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Wealth Seeking Reconsidered

by

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September 1990

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WEALTH SEEKING RECONSIDERED

by

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Abstract

If individuals are interested in their *relative* wealth position, they engage in contests for wealth. This leads to a steady state with overaccumulation. In a simple growth model it is shown that, if some individuals are engaged in wealth seeking activity, but others are not, the latter might benefit. However, wealth seeking is not welfare enhancing under usual assumptions concerning production technology. The steady-state equilibrium is characterized by a marginal productivity of capital that is below the steady-state rate of time preference and by emergence of a class structure.

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1. Introduction

For many goods, individuals derive utility from getting more than their reference group does¹. Recent work has shown that such status preferences can be based on an individually rational calculus in different ways. Frank (1985a) explains status-seeking demand for observable goods by a signalling approach. Coelho (1985) stresses some stability arguments from evolutionary theory and Frank (1985b) and Konrad (1990) try to give sociobiological explanations. The implications for welfare have been pointed out. Villar (1988), e.g., considers the existence of a pareto-efficient allocation if status preferences are present. The inefficiency of competitive equilibrium where there are status preferences and some amendments via income taxes have also been considered (see, e.g., Boskin and Sheshinski (1978) and Layard (1980)) and via other taxes (see, e.g., Congleton (1989), Konrad (1990), Seidman (1987), and, for related work, Ng (1987)).

Status seeking individuals compete with each other regarding the relative amount of status goods they have compared to other group members. Such status contests are structurally similar to military arms races and involve a special kind of mutually negative externalities. Congleton (1989) draws attention to the possibility of *positive* external effects of status competition. He argues that, if status preferences for certain goods and resulting status contests are restricted to a small group, some individuals might enjoy watching other people's status seeking without paying for this pleasure, or they may derive some other advantages from the "status seeking game". Consequently there is no reason for believing that there is "too much" status seeking.

Congleton (1989) gives an example in which some individuals derive utility from their relative wealth position and "play" a status seeking game that might be called "wealth-seeking" or "who becomes the richest" whom Congleton calls *wealth-seekers*. Those who do not participate in this game will be called *hedonists*. To put it in Congleton's (1989, p. 189) words:

"A good many status-seeking activities do generate positive externalities. The feats of athletes provide mass entertainment, those of scholars provide the foundations of improved productive technology and/or institutional arrangements. Capitalists

in their quest for status, produce and accumulate the capital necessary for mass production and widespread material wealth. These status games are efficiency enhancing."

The implications of this statement are rather strong. Capitalists should probably be subsidized for their wealth seeking and, while suffering mutually negative external effects, they unintentionally benefit modern society.

This paper derives the impact of wealth seeking in a neoclassical equilibrium growth model. It shows that wealth seeking has a positive distributional impact on workers and leads to overaccumulation. If other market failures are absent, a wealth tax or a capital income tax is unambiguously welfare improving. Moreover, the steady-state interest rate is below the steady-state rate of time preference. This implies that a negative real rate of interest is possible, even in a world that is characterized by "impatience".

2. Model assumptions

Consider a perfectly competitive economy. The production possibilities are described by a production function

$$Y(t) = f(K(t), L(t)), \quad (1)$$

with $K(t)$ the aggregate stock of capital and $L(t)$ is the aggregate flow of labour supply. Output $Y(t)$ consists of a homogenous good that can be used for consumption or investment. Assume that f is homogenous of degree 1 and twice differentiable with partial derivatives $f_K > 0$, $f_L > 0$, $f_{KK} < 0$, $f_{LL} < 0$ and $f_{KL} = f_{LK} > 0$. Factor prices and factor payments are determined by the marginal productivity theory of distribution, in particular, the prices of capital and labour equal their marginal productivity f_K and f_L , respectively, and factor payments, i.e. capital income $f_K K(t)$ and labour income $f_L L(t)$ just exhaust the product $Y(t)$.

