, for capital and interest rate :

$$(1 + \eta + \eta * \delta) * k^{1-a} = ((1 - \alpha) * (1 - \beta + \delta)) * A \quad (7)$$

$$r = \frac{\alpha * (1 + \eta + \eta * \delta)}{(1 - \alpha) * (1 - \beta) + \delta} \quad (8)$$

For $\delta=0$ equation (8) is the one found by Diamond (1965,p.11). So, the present formulation is more general than his. The effects of δ on the steady state stock capital-labor ratio and interest rate are clear cut. Take $A=1$, $\alpha=0.5$, $\beta=0.5$ and $\eta=0.05$. In the Diamond model the equilibrium capital-labor ratio and interest are 0.057 and 2.10. Now set $\delta = 20.5$. They become 100.0 and 0.05, respectively. For $A=1$, $\beta=1$ and $\eta=0$, equilibrium capital-labor ratio is $k^{1-a} = \delta$ and steady state production $y = k^a$. Then δ is promptly interpreted as the steady state capital-output ratio of the economy, and the real rate of return on capital is readily reckoned as $r = \alpha/\delta$.

Finally let $A=170.45507$, $\alpha = 0.20$, $\beta = 1$, $\delta = 20$ and $\eta = 4,03013$. The resulting competitive real rate of interest is 0.85633, much lower than that rate of population growth. Next section shows that this solution is dynamically efficient.

2. Dynamic efficiency revisited

This section solves the model for social optimum dynamic equilibrium conditions and presents a counter example to current text book criteria for dynamic efficiency.

First, remember that finitely-lived individuals born at different times in an OLG economy attain different levels of utility and so it is not clear how to evaluate social welfare. Nonetheless, a minimum requisite is that the balanced growth path be Pareto efficient. As pointed out by Diamond (1965, pp. 1128-9) and Romer (1996, pp.81-2) this requisite focuses only on steady states, ignores initial conditions for capital accumulation as well as the costs of achieving them. Moreover, it treats the allocation of resources over the lifetime of an individual as an allocation

between members of different generations, in a single period. So, let's assume a social planner and look only at steady state equilibria, represented by (\circ) .

Second, denote by L_t and $L_t/(1+\eta)$ the number of persons of each generation t and $t-1$ living together. At t , in steady state, aggregate consumption amounts to $C_1^* L_t + C_2^* L_t/(1+\eta)$ and the total quantity of capital, K_{t+1} , carried over $t+1$, is $(1+\eta) * k^* * L_t$. The sum of these two must equal total production, $A * (k^*)^\alpha * L_t$, plus total stock of capital, $K_t = k^* * L_t$, brought to period t . That is,

$$C_1^* + C_2^*/(1+\eta) + \eta * k^* = A * (k^*)^\alpha \quad (9)$$

Third, observe that in the Diamond model (9) is the only real resource constraint that the planner has to take into account. It is the trade-off between consumption and capital accumulation open to society in steady state. She or he has the freedom to choose k^* and so consumption. Its maximum is attained at the golden rule, as the marginal productivity of capital equals the economy growth rate, $r^* \equiv \alpha * A * (k^*)^{\alpha-1} = \eta$. But now the trade-off between consumption, bequest and capital accumulation must also be considered. In the steady state and with Cobb-Douglas production functions $(1+r^*) * k^* = k^* + \alpha * A * (k^*)^\alpha$. So, the steady state equivalent of (2) is (10). Hence, to choose k^* the planner maximizes $U = \beta * \ln C_1^* + (1-\beta) * \ln C_2^* + \delta * \ln W^*$ subject to (9) and (10).

