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PRICE AND WAGE DYNAMICS IN A SIMPLE MACROECONOMIC MODEL WITH STOCHASTIC RATIONING

by

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1. INTRODUCTION

This paper is concerned with the dynamics of prices and wages in a simple closed macroeconomic system. It will be so to speak an internal dynamics as the exogeneous data characterizing the economy such as population size, preferences, technological know-how, capital or resource availability will remain unchanged. Why should prices then change? Simply, because they have not yet reached their Walrasian market clearing values. In general equilibrium theory in that case one assumes the action of an invisible hand or of an auctioneer who adjusts prices so quickly to their market clearing levels that agents can postpone their trades until these prices have been found and established. This paradigm is known as tatônnement. It is, "however, powerless if we wish to take into account a phenomenon which is important in practice, i.e. the unemployment of resources (excess supply of labour, excess productive capacities, etc...) and can be observed in real economies no matter what their type of organization" [Grandmont (1982), p.904].

If one is thus willing to abandon the hypothesis of instantaneous price adjustment one is led to alternative approaches, one of which is the following "non-tatônnement." Time is divided into periods of equal length such that in each period t prices remain fixed at values p_t, say. At these prices trades take place. A possible imbalance of demands and supplies gives rise to a revision of prices at the end of the old or at the beginning of the new period. The revised prices p_{t+1} remain fixed in period t+1, trades take place, and so on. In this way a sequence of prices and associated allocations is formed the properties of which can be studied.

The approach just described involves two fundamental problems. The first is to determine a consistent allocation when prices are "wrong", i.e. not at their Walrasian levels, and a solution has been provided by the concept of equilibrium with quantity rationing. Main contributions are due to Benassy (1975) and Drèze (1975) as far as a treatment in a general framework is concerned; and to Barro and Grossman (1971) and Malinvaud (1977) regarding the application of this concept to simple macroeconomic models.

The second problem concerns the adjustment of prices. Any adjustment mechanism should in some sense be based on the size of "disequilibrium" or the size of dissatisfaction of agents in an equilibrium with rationing. A measure for this size of disequilibrium in turn might be obtained by a comparison of the desired trades or transaction offers with the actual trades. Thus Benassy (1976, 1978), Blad (1981), Laroque (1981) and Veendorp (1975), among others, have studied models in which the value of the aggregate excess demand arising from Benassy's concept of effective demand [Benassy (1975)] is taken as such a measure. But, as has been pointed out by Grandmont (1977, p.563) and Green (1980, pp.341-42), this measure cannot be considered reliable. Furthermore, as has been shown by Weinrich (1984a), this criticism generally applies to any measure derived from effective demands based on deterministic rationing constraints. Stochastic rationing on the other hand admits the construction of a reliable measure of disequilibrium [Weinrich (1984c)] and can morever be justified by incomplete information of agents on the precise network of rationing in a large economy.

The purpose of this paper is to illustrate the non-tatônnement approach with stochastic rationing in a most simple macroeconomic model consisting of consumers, producers and a government who exchange consumption goods and labour services against money among each other. Though our model has no claim to realism but rather to serve as a useful step towards

the study of a more general
andrealistic model, it nevertheless yields some interesting insights. The principal conclusion is that wage indexation may be desirable in order to stabilize the dynamic behaviour of the economy and to accelerate convergence to the Walrasian equilibrium. On the other hand, if the minimum real wage is too high, then the economy ends up in a state with persistent underemployment and no rationing on the goods market.

A remark is in order with respect to the treatment of money. In order to isolate the effect of price dynamics, all other potentially dynamic variables must be kept constant. This applies in particular to the initial money balances of agents in a monetary economy where money serves as means for intertemporal transfer of wealth. But if one assumes ex cathedra that initial money balances are the same for agents in all periods, no matter what amount of money an agent held at the end of the previous period, then no agent has an incentive to transfer money and the assumption of intertemporal decision making of agents becomes empty. Therefore it seems better and more honest not to assume this but rather to model agents' behaviour as being atemporal. We will then justify the existence of "money" as a substitute for consumers' perfect forsight of producers'profits.

In chapter two, the model is presented and the behaviour of consumers and producers under stochastic rationing is derived. Chapter three is concerned with the introduction of macroeconomic equilibrium with stochastic rationing, its unique existence, and the partitioning of the price-wage-plane into the regimes of different types of equilibria. In chapter four, finally, the dynamics of the system is set up and the above mentioned results are established. Concluding remarks indicate possibilities to make the model more general and realistic.

2. THE MODEL

There are three types of agents: consumers, firms and a government. Each of the identical consumers supplies labour and demands a composite consumption good. Each of the identical firms demands labour services which it uses as only input in the production of the good. The government may demand consumption goods.

Economic activity takes place sequentially in periods ...t-1, t, t+1 .... . At the outset of each period t, the price p_t of the consumption good and the wage rate w_t are fixed. Agents express their demands and supplies and a feasible allocation obtains by means of an equilibrium with rationing[1] If prices were not Walrasian, then they are revised at the end of period t on the basis of the imbalance of aggregate demands and supplies. That is, if the aggregate effective demand and supply in period t were L_t^d, L_t^s on the labour market and C_t^d, C_t^s on the goods market, then new prices for period t+1 are determined according to adjustment rules

$$p_{t+1} = \phi(p_t, C_t^d / C_t^s)$$

$$w_{t+1} = \psi(w_t, L_t^d / L_t^s)$$

The implementation and realization of these rules can be thought of to be performed by the government which is commissioned to do so by the agents in the economy in order to bring about eventually Walrasian equilibrium.

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1 See chapter 3.

In each period, the labour market opens first and then the consumption goods market. The rationing mechanism is stochastic.

Since we will assume decreasing returns to scale of production, firms make positive profits which have to be distributed to consumers and which enter into their budget constraints. In order to avoid the informational problem arising from the requirement that consumers know ex post realized profits *before* they decide on their transaction offers (which in turn determine profits), consumers are assumed to receive a "money" balance $m_t > 0$ at the outset of each period t. This buys $\frac{m_t}{p_t}$ units of consumption goods and can be considered as (nominal) "predistributed" profit income. Thus a consumer's budget constraint in period t reads

$$p_t c \leqslant w_t \ell + m_t$$

m_t has purchasing power in period t only. Its transfer to consumers can be thought of to be performed by the government which also collects profits from firms. If $M_t = n \cdot m_t$ (n = number of consumers) denotes the resulting aggregate money stock and (L_t, C_t) the aggregate transaction levels on labour and goods market, then individual budget constraints imply for aggregate profits

$$\Pi_t = p_t C_t - w_t L_t \leqslant (w_t L_t + M_t) - w_t L_t = M_t \ .$$

Thus profits are in fact completely distributed but it may be that consumers cannot spend all their money, namely if they are rationed on the goods market. In that case, left over money stocks become worthless. Finally, we assume $m_t = m > 0$ for all t.

Since there is no possibility of intertemporal transfer of wealth, from the point of view of individual agents there is no link between different periods. Thus a decision in period t is taken independently of what might be expected to happen in periods t+1, t+2... .

As we will in the remainder of the chapter be concerned with individual decision making within a given period, we suppress for the time being time subscripts.

2.1. Consumers

Being endowed with $\bar{\ell}$ time units of leisure, a consumer derives from consuming c units of goods and working ℓ units of time a utility $u(c,\ell) := U(c,\bar{\ell}-\ell)$ where c and ℓ are subject to $c \geq 0$, $0 \leq \ell \leq \bar{\ell}$ and $pc \leq m + w\ell$.

A transaction pair (c,ℓ) results from (c^d,ℓ^s), the consumer's goods demand and his labour supply, by means of a stochastic rationing procedure. More precisely, we set $\lambda^s = \min\{L^d/L^s,1\}$ and assume that

$$\ell = \begin{cases} \ell^s \text{ with prob. } \lambda^s \\ 0 \text{ with prob. } 1-\lambda^s \end{cases}.$$

Similarly, we define $\gamma^d = \min\{C^s/C^d,1\}$.

The realized purchase c then is assumed to be related to the demanded quantity c^d by means of

(1) $$c = \begin{cases} c^d & \text{with prob. } \rho\gamma^d \\ \alpha c^d & \text{with prob. } 1-\rho\gamma^d , \end{cases}$$

where $\rho \in (0,1)$ is a fixed parameter of the rationing mechanism whereas $\alpha \in [0,1]$ varies with γ^d according to

(2) $$\alpha = \frac{\gamma^d - \rho\gamma^d}{1 - \rho\gamma^d} .$$

This specification of α is not arbitrary but follows from the short sided rule, i.e.

$$\rho\gamma^d c^d + (1-\rho\gamma^d)\alpha c^d = \min \{c^d, c^s\} .$$

(1) and (2) imply that the expected transaction resulting from a demand c^d and a rationing quota γ^d is

(3) $$Ec = \gamma^d c^d .$$

Since the labour market opens first, the consumer knows whether he is employed or not before he has to express his demand on the goods market. The latter we denote with c_1^d in case of employment and with c_0^d in case of unemployment.

The expected utility function arising from the above made specifications is

$$v(\ell^s, c_1^d, c_0^d; \lambda^s, \gamma^d)$$

$$= \lambda^s [\rho\gamma^d u(c_1^d, \ell^s) + (1-\rho\gamma^d) u(\alpha c_1^d, \ell^s)]$$

$$+ (1-\lambda^s) [\rho\gamma^d u(c_0^d, 0) + (1-\rho\gamma^d) u(\alpha c_0^d, 0)]$$

$$=: \lambda^s v_1(\ell^s, c_1^d; \gamma^d) + (1-\lambda^s) v_0(c_0^d; \gamma^d) \;.$$

The maximization of this expression subject to $c_1^d, c_0^d \geq 0$, $0 \leq \ell^s \leq \bar{\ell}$, $pc_1^d \leq w\ell^s + m$ and $pc_0^d \leq m$ yields the consumer's effective labour supply $\ell^s(\gamma^d)$ and his effective goods demands $c_1^d(\gamma^d)$ and $c_0^d(\gamma^d)$. In order to facilitate their computation, we make the following assumption.