Assume that there are M wealth-seekers, indexed by m , and N hedonists, indexed by n . For simplicity assume that wealth-seekers are endowed with an initial wealth $K^m(0) > 0$ and do not supply labour, hedonists supply a constant flow of labour $L^n(t) = \bar{L}^n$ and initially are endowed with wealth $K^n(0) \geq 0$. All individuals face a lower limit-of-wealth constraint². For all time periods $t \geq 0$, $K^n(t) \geq K_{\min}$ and $K^m(t) \geq K_{\min}$. The minimum wealth K_{\min} might take any real value, in particular it might be negative. The only requirement needed is that K_{\min} is finite. The aggregate stock of capital

$$K(t) = \sum_m K^m(t) + \sum_n K^n(t)$$

is the sum of wealth of all individuals, and the aggregate labour supply

$$L(t) = \sum_n L^n(t)$$

is the sum of all hedonists' labour supplies.

A (representative) hedonist n maximizes an intertemporal utility function

$$\max_{\{C^n(t)\}} \int_0^{\infty} U^n(C^n(t)) e^{-\rho t} dt \quad (2a)$$

s.t.

$$\dot{K}^n(t) = f_K K^n(t) + f_L L^n(t) - C^n(t), \quad (2b)$$

$$K^n(t) \geq K_{\min} \quad \text{for all } t \geq 0, \quad (2c)$$

$$K^n(0) = K_0^n, \quad (2d)$$

$$L^n(t) = \bar{L}^n = \text{constant}. \quad (2e)$$

A hedonist is not interested in wealth as a status good and derives utility only from consumption, $U(C)$. He maximizes the discounted sum of instantaneous utilities, with $\rho > 0$ being the discount rate of time preference, which is assumed to be constant³. The marginal utility of consumption dU^n/dC^n is assumed to be positive. It is not necessary to assume diminishing marginal utility here. The results derived, however, are

compatible with diminishing marginal utility. Equation (2b) describes how his wealth changes (the dot on a variable denoting the time derivative, e.g., $\dot{K}^n \equiv dK^n/dt$). The change of wealth equals savings, depending on his capital income ($f_K K^n$) and labour income ($f_L L^n$) and his consumption decision C^n . Equation (2c) describes that there is a lower limit-of-wealth. Individuals are not able (allowed) to reduce their wealth below a given finite (possibly negative) limit. While there is no borrowing constraint in principle, this lower limit-of-wealth imposes a borrowing constraint indirectly. An individual who has only this minimum wealth cannot lower it via additional consumption loans. Equation (2d) determines his initial capital stock and (2e) describes the assumption of a constant labour supply.

The (representative) wealth-seeker m solves the problem

$$\max_{\{C^m(t)\}} \int_0^{\infty} V^m(C^m(t), s^m(t)) e^{-\rho t} dt, \quad (3a)$$

s. t.

$$\dot{K}^m(t) = f_K K^m(t) - C^m(t), \quad (3b)$$

$$K^m(t) \geq K_{\min} \quad \text{for all } t \geq 0, \quad (3c)$$

$$K^m(0) = K_0^m. \quad (3d)$$

By his choice of a consumption path $\{C^m(t)\}$ he maximizes the sum of his discounted instantaneous utility⁴ $V^m(C^m, s^m)$ that depends on his own instantaneous consumption C^m and his status position s^m . It is assumed that $\partial V^m / \partial C^m > 0$ and $\partial V^m / \partial s^m > 0$, i.e. marginal utilities of "ordinary" consumption and of status are strictly positive. Again, decreasing marginal utility is not a necessary assumption here, but it is compatible with the results. The status position of wealth-seekers who have been defined as individuals who gain status by being "relatively rich", may depend on the capital stocks of all other individuals. In its most general form, the utility that wealth-seeker m derives from status depends on all individuals' wealth, with $\partial V^m / \partial K^i \leq 0$ for all $i \neq m$, and $\partial V^m / \partial K^m \geq 0$. If wealth-seekers compare their wealth only with that of other wealth-seekers⁵, then $\partial V^m / \partial K^n = 0$ for all $n = 1, \dots, N$, implying that s^m is a functional of the wealth of wealth-seekers only, i.e.

$$s^m = s^m (K^1, K^2, \dots, K^m, \dots, K^M).$$

Equation (3b) describes that the amount of saving of wealth-seeker m is determined by the difference of his income ($f_K K^m$) and consumption. Equation (3c) is his lower limit-of-wealth constraint and (3d) determines his initial wealth.