$$C_2^* + W^* = (1+\eta) * (k^* + \alpha * A * (k^*)^\alpha) \quad (10)$$

First order conditions imply:

$$\frac{\beta}{(1+\eta) * C_1^*} + \frac{\delta}{W^*} = \frac{1-\beta}{C_2^*} \quad (11)$$

$$\frac{\beta(r^* - \eta)}{C_l^*} + \frac{\delta}{W^*} (1 + \eta)(1 + \alpha r^*) = 0 \quad (12)$$

in which the consumptions and the parameters α and β are always positive, bequests may be positive or null, depending on people's behavior toward the future, while η may also be positive or null. Social equilibrium conditions (11) and (12) are clear. With $\delta = 0$ we have the Diamond case in which the golden rule, $r^* = \eta$, applies. However, for $\delta > 0$ $r^* = \eta$ is not a feasible solution to the problem. Clearly, condition (12) requires $r^* < \eta$, exactly the opposite as to the well known condition found in the case of Ramsey-Cass-Koopmans model. Furthermore, for $\eta = 0$ condition (12) asks the planner to deepen capital until its marginal productivity falls to zero. Hence, neither the golden nor the modified golden rules are general enough to verify Pareto optimality in growth models. The result depends people's behavior towards the future.

In order to show that the economy exemplified at the end of the last section is dynamically efficient, the planner seeks to maximize $\ln C_l^* + \delta \ln W^*$ with respect to k^* subject to $C_l^* + \eta k^* = A^*(k^*)^\alpha$ and to $W^* = (1 + \eta)(k^* + \alpha A^*(k^*)^\alpha)$. Social optimum capital-labor ratio becomes :

$$\frac{\eta - \alpha A^*(k^*)^{\alpha-1}}{A^*(k^*)^\alpha - \eta k^*} = \delta \frac{1 + \alpha^2 A^*(k^*)^{\alpha-1}}{k^* + \alpha A^*(k^*)^\alpha} \quad (13)$$

For that economy we set $A = 170.45507$, $\alpha = 0.20$, $\beta = 1$, $\delta = 20$, $\eta = 4,03013$ and obtained a competitive real rate of return on capital equal to 0.85633, much lower than the above rate of population growth. To show that this is also the social optimum rate of interest, substitute these numbers into (13) and solve for k^* . The result is $k^* = 100$. Now compute $r^* = \alpha A^*(k^*)^{\alpha-1} = 0.20 * 170.45507 * (100)^{0.20-1}$ to find exactly $r^* = 0.85633 < \eta = 4,03013$. This proves our assertion.

3. Conclusions

A widely accepted criterion for assessing dynamic Pareto optimality is to compare the real interest rate r to the growth rate of the economy η . If $r < \eta$ it is said that the economy is

dynamically inefficient and has over-accumulated capital, in which case by decreasing the quantity of capital the social planner can increase consumption in all periods thereafter and makes everyone better off. In that respect, this paper argued that this criterion is derived from models in which welfare depends only upon the levels of *consumption* attained by the living individuals in the steady state, disregarding the level of wealth transferred to future generations. In the case of an overlapping generations economy with absolute bequest motive studied in this paper (along the lines of Hoover, 1988, and Martins, 1995), the condition for dynamic efficiency is precisely $r > \eta$. Hence, the widely accepted criterion is not general enough to characterize dynamic efficiency. It is also necessary to consider how individuals consider the future and treat future generations.

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Economic growth with finite lifetimes

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Abstract

Finite lifetimes do not preclude sustained growth with a convex technology when agents are finitely-lived and formulate their bequeathing decisions in terms of an absolute bequest motive. In this model the presence of government debt adversely affects the equilibrium rate of growth of the capital stock. © 1999 Elsevier Science S.A. All rights reserved.

Keywords: Endogenous growth; Bequest motive; Overlapping generations; Capital accumulation; Government debt

JEL classification: O41; E13

1. Introduction

Jones and Manuelli (1992) argue that one-sector overlapping-generations models with convex technologies but without an intergenerational mechanism of income transfers cannot generate a non-zero equilibrium growth rate. Using a version of Diamond's (1965) standard OLG model, they note that, when 'young', i.e. in the first-period of their lives, individuals do not have sufficient income with which to acquire a stock of capital large enough as to sustain long-run growth. Intergenerational transfers – for example, through income redistribution from the old generation to the young financed by income taxation – are required to produce endogenous growth without resorting to any kind of technological nonconvexity. Jones and Manuelli (1992) point out that sustained long-run growth equilibrium is possible with the introduction of a bequest motive in OLG models in an 'altruistic' manner a la Barro (1974).