(C) (i) u is increasing in c, decreasing in ℓ and strictly quasi-concave in (c,ℓ).

(ii) $u(c,\ell) > u(c',\bar{\ell})$ whenever $c > 0$, $c' \geq 0$ and $0 \leq \ell < \bar{\ell}$.

(iii) For all $\alpha > 0$

$$\alpha \frac{\frac{\partial u}{\partial c^d}(\alpha c^d, \ell^s)}{\frac{\partial u}{\partial \ell^s}(\alpha c^d, \ell^s)} = \frac{\frac{\partial u}{\partial c^d}(c^d, \ell^s)}{\frac{\partial u}{\partial \ell^s}(c^d, \ell^s)}$$

(C) (ii) insures that the consumer never wants to work the maximum amount of time physically possible for him. (iii) entails that the labour supply is independent of p. This is illustrated in Fig. 1. The class of utility functions characterized by (C) includes Cobb-Douglas-functions.

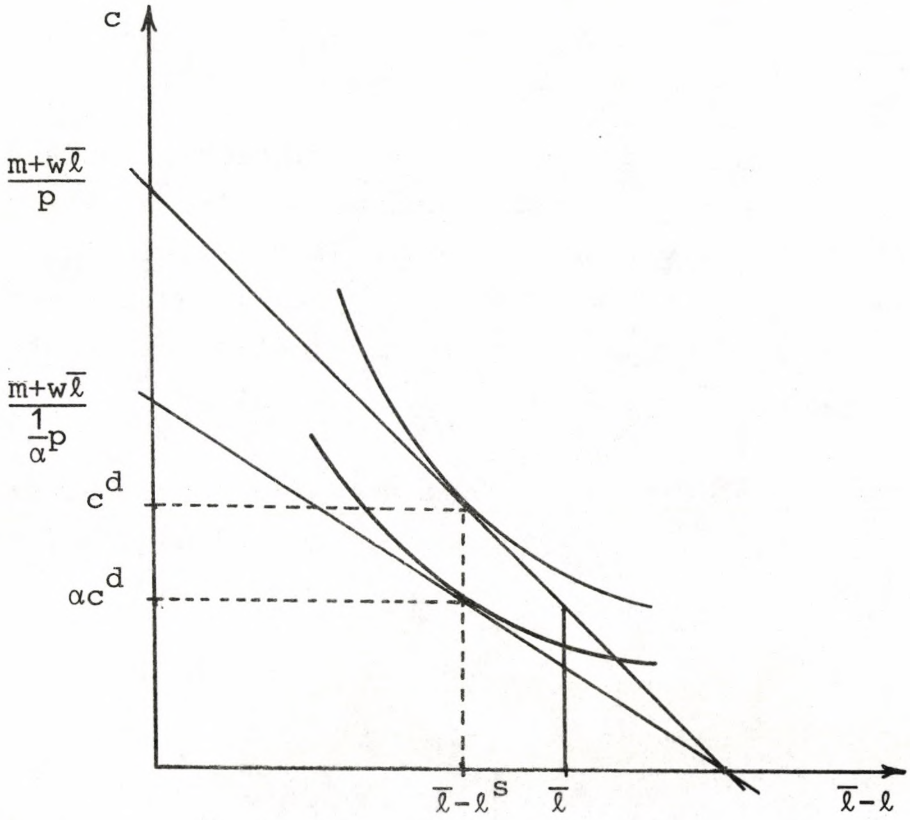

Figure 1

Lemma 1. Under condition (C), the following statements hold.
(a) The effective labour supply ℓ^s is determined as the solution of

$$\max_{\ell \geqslant 0} \quad u\left(\frac{w\ell+m}{p}, \ell\right) .$$

In particular, ℓ^s does not depend on γ^d.
(b) ℓ^s does not depend on p.
(c) $\frac{d\ell^s}{dw} > 0$ whenever $\ell^s > 0$.
(d) $c_1^d = (w\ell^s+m)/p$, $c_0^d = m/p$.

Proof: Appendix.

Next we derive the loci of aggregate transaction offers and of expected aggregate transactions (in ℓ-c-plane). These concepts will provide a useful diagrammatical representation both of the various types of equilibria with rationing and of the size of disequilibrium in these equilibria.

Since there are n identical consumers, aggregate labour supply is simply $L^s = n\ell^s$. Aggregate goods demand depends on λ^s and is

$$C^d(\lambda^s) = \lambda^s nc_1^d + (1-\lambda^s)nc_0^d$$
$$=: \lambda^s C_1^d + (1-\lambda^s)C_0^d \ .$$

The locus

$$H := \{(L^s, C^d(\lambda^s)) \mid \lambda^s \in [0,1]\}$$

thus describes all aggregate transaction offers of consumers in response to varying rationing signals λ^s.

Using (3), the locus of expected aggregate transactions is

$$\tilde{H} = \{(\lambda^s L^s, \gamma^d C^d(\lambda^s)) \mid (\lambda^s, \gamma^d) \in [0,1]^2\}$$

It will be useful to introduce the following partitioning of $\tilde{H}$:

$$\tilde{H}^K := \tilde{H}|_{\gamma^d=1, \lambda^s<1} = \{(\lambda^s L^s, C^d(\lambda^s)) \mid \lambda^s \in [0,1[\,\}$$

$$\tilde{H}^I := \tilde{H}|_{\gamma^d<1, \lambda^s=1} \ , \quad \tilde{H}^C = \tilde{H}|_{\gamma^d<1, \lambda^s<1}$$

$$\tilde{H}^U = \tilde{H}|_{\gamma^d=1, \lambda^s=1} \ .$$

These loci are shown in Figure 2.

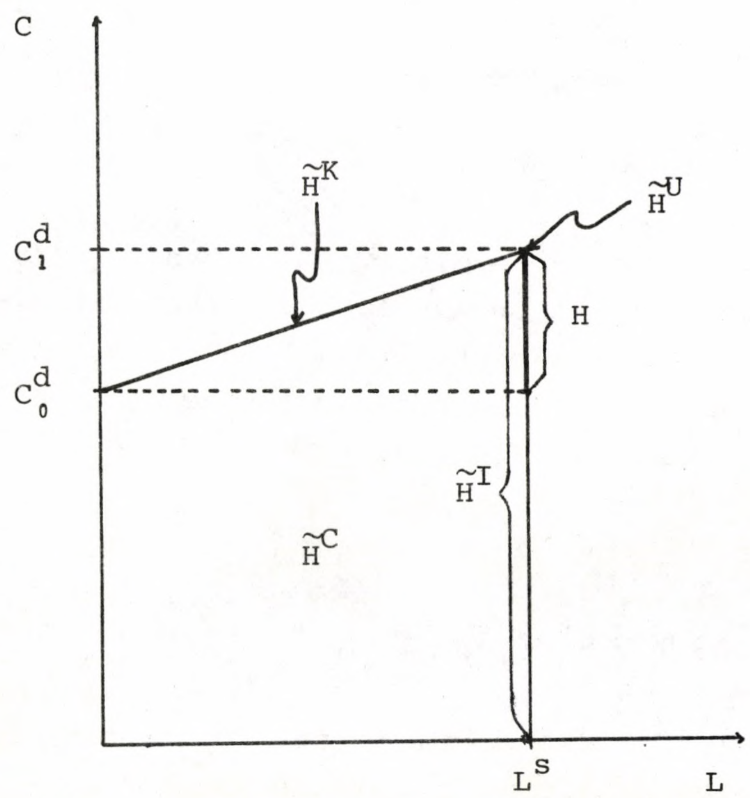

Figure 2

2.2. Firms

A firm's technology is described by a differentiable, increasing, strictly concave production function f satisfying $f(0) = 0$ and $f'(0) = \infty$. An actual transaction (c,ℓ) results from a pair (c^s,ℓ^d), the firm's effective consumption goods supply c^s and its effective labour demand ℓ^d, by means of quantity rationing.

In complete analogy to rationing of consumers, rationing of firms on the labour market is assumed to be all-or-nothing, whereas on the goods market it is described by

$$c = \begin{cases} c^s \text{ with prob. } \rho\gamma^s \\ \alpha c^s \text{ with prob. } 1-\rho\gamma^s \end{cases}$$

with $\rho \in (0,1)$ fixed, $\gamma^s = \min\{C^d/C^s, 1\}$ and $\alpha = (\gamma^s - \rho\gamma^s)/(1-\rho\gamma^s)$. If the firm is rationed on the labour market, it withdraws from economic activity in the prevailing period. If not, it realizes its effective labour demand being derived from maximizing expected profit, i.e. from

$$\max_{\ell^d} \ [\gamma^s pf(\ell^d) - w\ell^d]$$

$$\text{s.t.} \quad 0 \leqslant \ell^d \leqslant \alpha\frac{p}{w}f(\ell^d) \ .$$

The upper bound on admissible values for labour demand results from the requirement that the firm be able to finance its labour purchases also in the case of rationing on the goods market. It will become irrelevant, however, under the following assumption, in which we denote with $\ell^d(\gamma^s)$ an interior solution of the above problem.

(P) (i) The labour share in expected output is constant, i.e.

$$\frac{\gamma^s pf(\ell^d(\gamma^s))}{w\ell^d(\gamma^s)} =: k$$

(ii) $\quad k \geqslant \frac{1}{1-\rho}$.

Expected profit maximization and $f'(0) = \infty$ already imply $k > 1$. This fact is reinforced by (P)(ii), where ρ is the parameter referring to the rationing mechanism.

An example of a production function meeting (P) is

$$f(\ell) = a\ell^b, \quad a > 0, \quad 0 < b \leqslant 1-\rho$$

in which case $k = \frac{1}{b}$.