For simplicity two further assumptions are made here. First, it is assumed that the group of wealth-seekers is homogenous, i.e., all wealth-seekers are identical with respect to their utility functions (3a) and their initial endowments⁶. This simplifies further calculations considerably, because it implies that in equilibrium all wealth-seekers have the same wealth. The status position of an individual wealth-seeker can be written as

$$s^m = s^m(K^m, K^{\bar{m}}), \quad (4)$$

with $K^{\bar{m}}$ being the (Cournot-Nash) equilibrium value of wealth of any other wealth-seeker.

Second, status only depends on *relative* wealth⁷. Given $K^1 = K^2 = \dots = K^M$, it is assumed that $s^m(K^1, \dots, K^m, \dots, K^M) = s^m(\mu K^1, \dots, \mu K^m, \dots, \mu K^M)$ for any $\mu > 0$. This is not a strong assumption, but it captures the essence of status goods, namely that individuals like to have much of them *relative to their reference group*. If all members of the group have the same amount of status goods, their status position is the same, irrespectively of how big this amount is.

3. Properties of a steady-state equilibrium

Solving the maximization problem of (a representative) wealth-seeker m that is given by equations (3), leads to the current-value Hamiltonian

$$\mathcal{H} = V^m(C^m, s^m) + \lambda(f_K K^m - C^m).$$

The first-order conditions for an interior maximum yield

$$-(\partial V^m / \partial s^m) (\partial s^m / \partial K^m) - \lambda f_K = \dot{\lambda} - \rho \lambda \quad (5)$$

with

$$\lambda = \partial V^m / \partial C^m. \quad (6)$$

A steady-state equilibrium is determined by $\dot{\lambda} = \dot{K}^m = \dot{K}^n = 0$, since there is no population growth or technological change. All individuals keep their wealth constant. Inserting these conditions in (5) and (6) leads to the steady-state-equilibrium condition⁸

$$-(\partial V^m / \partial s^m) (\partial s^m / \partial K^m) = (f_K - \rho) \partial V^m / \partial C^m. \quad (7)$$

Two properties of an equilibrium that is characterized by condition (7) can be pointed out here.

Property 1: In the steady state that is described by (7) the marginal productivity of capital is smaller than the discount rate of time preference ρ .

This property is true because $\partial V^m / \partial s^m$, $\partial s^m / \partial K^m$ and $\partial V^m / \partial C^m$ are strictly positive, and, therefore, $f_K - \rho < 0$. In this steady-state equilibrium the *modified golden rule of accumulation* (c.f., e.g., Arrow and Kurz (1970, p. 73), and Sinn (1985, p. 38)) is violated and the capital stock is larger than in the stationary state that fulfills the modified golden rule ($f_K = \rho$). The intuition behind this result is as follows. An individual who increases his wealth by one unit loses the utility from consuming this unit and is compensated by the additional future consumption that he gains by saving this unit. In a stationary steady state without externalities a household is just indifferent between saving and consuming an additional unit of goods, if the condition $f_K = \rho$ holds. A wealth-seeker, however, receives an additional compensation, because his saving increases his wealth position and, therefore, he gains some utility from his increased status position. If he accumulates an additional unit, he improves indivi-

dually his wealth position. This additional incentive to save leads to a steady-state capital stock that is larger than in the modified golden rule. The group of wealth-seekers drives the aggregate stock of capital up, but it cannot reach an increase in status consumption as a whole. The increase of one wealth-seeker's status position decreases that of all others. As wealth-seekers are assumed to be homogenous, in equilibrium all wealth-seekers enjoy the same amount of status, irrespective of how much wealth each accumulates. If wealth-seekers could act collectively, they would like to reduce their savings. Given an economy with all individuals acting as wealth-seekers, it is obvious that property 1 implies overaccumulation.

Whether property 1 also implies overaccumulation under welfare theoretic aspects if some individuals do not seek wealth, or, instead, is welfare improving will be considered in section 4. First, it must be shown that (7) is compatible with the maximizing behavior of hedonists, i.e. individuals who do not play wealth seeking. Solving the maximization problem (2) of hedonists, inserting into the first-order conditions⁹ and using the steady-state conditions $\dot{K}^m = \dot{K}^n = \dot{\lambda} = 0$ yields