Altruism in the above sense is not the unique method of introducing a bequest motive in OLG models. Parents may not directly consider the utility of their children, but may instead confront their own consumption level with the absolute magnitude of the bequest to be left. In this case, it is the absolute bequest, not children's total welfare, the decision variable of direct concern to parents. And neutrality results such as the Ricardian Equivalence theorem are not to be expected to hold (Hoover, 1988; Andreoni, 1989). It is a straightforward consequence of the fact that, in this case, individuals do not behave as if they were infinitely-lived.

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In this paper, we show that sustained long-run growth is possible within this class of finite-lifetime models. As an application of the basic model, we demonstrate that the non-neutrality result of the previous literature goes one step further: the equilibrium growth rate is also influenced by government debt. Public debt hampers growth, in this model, because it competes with physical capital for individuals' savings.

Section 2 introduces the basic model. Section 3 explores the notion that, with a bequest motive of this nature, the rate of growth of the capital stock is adversely affected by the presence of government debt. Section 4 contains some concluding comments.

2. A simple model of capital accumulation

The present formulation is a straightforward extension of Martins (1980, 1994, 1995) which relies on Samuelson's (1958) pioneering OLG model as a framework of analysis. Population growth is absent. There is one consumption good, which may be immediately consumed or saved as capital for next period's production. The (net) production function is taken to be one of the 'AK' type (Rebelo, 1991). At each period t , generation t inherits W_t units of the good, leaving W_{t+1} as a bequest for the next generation. Positive growth is said to occur when the stock of the good increases from one generation to the following one.

At time t , a fraction $C_t(t)$ of the initial endowment of an individual born at time t is consumed, and the remaining is saved so as to generate productive resources for the next period's production activity. K_t is the non-consumed part of the representative agent's endowment W_t at time t , so that the productive process not only recovers K_t but also generates a net product AK_t . Gross product $AK_t + K_t$ will then form the agent's next period endowment. It goes without saying that the only reason why our representative agent cares about the endowment at $t + 1$ is that he/she possesses an absolute bequest motive. We postulate a separable logarithmic utility function in order to generate a closed-form solution. Assuming perfect foresight, the representative individual takes W_t as given and maximizes utility with respect to $C_t(t)$, K_t and W_{t+1} . The optimization problem is¹:

$$\begin{aligned} \text{Max } U(C_t(t), W_{t+1}) &= \ln C_t(t) + \delta \ln W_{t+1} \\ \text{s.t. } C_t(t) + K_t &= W_t \\ W_{t+1} &= AK_t + K_t \end{aligned} \quad (2.1)$$

From the first-order conditions, we obtain:

$$W_{t+1}/W_t = [\delta/(1 + \delta)](1 + A) \quad (2.2)$$

From Eq. (2.2), we can determine the rate of growth of the representative agent's endowment of the good, γ :

¹The formulation in Eq. (2.1) collapses the individual's and the firms' problem in a single one. It is straightforward to rewrite the maximization problem for individuals and firms separately, as in Diamond's (1965) model.

$$\gamma = \frac{K_t - K_{t-1}}{K_{t-1}} = \frac{\delta A - 1}{1 + \delta} = \frac{A - \frac{1}{\delta}}{1 + \frac{1}{\delta}} \quad (2.3)$$

Eq. (2.3) resembles the solution of infinite horizon models with an 'AK' production function, in that the endogenous rate of growth γ depends on technology (A) and preferences (δ). As in those models, constant returns to capital are sufficient to generate endogenous growth. The economy will grow irrespectively of the size of the initial endowment, as long as $\delta > 0$ and $A > 1/\delta$.