Lemma 2. Under assumption (P), the producer's decision problem possesses interior solutionsonly and these are characterized by

$$\gamma^s pf'(\ell^d) = w$$

Proof: $k \geqslant \frac{1}{1-\rho} \geqslant \frac{1-\rho\gamma^s}{1-\rho}$ or $\frac{1-\rho}{1-\rho\gamma^s} k \geqslant 1$. Multiplying this inequality with $w\ell^d$ and using (P)(i) yields

$$w\ell^d \leqslant \frac{1-\rho}{1-\rho\gamma^s} kw\ell^d = \frac{\gamma^s-\rho\gamma^s}{1-\rho\gamma^s} \frac{1}{\gamma^s} kw\ell^d$$

$$= \alpha \frac{1}{\gamma^s} \gamma^s pf(\ell^d) = \alpha pf(\ell^d) \qquad \blacksquare$$

The firm's effective consumption goods supply clearly is $c^s(\gamma^s) = f(\ell^d(\gamma^s))$. Morever, $d\ell^d/d\gamma^s > 0$, $dc^s/d\gamma^s > 0$ and $\ell^d(0) = 0 = c^s(0)$.

Assuming that there are n' identical firms, the aggregate effective labour demand is

$$L^d(\gamma^s) = n'\ell^d(\gamma^s) \ .$$

Since only the fraction $\lambda^d := \min\{L^s/L^d, 1\}$ of firms will be able to buy labour, aggregate effective consumption goods supply is

$$C^s(\lambda^d, \gamma^s) = \lambda^d n' f(\ell^d(\gamma^s)).$$

Consequently, the set

$$F := \{(L^d(\gamma^s), C^s(\lambda^d, \gamma^s)) \mid (\lambda^d, \gamma^s) \in [0,1]^2\}$$

describes the locus of all aggregate transaction offers in response to varying signals λ^d and γ^s in L-C-plane. The following notations will be useful:

$$F^K := F|_{\lambda^d=1, \gamma^s<1}, \quad F^I := F|_{\lambda^d<1, \gamma^s=1}$$

$$F^C := F|_{\lambda^d=1, \gamma^s=1}, \quad F^U := F|_{\lambda^d<1, \gamma^s<1}.$$

These loci are shown in Figure 3. In particular,

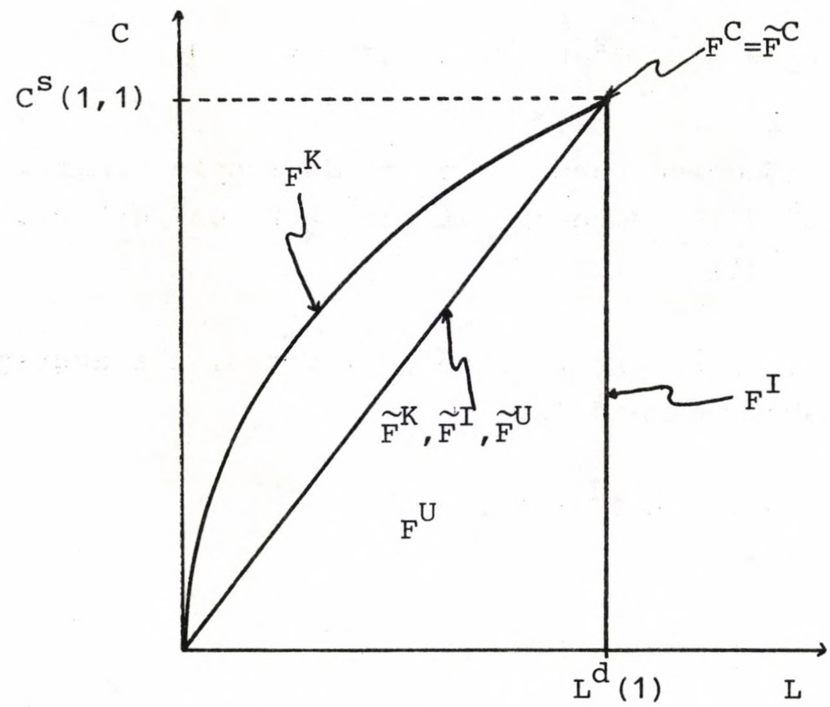

Figure 3.

F^K coincides with that part of the aggregate production function n'f for which $f'(\ell) \geqslant \frac{w}{p}$.

The locus of aggregate expected transactions of firms in response to varying λ^d and γ^s in L-C-plane is given by

$$\tilde{F} := \{(\lambda^d L^d(\gamma^s), \gamma^s C^s(\lambda^d, \gamma^s)) \mid (\lambda^d, \gamma^s) \in [0,1]^2\}.$$

Defining

$$\tilde{F}^K := \tilde{F}|_{\lambda^d=1, \gamma^s<1}, \quad \tilde{F}^I := \tilde{F}|_{\lambda^d<1, \gamma^s=1}$$

$$\tilde{F}^C := \tilde{F}|_{\lambda^d=1, \gamma^s=1}, \quad \tilde{F}^U := \tilde{F}|_{\lambda^d<1, \gamma^s<1},$$

we have the following

Lemma 3. Under (P)(i), the loci $\tilde{F}^K$, $\tilde{F}^I$ and $\tilde{F}^U$ possess the same parameterfree representation

$$\tilde{F}^K = \tilde{F}^I = \tilde{F}^U = \{(L, k\frac{w}{p}L) \mid 0 \leqslant L < L^d(1)\}$$

Proof: $\gamma^s C^s(\lambda^d, \gamma^s) = \gamma^s \lambda^d n' f(\ell^d(\gamma^s))$

$$= k\frac{w}{p}\lambda^d n' \ell^d(\gamma^s) = k\frac{w}{p}\lambda^d L^d(\gamma^s) \;. \quad \blacksquare$$

These loci are shown in Figure 3, too.

3. MACROECONOMIC EQUILIBRIUM WITH RATIONING

3.1. Definition and Classification

Taking into account the government's consumption goods demand $G \geqslant 0$[1], aggregate supplies and demands are L^s and L^d on the labour market and C^s and C^d+G on the goods market. These values result from rationing signals λ^s, λ^d and γ^s where we have to revise now the previous definition of γ^s so that

$$\gamma^s = \min \left\{ \frac{C^d + G}{C^s}, 1 \right\}.$$

For given γ^s, firms' labour demand is $L^d(\gamma^s)$ which, together with consumers' labour supply, determines

$$\lambda^s = \min \{L^d(\gamma^s)/L^s, 1\}$$
$$\lambda^d = \min \{L^s/L^d(\gamma^s), 1\}.$$

These quotas in turn induce a new value

$$\tilde{\gamma}^s = \min \left\{ \frac{C^d(\lambda^s) + G}{C^s(\lambda^d, \gamma^s)}, 1 \right\}$$

If γ^s is such that $\gamma^s = \tilde{\gamma}^s$, then all agents are confirmed in their expectations concerning the rationing signals relevant to their decisions. Thus no agent has an incentive to revise his actual transaction offer. This leads to the following

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1. The government pays pG to firms which however it gets back since it collects firms' profits.

<u>Definition</u>. For given price p, wage w and government consumption $G \geqslant 0$, a pair $(L,C) \in \mathbb{R}_+^2$ is an *equilibrium with quantity rationing* if there exists a quadrupel $(\lambda^s,\lambda^d,\gamma^s,\gamma^d) \in [0,1]^4$ such that

$$L = \lambda^s L^s = \lambda^d L^d(\gamma^s)$$

$$C = \gamma^s C^s(\lambda^d,\gamma^s) = \gamma^d C^d(\lambda^s) + G$$

$$(1-\lambda^s)(1-\lambda^d) = 0$$

$$(1-\gamma^s)(1-\gamma^d) = 0 .$$

The last two equations formalize the short-sided-rule which is assumed here and which requires that at most one side of the market be rationed. Morever, they exclude the trivial equilibrium that would arise from $\lambda^s = \lambda^d = \gamma^s = \gamma^d = 0$ in the case that $G = 0$.

By means of the parameters λ^s, λ^d, γ^s and γ^d we can classify the various equilibrium states into the four well known types of Keynesian unemployment (K), Repressed inflation (I), Classical unemployment (C) and Underconsumption (U), according to table 1. In addition

	K	I	C	U
λ^s	<1	=1	<1	=1
λ^d	=1	<1	=1	<1
γ^s	<1	=1	=1	<1
γ^d	=1	<1	<1	=1

Table 1

there exist intermediate cases, the most important of which is Walrasian equilibrium, at which all rationing parameters are equal to one.