$$f_K = \rho. \quad (8)$$

Conditions (7) and (8) cannot be fulfilled both simultaneously. Given (8), wealth-seekers would like to accumulate, i.e. choose $\dot{K}^m > 0$. And, because there is no upper constraint for K^m , no steady-state with $\dot{K}^m = 0$ that fulfills (8) can be found. Instead of condition (8), condition (7) characterizes an equilibrium steady state. Hedonists are at their lower limit-of-wealth, $K(t) = K_{\min}$. Given (7) and $K^n = K_{\min}$, hedonists would like to choose $\dot{K}^n \leq 0$. A transitory marginal increase dC^n of consumption during the infinitely small time interval between t_0 and $t_0 + dt$, produces an additional utility of

$$W_1 \equiv (\partial U^n / \partial C^n) dC^n dt.$$

Savings are lower in the interval $[t_0, t_0 + dt]$ by the same amount dC^n , inducing a reduction of wealth by $dK^n = -dC^n dt$. Capital income, therefore, is lower in all future periods by the amount $dK^n f_K$. The utility loss from this capital income reduction equals

$$\begin{aligned}
W_2 &= \int_{t_0}^{\infty} (\partial U^n / \partial C^n) (dK^n f_K) e^{-\rho(\vartheta - t_0)} d\vartheta \\
&= (\partial U^n / \partial C^n) dK^n f_K / \rho. \\
&= -W_1 f_K / \rho,
\end{aligned}$$

factoring out $(\partial U^n / \partial C^n) dK^n f_K$ and using the definition of W_1 . With condition (7) implying that $f_K < \rho$, it can be concluded that opportunity costs W_2 are lower than the utility gain W_1 of the initial increase of consumption. The only parameter constellation fulfilling (7), optimal for hedonists and fulfilling the steady-state condition $\dot{K}^m = \dot{K}^n = 0$, therefore, is given by $K^n = K_{\min}$ for all $n = 1, \dots, N$, i.e., a situation where all hedonists are willing to increase their loans (but cannot). This reveals the second property of the equilibrium steady state.

Property 2: In the steady-state equilibrium that is described by (7) hedonists hold their minimum wealth, i.e., $K^n(t) = K_{\min}$ for all $n = 1, \dots, N$, and they would like to borrow for consumption purposes.

In the equilibrium steady state only wealth-seekers voluntarily keep wealth. Hedonists could save and could become wealthy. However, they prefer not to do this. They would even be willing to reduce their wealth or to increase their stock of debt steadily for additional consumption purposes. Therefore, if there is some finite minimum wealth-level, they are in the "corner solution" with $K^n(t) = K_{\min}$.

4. Wealth seeking and welfare

Property 1 showed that wealth-seeking by a group of individuals induces a steady-state capital stock that is higher than in the steady-state equilibrium that fulfills the modified golden rule of accumulation. Hedonists gain by the wealth-seeking activity. Their labour income is determined by $\bar{L}^n f_L(K, L)$, i.e., by the product of labour supply and the equilibrium price of labour. As $f_{LK} > 0$, the increase of capital stock shifts the marginal productivity of labour curve upwards, i.e., labour becomes more productive and wages increase. This is a technical effect. It is, however, not a technical *external*

effect. A technical externality is an activity for which the producer is not paid or charged by the opportunity costs to the rest of the economy arising from the activity. The increase of capital stock here, however, is paid by its marginal product. The change of relative scarcity of labour and capital in production is fully reflected in a change of wage and interest rate. For this reason, the distributional impact is what is sometimes called a "pecuniary" external effect (cf. Scitovsky (1954)). From a purely allocative perspective, in an economy with complete and perfectly competitive markets such pecuniary externalities "do not matter" (cf., e.g., Mishan (1971), p. 8). Despite its distributional impact, the pecuniary externality of wealth seeking cannot offset the well known welfare losses of arms races within the group of wealth-seekers, but implies overaccumulation.

To see this, the Kaldor-Hicks compensation criterion (cf. Kaldor (1939) and Hicks (1939)) is used here. This criterion is widely used in cost-benefit-analysis. Despite its rather general acceptance, it reveals only a potential welfare increase as long as compensation does not actually take place. Apart from that, a further weakness of the criterion has been shown by Scitovsky (1941/42). If a policy has been implemented that makes some individuals better off and others worse off, moving from the new allocation to the original one might again be a potential pareto improvement by the Kaldor-Hicks criterion. For a more general consideration regarding this paradox see Samuelson (1950). Further, the criterion has been attacked from a distributional point of view, e.g., by Little (1957). For a comprehensive discussion and a methodological justification for its use see Sohmen (1976).