3. An application: the impact of government debt on growth

How does the mode of financing government spending affect the rate of growth in this model? We now assume that, at time t , the government makes $E_t - T_t$ of net transfer payments to generation t , where E_t and T_t are, respectively, gross transfers and lump sum taxes at time t . The government also sells to the same generation B_t units of bonds, to be redeemed one period later, at the price of $(1 + r_t)^{-1}$, where r_t is the current real rate of interest. Taking W_t , E_t and T_t as given, the representative individual maximizes utility with respect to $C_t(t)$, K_t , B_t and W_{t+1} . The problem now becomes:

$$\begin{aligned} &\text{Max } \ln C_t + \delta \ln W_{t+1} \\ &\text{s.t. } C_t(t) + K_t + B_t(1 + r_t)^{-1} = W_t + E_t - T_t \\ &W_{t+1} = (1 + A)K_t + B_t \end{aligned} \quad (3.1)$$

Note that B_t is a flow variable (new bond issues); in this simple two-period framework, it is also the outstanding stock of bonds at the beginning of period t . From the first-order conditions with respect to capital and bonds, we immediately see that $r_t = A$ for all t . The first-order conditions also allow us to write:

$$\frac{(1 + A)K_t + B_t}{\delta \left[W_t + E_t - T_t - \frac{B_t}{1 + A} - K_t \right]} = 1 + A \quad (3.2)$$

Given the initial endowment W_t , we can now derive the demand functions for $C_t(t)$, K_t , B_t and W_{t+1} . However, bonds and capital are perfect substitutes in the representative individual's portfolio, so that we can only determine their joint demand function. We then obtain:

$$K_t + \frac{B_t}{1 + A} = \frac{\delta}{1 + \delta} [W_t + E_t - T_t] \quad (3.3)$$

$$C_t(t) = \frac{W_t + E_t - T_t}{1 + \delta} \quad (3.4)$$

$$W_{t+1} = (K_t + \frac{B_t}{1 + A})(1 + A) = \frac{(1 + A)\delta}{1 + \delta} (W_t + E_t - T_t) \quad (3.5)$$

At time t , government spending comprises net transfers $E_t - T_t$ and B_{t-1} units of redeemed bonds

(including interest payments). They are financed by the auction of B_t units of newly-issued bonds at the market price of $(1+r_t)^{-1}$ (where $r_t=A$ in equilibrium). The government's budget constraint is thus as follows:

$$E_t - T_t = \frac{B_t}{1+A} - B_{t-1} \quad (3.6)$$

Substituting the government's budget constraint into Eqs. (3.3)–(3.5) yields:

$$K_t + \frac{B_t}{1+A} = \frac{\delta}{1+\delta} \left[W_t + \frac{B_t}{1+A} - B_{t-1} \right] \quad (3.7)$$

$$C_t(t) = \frac{W_t}{1+\delta} + \frac{1}{1+\delta} \left[\frac{B_t}{1+A} - B_{t-1} \right] \quad (3.8)$$

$$W_{t+1} = \frac{(1+A)\delta}{1+\delta} \left[W_t + \frac{B_t}{1+A} - B_{t-1} \right] \quad (3.9)$$

Eqs. (3.7)–(3.9) show that the equilibrium allocation $(C_t(t), K_t, W_{t+1})$ is not independent of national debt, so that Ricardian Equivalence is not generally valid with the kind of preferences we are considering.

Note that individual's endowment, W , is no longer the appropriate variable with which to treat capital accumulation: from the second-period restriction to the problem (3.1), we see that the endowment is composed of both capital and government bonds. Taking into consideration the corresponding restriction to an individual born at time $t-1$ and substituting into Eq. (3.7) yields:

$$\frac{K_t - K_{t-1}}{K_{t-1}} = \frac{\delta A - 1}{1+\delta} - \frac{B_t/K_{t-1}}{(1+A)(1+\delta)} \quad (3.10)$$

Eq. (3.10) gives us the endogenous rate of growth of the capital stock. The flow of government debt financing as a proportion of the pre-existing stock of capital actually negatively affects the rate of capital accumulation. Government debt crowds out productive investment as it competes with capital for individuals' non-consumed output.

4. Concluding remarks

The model presented in this paper demonstrates that sustained growth is possible in a one-sector overlapping-generations framework with convex technologies (represented here by a relevant particular case: the AK production function) without income redistribution from the old to the young supported by income taxation and without 'pure' altruism of the Barro (1974) kind. The critical assumption is that agents' utility function embodies an absolute bequest motive. This representation of the bequest motive allows us to derive one clear policy implication from the model: an increase in government debt negatively affects the rate of growth of the capital stock.

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