Using the loci of aggregate effective demands and aggregate expected transactions derived in the previous sections, we can illustrate graphically

the various equilibrium states. Assuming first $G = 0$, a Keynesian unemployment equilibrium is according to Table 1 and the definition of the loci $\tilde{H}^K$ and $\tilde{F}^K$ given by an intersection of $\tilde{H}^K$ and $\tilde{F}^K$, that is, by

$$\begin{aligned}(L,C) \in & \{(\lambda^s L^s, C^d(\lambda^s)) \mid 0 \leq \lambda^s < 1\} \\ & \cap \{(L^d(\gamma^s), \gamma^s C^s(1,\gamma^s)) \mid 0 \leq \gamma^s < 1\} \\ & = \tilde{H}^K \cap \tilde{F}^K.\end{aligned}$$

These loci were introduced in Figures 2 and 3 and are represented in Figure 4. Consumers supply

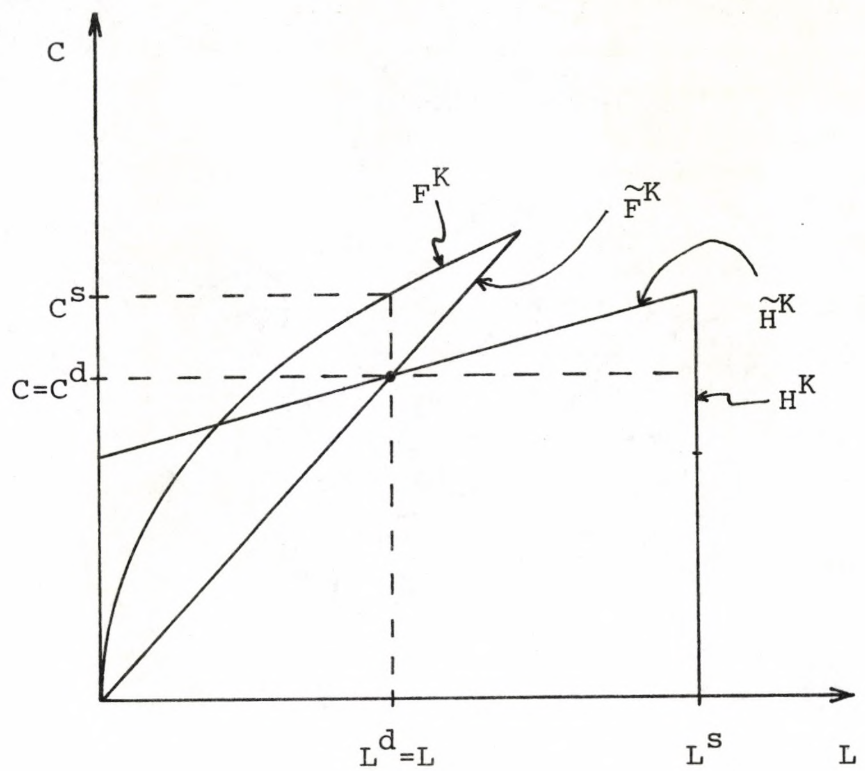


Figure 4

labour $L^s > L$ and demand goods $C^d = C$, whereas producers demand labour $L^d = L$ and supply goods $C^s > C$. The resulting quotas are $\lambda^s = L/L^s$, $\lambda^d = 1$, $\gamma^s = C/C^s$ and $\gamma^d = 1$ which are just the ones that lead consumers and producers to express their aggregate transaction offers (L^s, C^d) and (L^d, C^s), respectively.

The diagram evidently shows that aggregate effective supplies of rationed agents exceed aggregate actual transactions. This is due to the uncertainty agents are facing with respect to the amount they can trade; it is in contrast to the concept of (contrained) effective demand under deterministic rationing as applied e.g. by Muellbauer and Portes (1978) to the diagrammatical representation of the equilibrium with quantity rationing.

Moreover, these excesses can be used to get an indicator for the size of disequilibrium. Since there is all-or-nothing rationing in the labour market, the value $1 - L/L^s$ is just the ratio of the number of unemployed consumers to the total number of consumers. But even if rationing were not all-or-nothing, $1 - \lambda^s$ could be looked at as a measure of the size of disequilibrium (in equilibrium) whenever it increases with a decrease of L, since a decrease of L, the total amount of labour available to consumers, means in an objective sense an aggravation of consumers' rationing in the labour market. But

$$\frac{d(1-\lambda^s)}{dL} = -\frac{1}{L^s} < 0 \quad .$$

Similarly, from $\gamma^s c^s(1,\gamma^s) - C = 0$ one obtains

$$\frac{d(1-\gamma^s)}{dC} = -\frac{d\gamma^s}{dC} = -\frac{1}{c^s + \lambda^s \frac{\partial c^s}{\partial \gamma^s}} < 0 ,$$

since

$$\frac{\partial c^s}{\partial \gamma^s}(1,\gamma^s) = n'f'(\ell^d(\gamma^s))\frac{d\ell^d}{d\gamma^s} > 0 .$$

A similar reasoning justifies an interpretation of the terms $1 - \lambda^d$ and $1 - \gamma^d$ as indicators for the size of disequilibrium in the various other regimes. For a general discussion and systematic treatment of this issue, the reader is referred to Weinrich (1984c).

In the case that $G > 0$, one can use the same diagrammatical representation by slightly modifying Figure 4. In Figure 5 the Goverment's demand is taken into account by means of shifting upwards the consumers sector by the amount G.

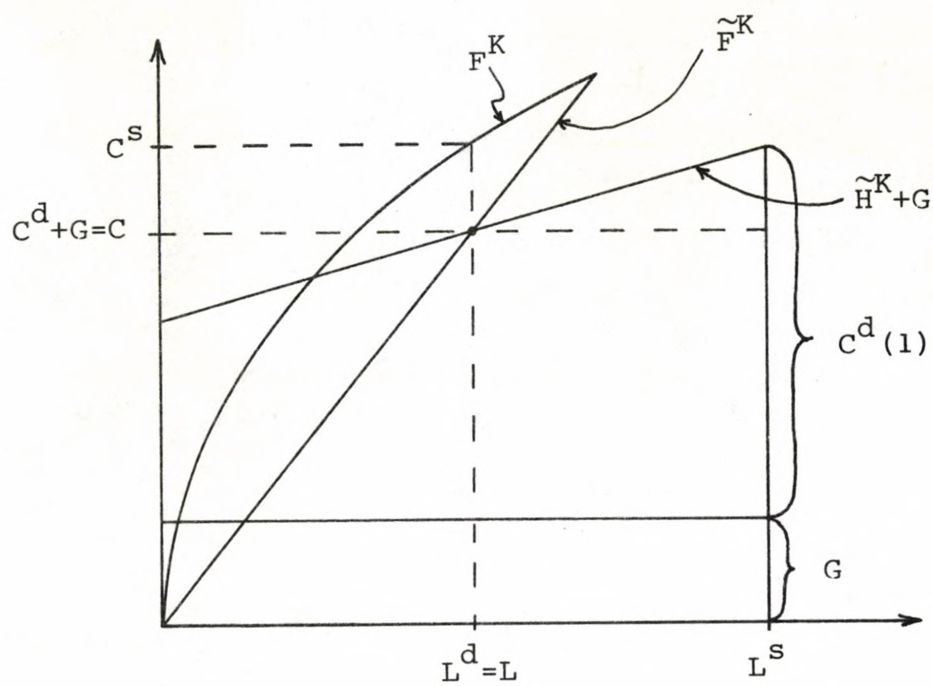
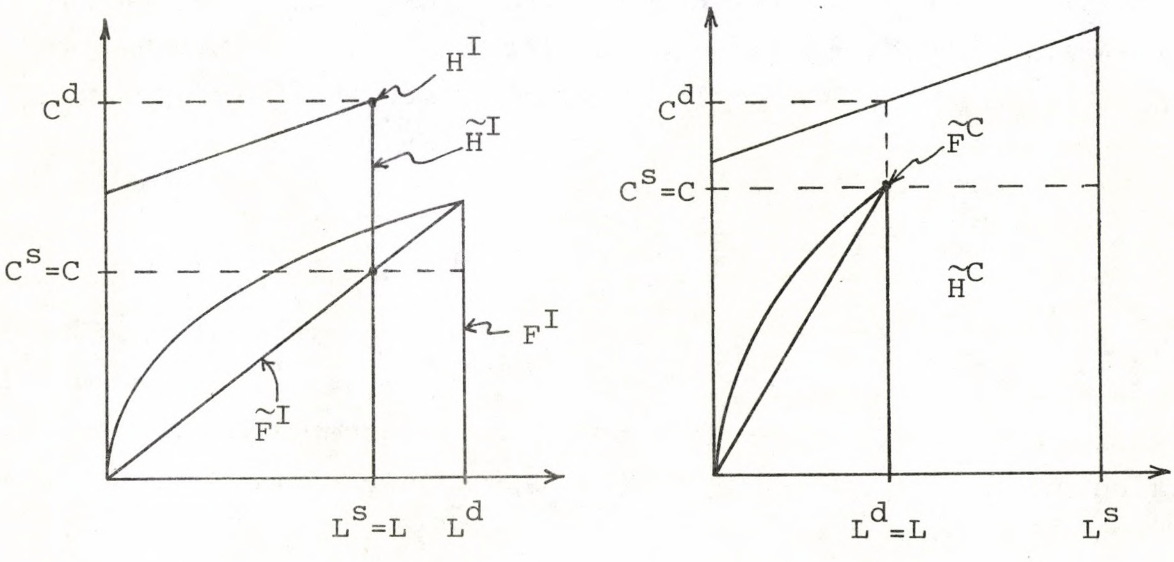


Figure 5

Referring to Figures 2 and 3, one can similarly represent the other types of equilibria, repressing for simplicity and without loss of generality the goverment's contribution G. This is done in Figure 6. It should be remarked that any Underconsumption equilibrium can be considered as limit case of a Keynesian unemployment equilibrium as well as of a Repressed inflation equilibrium. Moreover, in the Underconsumption case, the values of producers' aggregate labour demand/goods supply are not uniquely determined through the values of aggregate transactions (L,C); rather, any demand (L^d,C^s) of the (uncountable) set