Starting from the laissez-faire steady-state equilibrium, assume that all wealth-seekers decide to lower their individual wealth K^m by one marginal unit dK^m . It is sufficient to show that the marginal decrease in the aggregated capital stock, $dK = \sum_m dK^m$ implied by the wealth reductions, allows all hedonists to be made better off without making any wealth-seeker worse off. The collective dissaving of wealth-seekers does not change their individual status positions: using the assumption that s^m only depends on *relative* wealth, all wealth-seekers end up with the same status positions as before. The reduction in the capital stock takes place during an infinitely

small time interval $[t_0, t_0+dt]$ and leads to a proportionately increased amount of consumption in this interval. Assume that all additional consumption goods are equally distributed among all hedonists, i.e. each of them gets $dC^n dt = -dK/N$. Their utilities, therefore, increase by

$$W_1 = (\partial U^n / \partial C^n) dK/N. \quad (9)$$

In return, hedonists have to compensate wealth-seekers for their capital income reductions $\sum_m f_K dK^m = f_K dK$. Each hedonist must pay $f_K dK (1/N)$ to wealth-seekers for all future periods. These payments lower the utility of each hedonist by

$$\begin{aligned} W_2 &= \int_{t_0}^{\infty} (\partial U^n / \partial C^n) (dK/N) f_K e^{-\rho(\vartheta - t_0)} d\vartheta \\ &= (\partial U^n / \partial C^n) (dK/N) (f_K / \rho) \\ &= -W_1 (f_K / \rho), \end{aligned}$$

factoring out $(\partial U^n / \partial C^n) (dK/N) f_K$ again and making use of (9). $W_1 + W_2 > 0$ by property 1. Even if hedonists compensate wealth-seekers, hedonists are made better off. A capital stock that is larger than the capital stock of the modified golden rule therefore means overaccumulation. It does not matter if all individuals participate in the "wealth-seeking game" or not. The distributional impact of wealth-seeking games cannot offset the inefficiency that is induced by the status contest within the group of wealth-seekers.

If the group of wealth-seekers consists of different wealth-seekers with different initial endowments and/or different wealth-seeking intensities and/or if s^m is not homogenous of degree zero, calculations are more tedious. However, as long as s^m fulfills some continuity properties and depends only on *relative* wealth, a similar marginal decrease of the steady-state capital stock by dK that is distributed among the wealth-seekers such that all wealth-seekers retain the same status position as before and such that the wealth of each wealth-seeker changes only marginally, should be expected to exist. A similar reasoning applies then.

Given that wealth seeking induces overaccumulation, it is straightforward to show that the amount of this misallocation can be reduced or eliminated by a wealth tax or a tax on capital income. A tax on capital income, $T = \tau f_K K^m$, with τ being the tax rate that is determined by

$$\tau = (1/f_K) \frac{\partial V^m / \partial K^m}{\partial V^m / \partial C^m}, \quad (10)$$

leads to a steady-state that fulfills the modified golden rule of accumulation, $f_K = \rho$. This is verified by solving the maximization problem (3), replacing (3b) with

$$\dot{K}^m = f_K(1 - \tau)K^m - C^m, \quad (11)$$

with τ defined by (10). However, this tax cannot offset the bias of hedonists against saving as long as they too have to pay this tax.

5. Discussion

The assumptions of the neoclassical growth model used here are well known to be very particular. Many of them (1 sector, no exogenous population growth or technical progress) are simply made to ease the analysis. Others, like homogeneity of degree 1 of the production function, no endogenous technical progress, well defined property rights and perfect competition, are more decisive. They are chosen here because, in this case, the market equilibrium yields a pareto optimum if wealth seeking is absent. Introducing wealth seeking in this framework allows the allocative and distributional impact of wealth seeking of a fraction of individuals compared with this benchmark case to be considered. If wealth seeking takes place in an environment with many other market failures being present, it is easily possible and not surprising that wealth seeking might reinforce or diminish other existing distortions. The capital stock might be too small without wealth seeking, if, e.g., there is monopoly power, increasing returns to scale (cf.

Dixit (1976)), positive external effects of endogenous technical progress (cf., e.g., Hahn and Matthews (1964, p. 845) and Romer (1986)), capital income taxation (cf., e.g., Sinn (1985)), uncertainty about future property rights (cf., e.g., Sinn (1981), p. 192), or if the isolation paradox (cf. Sen (1961) and Marglin (1963)) is at work. In these cases the distortionary effect of wealth seeking might counteract these distortions. To remain valid, Congleton's (1989) claim regarding welfare enhancing wealth seeking must be seen as a repetition of this well known argument from second best theory (cf. Lipsey and Lancaster (1956)).