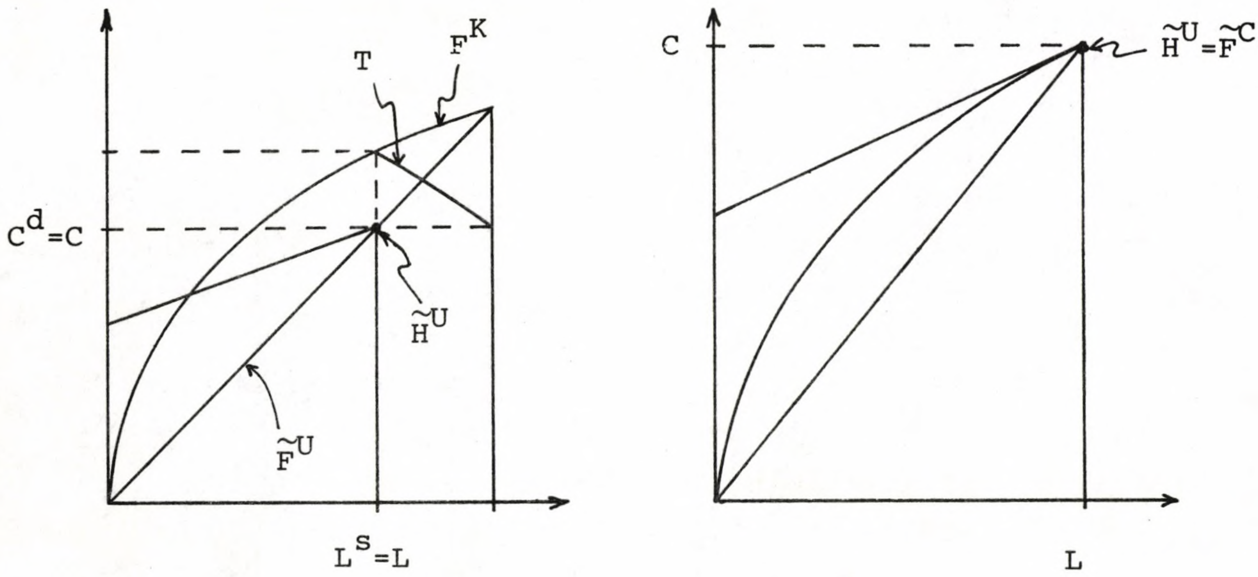
$$T = \{(L^d,C^s) \mid \lambda^d L^d(\gamma^s) = L, \gamma^s C^s(\lambda^d,\gamma^s) = C \text{ for some } (\lambda^d,\gamma^s) \in [0,1]^2\}$$

is a possible aggregate transaction offer of producers.



(a) Repressed Inflation (b) Classical Underemployment

(Figure 6)



(c) Underconsumption (d) Walrasian Equilibrium

Figure 6

3.2. Existence and Uniqueness of Equilibrium

Using the diagrammatic tools developped above, it is now immediate to see the existence of an equilibrium. In fact, a pair $(L,C) \in \mathbb{R}_+^2$ is an equilibrium if it is an element of the set

$$(\bar{\tilde{H}}^K \cap \bar{\tilde{F}}^K) \cup (\bar{\tilde{H}}^I \cap \bar{\tilde{F}}^I) \cup (\tilde{H}^C \cap \tilde{F}^C) \cup (\tilde{H}^U \cap \tilde{F}^U)$$

where $\bar{\tilde{H}}^X$, $\bar{\tilde{F}}^X$, $X \in \{K,I\}$, denotes the topological closure of $\tilde{H}^X$, $\tilde{F}^X$, respectively. But since $\tilde{F}^K = \tilde{F}^I$ starts from the origin whereas $\tilde{H}^K$ and $\tilde{H}^I$ do so from positive intercepts on the respective axes, the non-emptyness of the above set is evident from Figures 4 and 6.

Turning to the uniqueness of equilibrium, one first observes that $\tilde{H}^K$ runs to the left of $\tilde{H}^I$ whereas $\tilde{F}^K$ coincides with $\tilde{F}^I$. Next, since all these loci are straight lines, their respective slopes are constant. Consequently, $\tilde{H}^K$ and $\tilde{F}^K$ intersect at most once as the same is true for $\tilde{H}^I$ and $\tilde{F}^I$. But this assures uniqueness since it entails that intersection of $\tilde{H}^K$ and $\tilde{F}^K$ excludes intersection of $\tilde{H}^I$ and $\tilde{F}^I$, and vice versa.

3.3. Representation of Equilibrium Regimes in p-w-plane

Existence and uniqueness of equilibrium enable to divide up the p-w-plane into the four regions[1] of different types of equilibria with quantity rationing according to Table 1. The result is shown in Figure 7, where (p^*,w^*) denotes the Walrasian price-wage-pair[2]. The partitioning shown in Figure 7 differs from those ones given in the

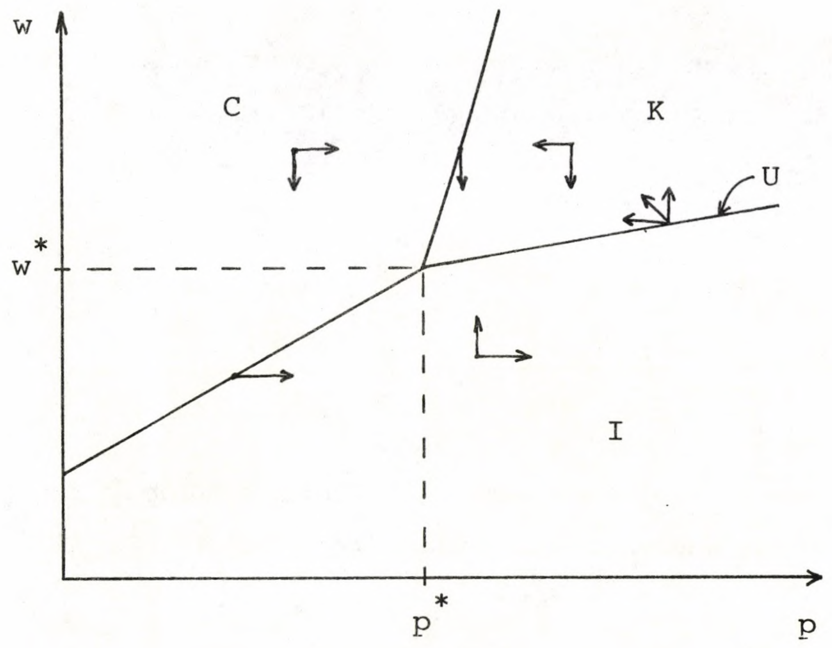


Figure 7

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1 Since the "region" of underconsumption coincides with the border line between Keynesian unemployment and repressed inflation, there are actually three proper regions only.

2 Fig. 7 is drawn under the hypothesis that $G > 0$. If $G = 0$, then the border line between K and I is horizontal, as will be shown below.

literature in one aspect distinctively: the border line between Keynesian unemployment and repressed inflation has a non-negative slope whereas this does not hold for the partitionings shown in the literature[1]. To see this, we recall that for any price-wage-tuple (p,w) on the K-I-border line, households are not rationed. Thus an equilibrium for such a (p,w) fulfills

$$L^s(p,w) = \lambda^d L^d(\gamma^s,p,w)$$

$$C^d(1,p,w) + G = \gamma^s C^s(\lambda^d,\gamma^s,p,w)$$

$$\lambda^d \gamma^s \leq 1$$

where we have written explicitly p and w as arguments of the various functions in order to point out the dependence of these functions on p and w. By definition of $\tilde{F}$ and Lemma 3, this implies (compare Fig. 6c)

$$C^d(1,p,w) + G = k\,\frac{w}{p}\,L^s(p,w)$$

or

$$n\,\frac{m + w\ell^s(w)}{p} + G - k\,\frac{w}{p}\,n\ell^s(w) = 0,$$

where we have used the fact that labour supply is independent of p. Upon differentiation of this expression, one gets

$$\frac{dw}{dp} = \frac{-G}{n(1-k)[\,\ell^s(w) + w\,\frac{d\ell^s}{dw}]}$$

which is positive since $k > 1$ and $\frac{d\ell^s}{dw} > 0$ by (c) of Lemma 1.

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1 See e.g. Malinvaud (1977), p. 85, or Muellbauer and Portes (1978), p. 810.

It is to be stressed here that the non-negative slope of the K/I - border line is not due to our treatment of money and the assumption of atemporal decision making of consumers but to stochastic rationing. In fact, in [Weinrich (1984b)] a model has been analyzed which differs from Malinvaud's (1977) model only by the fact that rationing is stochastic instead of being deterministic. That model gives rise to the same shape of partitioning as the one derived is this paper.

4. DYNAMICS

So far our analysis was purely static. With each pair of prices (p,w) we have associated an equilibrium with quantity rationing, by this identifying the aggregate transaction levels, the rationed market sides, and, in terms of the quotas λ^s, λ^d, γ^s and γ^d, the size of disequilibrium in each market. We will now dynamize the model by considering a sequence of periods, in each of which an equilibrium with rationing obtains. The link between successive periods is given by price adjustment, that is, the prices in period t + 1 depend functionally on the prices in period t. With respect to the directions of price changes we follow the traditional hypothesis: excess supply gives rise to a decrease whereas excess demand makes them increase. Alternatively, we can express this using the rationing quotas λ_t^s, λ_t^d, γ_t^s and γ_t^d realized in period t:

$$p_{t+1} > p_t \Leftrightarrow \gamma_t^d < 1$$

$$p_{t+1} < p_t \Leftrightarrow \gamma_t^s < 1$$

$$w_{t+1} > w_t \Leftrightarrow \lambda_t^d < 1$$

$$w_{t+1} < w_t \Leftrightarrow \lambda_t^s < 1 \ .$$

This gives rise to the arrows in Fig. 7 indicating the respective directions of price changes.

A remark is in order with respect to pairs (p,w) which lie on the border line between K and I. In that case, $\lambda^s = \gamma^d = 1$ and $\lambda^d \gamma^s < 1$, but λ^d and γ^s are not uniquely determined. One possibility is $\lambda^d = 1$, $\gamma^s < 1$, in which case only the goods price is adjusted whereas the wage remains unchanged.

The opposite extreme possibility is $\lambda^d < 1$ and $\gamma^s = 1$ which implies an adjustment of the wage rate only. For $\lambda^d < 1$ and $\gamma^s < 1$ both prices change. This indeterminacy of price adjustment is much less problematic, however, as it may appear at first glance; because, whatever are the concretely realized values of λ^d and γ^s, p will never increase and w will never decrease. This, together with the fact that the K/I border line is positively sloped, implies that $(p_{t+1}, w_{t+1}) \in K$ whenever $(p_t, w_t) \in U$. But this fact will be sufficient for the qualitative analysis that will follow.

From Fig. 7 it is immediate to see the behaviour of the dynamical system in the regions C and K: whereas C is a transient region, K is persistent, that is, whenever $(p_t, w_t) \in K$ for some t, then $(p_\tau, w_\tau) \in K$ for all $\tau \geq t$, with convergence to the Walrasian point (p^*, w^*). On the other hand, the characterization of the inflationary region I with respect to the system's behaviour is not obvious. In orger to get some insight, we will be more precise now about the mapping $(p_t, w_t) \mapsto (p_{t+1}, w_{t+1})$.

4.1. Dynamics in the inflationary region

For given $G \geq 0$, with each pair $(p_t, w_t) \in I$ there is associated a unique pair of rationing quotas

$$(\lambda_t^d, \gamma_t^d) = (\lambda^d(p_t, w_t),\ \gamma^d(p_t, w_t)),$$

by means of the equilibrium conditions

$$L^s(w_t) = \lambda_t^d L^d(1, p_t, w_t)$$

$$C^s(\lambda_t^d, 1, p_t, w_t) = \gamma_t^d C_t^d(1, p_t, w_t) + G.$$

Since there is excess demand on both markets, prices have to be increased. More precisely, we concentrate in the following on adjustment functions of the type

$$(4) \qquad p_{t+1} = \phi_\nu(\gamma_t^d)\, p_t$$

$$w_{t+1} = \psi_\mu(\lambda_t^d)\, w_t \, ,$$

where $\{\phi_\nu\}_{\nu\geqslant 0}$ and $\{\psi_\mu\}_{\mu\geqslant 0}$ are families of functions

$$\phi_\nu : \,]0,1[\; \rightarrow [1,\infty[$$

$$\psi_\mu : \,]0,1[\; \rightarrow [1,\infty[$$

indexed by coefficients ν and μ reflecting speeds of adjustment in a sense made precise by (ii) of the following assumption.

(D) (i) ϕ_ν and ψ_μ are differentiable and $\phi_\nu' < 0$, $\psi_\mu' < 0$.

(ii) $\nu_1 > \nu_2 \Leftrightarrow \phi_{\nu_1}(\gamma) > \phi_{\nu_2}(\gamma) \;\forall\, \gamma$
$\mu_1 > \mu_2 \Leftrightarrow \psi_{\mu_1}(\lambda) > \psi_{\mu_2}(\lambda) \;\forall\, \lambda .$

(iii) $\phi_0(\gamma) = 1 \;\forall\, \gamma$, $\psi_0(\lambda) = 1 \;\forall\, \lambda$.

(iv) The functions $\phi_\cdot(\gamma) : \nu \mapsto \phi_\nu(\gamma)$ and $\psi_\cdot(\lambda) : \mu \mapsto \psi_\mu(\lambda)$ are continuous in $\nu = 0$ and $\mu = 0$, respectively.

An example of a class of functions meeting (D) is

$$\phi_\nu(\gamma) = \gamma^{-\nu} \qquad \psi_\mu(\lambda) = \lambda^{-\mu}$$

We then get the following

Proposition: Assume (D). (a) If $(p_t, w_t) \in I$ and $\nu > 0$, then

$$\frac{dp_{t+1}}{dp_t} > 1 \quad .$$

(b) If $(p_0, w_0) \in I$, $\nu > 0$, $\mu = 0$, then $(p_t, w_t) \in I$ for all $t = 1,2...$ and $p_t \to \infty$. (c) If $(p_0, w_0) \in I$, $\nu > 0$, then for any $\bar{p} > 0$ there exists $\mu > 0$ such that for some t $(p_\tau, w_\tau) \in I$ for all $\tau \leqslant t$ and $p_t \geqslant \bar{p}$.

Proof: Appendix.

According to this result, adjustment of the goods price only (i.e. $\nu > 0$ and $\mu = 0$) by (b) entails that the economy remains forever in the region of repressed inflation and that p increases explosively, the latter by (a). If p and w are adjusted, then, for any given speed of adjustment of p and for any given high price $\bar{p}$, there exists a sufficiently small (but non-zero) speed of adjustment of w such that the economy reaches in some period t a state in which p_t is higher than $\bar{p}$. Thus, even if both prices are adjusted, the trajectory of the system may be very undesirable from the point of view of economic agents.

The essential fact driving the result is that $\frac{\partial \gamma^d}{\partial p}(p,w) < 0$ [1] whenever $(p,w) \in I$. Thus, if there is demand rationing in the goods market, p is augmented; but instead of relaxing rationing, the increase in price reinforces rationing, as is reflected by a decrease of γ^d. This in turn leads to a still higher price increase. The process continues as long as the economy remains in the regime of repressed inflation.

1 This inequality is formally shown in the proof of the proposition.

It may be instructive to visualize the effect of a price increase in L-C-plane. In Figure 8

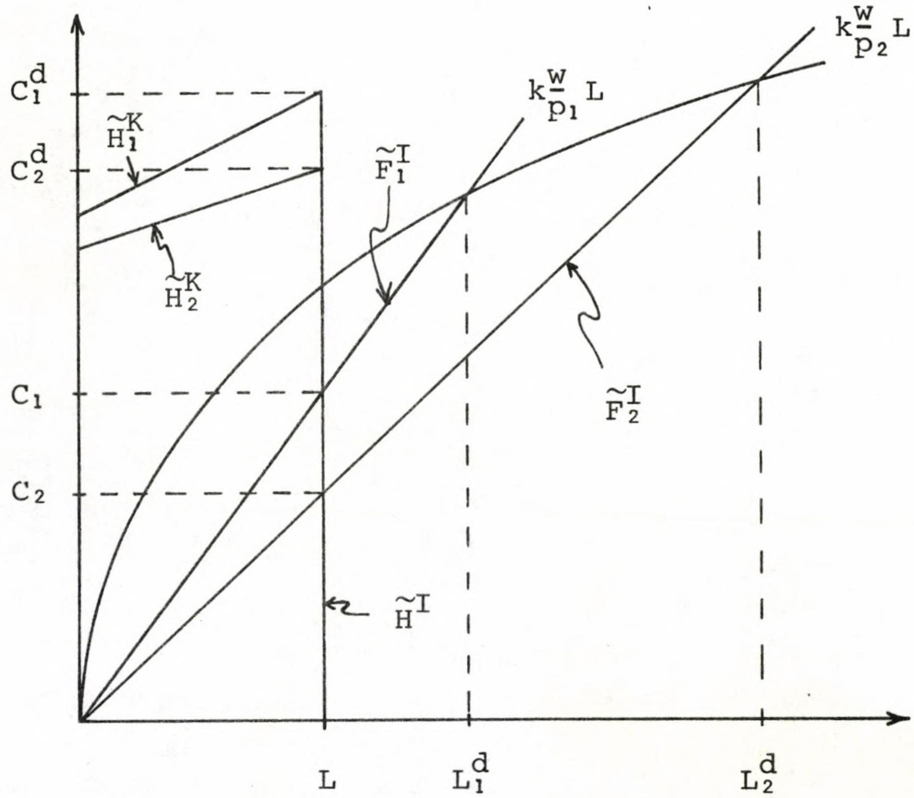

Figure 8

we have represented two situations of equilibrium under repressed inflation, arising from two prices p_1, p_2, with $p_1 < p_2$. Variables indexed by i refer to p_i. The rationing parameters for the goods market belonging to the two situations are $\gamma_i^d = C_i/C_i^d$. Since $p_2 > p_1$, aggregate consumption goods demand is smaller for p_2 than for p_1, that is $C_2^d < C_1^d$. On the other hand, an increase in p increases the labour demand of each firm. But as supply of labour remains uneffected, a smaller number of firms succeeds to hire labour. This in turn entails that aggregate supply of goods decreases -and hence the aggregate transaction level-, that is, $C_2 < C_1$. Moreover, aggregate supply decreases relatively more than aggregate demand, that is, $\gamma_2^d = C_2/C_2^d < C_1/C_1^d = \gamma_1^d$.

4.2. Stabilization through Wage Indexation

The foregoing proposition shows that the dynamic behaviour of the economy considered in our model is not very satisfactory. Indeed, even if the sequence of equilibria with quantity rationing eventually converges to the Walrasian equilibrium, it may follow a path on which occur very high prices and strong demand rationing on the goods market. This is in particular the case if the wage rate adjusts slowly compared to the goods price - an assumption that is often attributed to Keynes.

On the other hand, an inspection of Fig.7 suggests that the inconvenience of the dynamic behaviour in the inflationary regime can easily be removed by indexing the wage rate on the goods price. Thus, let $W > 0$ denote a suitably to be chosen real wage rate. Assuming that every (p_t,w_t) occuring in time has to obey

$$w_t \geqslant Wp_t ,$$

this will prevent the economy from getting too far away from the Walrasian equilibrium and will shorten the time needed to come close to it. More precisely, we define for any given (p_t,w_t) the new prices (p_{t+1},w_{t+1}) by

$$(5) \qquad p_{t+1} = \phi_\nu(\gamma_t^d)p_t$$

$$w_{t+1} = \max\{\psi_\mu(\lambda_t^d)w_t, Wp_{t+1}\} .$$

The impact of this wage indexation is shown in Fig. 9 for some $W < {}^{w^*}/_{p^*}$. Assume that the price-wage combination