It was sometimes claimed that agglomeration of wealth in the hands of few could be beneficial because these few might be exceptionally able to handle and to invest this wealth in profitable ways. Wealth-seekers might be better entrepreneurs simply because they are more interested in wealth, but also the opposite might be true. More promising might be to consider questions like whether moral hazard and adverse selection problems regarding control of management are reduced if wealth is concentrated in the hands of few. Given corporate ownership with many shareholders, their incentive to exert control is inefficiently small (cf., e.g., Stiglitz (1985) for an overview). If wealth is concentrated and large and well diversified firms are controlled by one single owner who gets the surplus, these efficiency problems might be reduced. But these questions are outside the scope of this paper.

An outcome of wealth seeking here is social stratification, the emergence of two classes, one of them not accumulating capital (hedonists, or "working class") and the other deliberately accumulating and owning productive capital (wealth-seekers, or "capitalists"). This class structure is simply the outcome of the particular status preferences. Capital accumulation is more attractive for wealth-seekers than for hedonists, as the former receive some "extra"-utility of saving in terms of an improvement of their individual relative wealth position. Roemer (1986, pp. 70-71) tries to explain the emergence of capitalists and workers by differences of savings propensities. Wealth seeking might explain why differences of savings propensities can be persistent, i.e., are not equated via the capital market.

Footnotes

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1. This fact has been recognized by many economists, among them Duesenberry (1949), Mill (1847/1911, pp. 523n.), Pigou (1929, p. 227) and Veblen (1899/1953), and more recently Easterlin (1974), Frank (1982), (1984), (1985a), (1985b), (1989), Hirsch (1976), Hirshleifer (1985), Lommerud (1989) and Sen (1983).

2. The assumption is made simply to exclude the possibility of a permanent flow of credits from wealth seekers to hedonists that sums to an *infinite* stock of loans, something that is not very reasonable given intertemporally constant and finite production possibilities of the stationary economy considered here.

3. This assumption is standard in intertemporal general equilibrium models (cf., e.g., Arrow and Kurz (1970, p. 162), and Sinn (1985, p. 27) for some discussion). Constancy of ρ does not imply that the subjective rate of time preference is constant. This rate depends on ρ and on the ratio of marginal utilities of consumption today and in the future, and this ratio of marginal utilities depends on the equilibrium consumption path.

4. For simplicity, the time dependence of variables is not made explicit hereafter.

5. Congleton (1989, p. 182), e.g., makes this assumption.

6. Heterogeneity of wealth-seekers does not qualitatively change the results given plausible assumptions about the dependence of V^m on (s_1, \dots, s_M) .

7. A sufficient (but not a necessary) condition for this property to hold is that s^m is homogenous to degree zero. This condition is fulfilled, e.g., for all functions $s^m = s^m(K^1/K^m, \dots, K^M/K^m)$.

8. It is well known from ordinary one-sector growth models that this stationary state equilibrium does not necessarily exist. Existence depends on the shapes of $f(K,L)$, $U(C)$ and $V(C,s)$ and this dependence is not considered in detail, here. Given that a stationary state equilibrium exists that fulfills (7), this equilibrium fulfills also the sufficient conditions for an intertemporal maximum for wealth-seekers, as (see Feichtinger and Hartl (1986, pp. 39-43)) (i) $K^m(t) \geq 0$ (cf. equation (3c)), (ii) $K^m(t) = \text{constant}$ and, therefore, bounded, and (iii) in the stationary state $\dot{\lambda} = 0$, implying that $\lim_{t \rightarrow \infty} \lambda(t)e^{-\rho t} = 0$.

9. The Hamiltonian of this problem is $\mathcal{H} = U^n(C^n) + \mu(f_L \bar{L} + f_K K^n - C^n)$. Calculating the first order condition $\partial \mathcal{H} / \partial C^n = 0$ and $-\partial \mathcal{H} / \partial K^n = \dot{\mu} - \mu\rho$ yields $\mu = dU^n/dC^n$ and $-\mu f_K = \dot{\mu} - \rho\mu$.

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