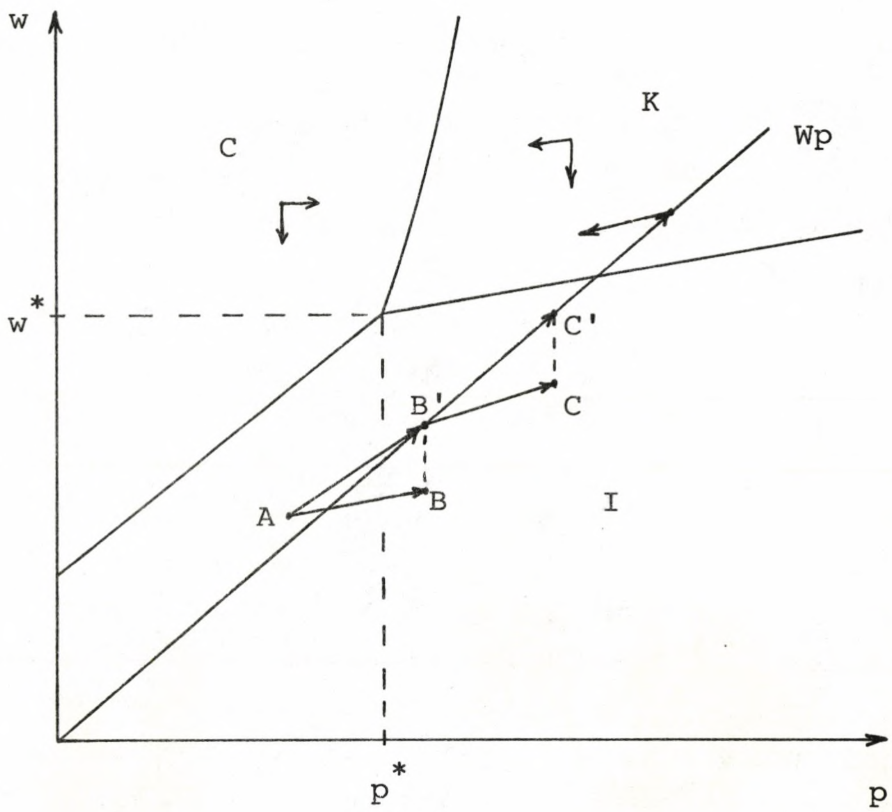

Figure 9

prevailing in period t is given by point A and that the subsequent price-wage pair that would result from applying the "uncorrected" rules (4) is represented by point B. Then (5) tells us to go to point B'. Analogously, starting from B', (5) would determine C' instead of C as would have been prescribed by (4), and so on, until the sequence of equilibria reaches the regime of Keynesian Underemployment, with subsequent convergence to the Walrasian equilibrium.

What happens if the minimum real wage W lies above the Walrasian real wage $^{w*}/_{p*}$? To answer this question, we consider Fig. 10. There the economy is assumed to find

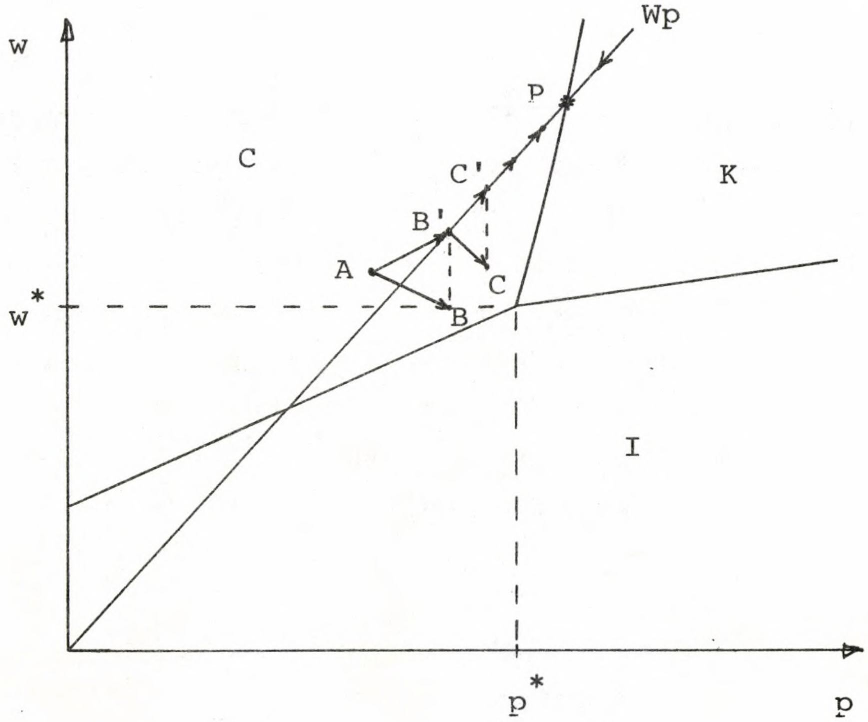

Figure 10

itself in period t in point A. Instead of going to point B in period t+1, (5) tells us to go to B'. The next point to be realized will be C', and so on. The process converges to point P, where the dynamic evolution stops. P represents a price and wage combination where there is no rationing on the goods market and supply rationing on the labour market.

This result does not depend on the fact that the original price-wage pair was is the region of classical unemployment.

In fact, if (p_0,w_0) is any starting point such that $^{w_0}/_{p_0} \leqslant W$, then (5) entails that $w_1 = Wp_1$. But then again, convergence to P occurs. Thus, whenever the minimum real wage W is fixed above the Walrasian real wage, the economy gets stuck in a situation with persistent unemployment and no rationing on the goods market.

The question may arise whether one can cure this unemployment situation by changing money endowments of consumers m and/or goverment spending G. The answer is no. With respect to m, this is easily seem from Fig.11, where (p_i^*,w_i^*), i =1,2, correspond to two values m_1 and m_2 such that $m_1 < m_2$. Changing m does not change the Walrasian real wage. Thus, if W is higher than that value, Walrasian equlibrium is not attainable whatever is the value of m. With a similar consideration in p-w-plane one can show the ineffectiveness of changing G.

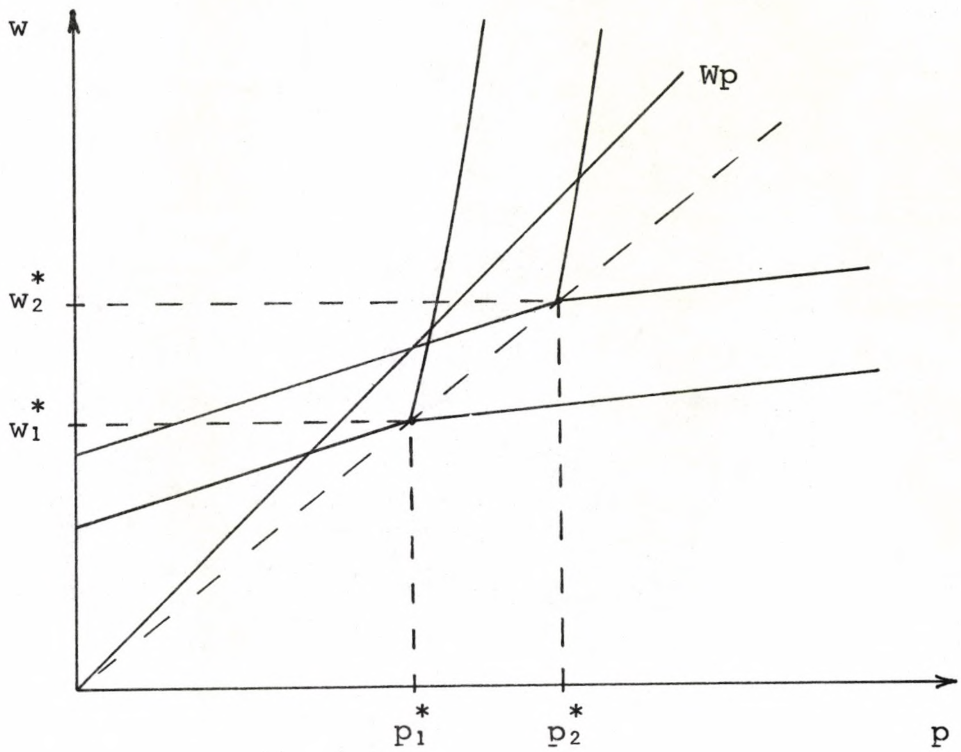

Figure 11

5. CONCLUDING REMARKS

Though the model presented in this paper is a most simple one, it allowed us to illustrate how stochastic rationing can be used to set up and analyze price dynamics. As a result it turned out that wage indexation may be desirable in order to stabilize the dynamic behaviour of the economy. On the other hand, a too high minimum real wage in our model gives rise to persistent unemployment.

Further extensions of the analysis conducted in the text are perhaps worth to be mentioned. Introducing nominal wage rigidity downwards (i.e. $w_{t+1} \geqslant w_t$ for all t) will lead to persistent unemployment (and no rationing on the goods market) as was the case with wage indexation with a too high minimum real wage. This can easily be seen from Fig. 7 and is due to the positivity of the slope between the K- and the I-region. Furthermore, the higher is government spending, the steeper is the slope of the K/I-border line; hence the larger will be underemployment in the resulting rest point. But, in contrast to the case of a too high minimum real wage, this underemployment situation can (temporarily) be removed by increasing money endowment m.

In order to make the model more realistic, one could think of the following modifications. First, one could distinguish between two types of consumers, workers and capitalists, the latter receiving all profits. This would allow to take into account the distributional aspects of wage indexation. Second, one could introduce an overlapping generations structure. Through this, money becomes a means of store of value and it would loose the somewhat artificial character that it has in the present paper. This would, as a third point, imply to include the dynamics of money into the analysis. As a consequence, it will become difficult to describe trajectories explicitly, but the stability of the Walrasian equilibrium, for example, could still be investigated.

Appendix

Proof of Lemma 1: By (C)(i), statement (d) of Lemma 1 is trivial. In order to show (a), we consider the problem

$$\max v_1(\ell^s, c^d; \gamma^d)$$
$$\text{s.t.} \quad c^d \geqslant 0$$
$$0 \leqslant \ell^s \leqslant \bar{\ell}$$
$$pc^d \leqslant w\ell^s + m$$

where $v_1(\ell^s, c^d; \gamma^d) = \rho\gamma^d u(c^d, \ell^s) + (1-\rho\gamma^d)u(\alpha c^d, \ell^s)$.
(C)(i) and (ii) imply that a solution is characterized by the conditions

(1a) $$\left[\frac{w}{p}\frac{\partial v_1}{\partial c^d}(\ell^s, c^d; \gamma^d) + \frac{\partial v_1}{\partial \ell^s}(\ell^s, c^d; \gamma^d)\right] \ell^s = 0$$

(2a) $$\frac{w}{p}\frac{\partial v_1}{\partial c^d}(\ell^s, c^d; \gamma^d) + \frac{\partial v_1}{\partial \ell^s}(\ell^s, c^d; \gamma^d) \geqslant 0, \; \ell^s \geqslant 0 \; .$$

By definition of v_1, the term in square brackets in (1a) is equal to

$$\frac{w}{p}\left[\rho\gamma^d \frac{\partial u}{\partial c^d}(c^d, \ell^s) + (1-\rho\gamma^d)\alpha \frac{\partial u}{\partial c^d}(\alpha c^d, \ell^s)\right]$$
$$+ \rho\gamma^d \frac{\partial u}{\partial \ell^s}(c^d, \ell^s) + (1-\rho\gamma^d) \frac{\partial u}{\partial \ell^s}(\alpha c^d, \ell^s) \; .$$

Using (C)(iii), this expression can be transformed to become

$$\frac{w}{p}\frac{\partial u}{\partial c^d}(c^d, \ell^s)\left[\rho\gamma^d + (1-\rho\gamma^d)\frac{\frac{\partial u}{\partial \ell^s}(\alpha c^d, \ell^s)}{\frac{\partial u}{\partial \ell^s}(c^d, \ell^s)}\right]$$

$$+ \frac{\partial u}{\partial \ell^s}(c^d,\ell^s)\,[\rho\gamma^d + (1-\rho\gamma^d)\,\alpha\,\frac{\frac{\partial u}{\partial c^d}(\alpha c^d,\ell^s)}{\frac{\partial u}{\partial c^d}(c^d,\ell^s)}]$$

$$=: k_1\,[\frac{w}{p}\frac{\partial u}{\partial c^d}(c^d,\ell^s) + \frac{\partial u}{\partial \ell^s}(c^d,\ell^s)]$$

with $k_1 > 0$. Hence (1a) and (2a) are equivalent to

$$[\frac{w}{p}\frac{\partial u}{\partial c^d}(c^d,\ell^s) + \frac{\partial u}{\partial \ell^s}(c^d,\ell^s)]\;\ell^s = 0$$

$$\frac{w}{p}\frac{\partial u}{\partial c^d}(c^d,\ell^s) + \frac{\partial u}{\partial \ell^s}(c^d,\ell^s) \geq 0,\; \ell^s \geq 0,$$

which, together with $c^d = (w\ell^s+m)/p$, are precisely the conditions characterizing a solution to the program started in (a) of Lemma 1.

In order to see (b), consider $\tilde{p}$, p such that $\tilde{p} = \frac{1}{\alpha}p$ with $0 < \alpha < 1$. Let (c^d,ℓ^s) such that

$$\frac{w}{p}\frac{\partial u}{\partial c^d}(c^d,\ell^s) + \frac{\partial u}{\partial \ell^s}(c^d,\ell^s) = 0$$

Then, using (C)(iii),

$$\frac{w}{\tilde{p}}\frac{\partial u}{\partial c^d}(\alpha c^d,\ell^s) + \frac{\partial u}{\partial \ell^s}(\alpha c^d,\ell^s)$$

$$= \frac{w}{p}\frac{\partial u}{\partial c^d}(c^d,\ell^s)\cdot\frac{\frac{\partial u}{\partial \ell^s}(\alpha c^d,\ell^s)}{\frac{\partial u}{\partial \ell^s}(c^d,\ell^s)}$$

$$+ \frac{\partial u}{\partial \ell^s}(c^d,\ell^s)\,\alpha\,\frac{\frac{\partial u}{\partial c^d}(\alpha c^d,\ell^s)}{\frac{\partial u}{\partial c^d}(c^d,\ell^s)}$$

$$= k_2 \left[\frac{w}{p} \frac{\partial u}{\partial c^d} (c^d, \ell^s) + \frac{\partial u}{\partial \ell^s} (c^d, \ell^s)\right] = 0$$

Thus $(\alpha c^d, \ell^s)$ maximizes utility for $(\tilde{p}, w)$ and in particular ℓ^s is independent of p.

In order to show (c), we argue best in a diagram.

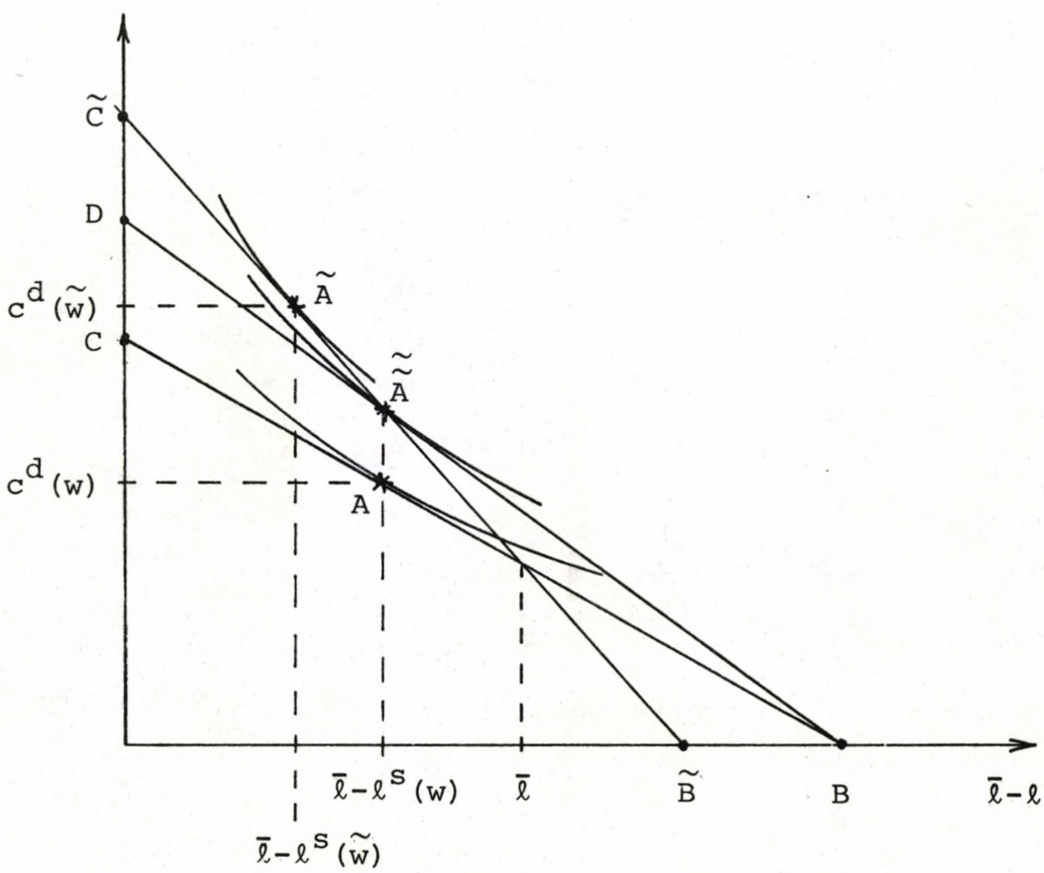

Figure 1a

In Fig. 1a, the point $A = (\bar{\ell}-\ell^s(w), c^d(w))$ represents the solution to the consumer's preference maximization problem for a wage rate w (and a price p) which gives rise to the budget line BC. The line $\widetilde{\widetilde{BC}}$ on the other hand represents the budget line for some wage $\tilde{w} > w$ (and the same price p). By (C)(iii), the slope of the indifference curve passing through point $\tilde{\tilde{A}}$ is equal to the slope of the straight line BD which (in absolute value) is smaller than the slope of the line $\widetilde{\widetilde{BC}}$. Thus $\tilde{\tilde{A}}$ is not the utility maximizer for $\tilde{w}$ but it is some point $\tilde{A}$ which, by strict quasi-concavity of the utility function, lies to the left (and above) $\tilde{\tilde{A}}$. Thus $\ell^s(\tilde{w}) > \ell^s(w)$. ∎

<u>Proof of the Proposition</u>

(a) By (4),

$$\frac{dp_{t+1}}{dp_t} = \phi'_\nu \frac{\partial \gamma_t^d}{\partial p_t} p_t + \phi_\nu(\gamma_t^d).$$

Using Lemma 3,

$$\gamma^d(p,w) = \frac{C-G}{c^d(1,p,w)} = \frac{nk\frac{w}{p}\ell^s(w)-G}{n\frac{w\ell^s(w)+m}{p}}$$

$$= \frac{kw\ell^s(w)}{w\ell^s(w)+m} - \frac{pG}{n(w\ell^s(w)+m)}$$

This implies $\frac{\partial \gamma^d}{\partial p} \leqslant 0$ with inequality if $G > 0$. Recalling that $\phi'_\nu < 0$ and $\phi_\nu(\gamma_t^d) > 1$, this yields

$$\frac{dp_{t+1}}{dp_t} > 1.$$

(b) Since $w_t = w_0$ for all t, the conclusion is immediate by (a) and the fact that the border line between K and I has a non-negative slope.

(c) Setting

$$\tilde{\phi}_\nu(p,w) := \phi_\nu(\gamma^d(p,w))p$$

$$\tilde{\psi}_\mu(p,w) := \psi_\mu(\lambda^d(p,w))w,$$

prices in period t can be written

$$(p_t,w_t) = (\tilde{\phi}_\nu,\tilde{\psi}_\mu)^t(p_0,w_0)$$

By (D)(iv), the function

$$(\tilde{\phi}_\nu,\tilde{\psi}_.)^t(p_0,w_0): \mu \rightarrow (p_t,w_t)$$

is continuous in $\mu = 0$. Together with (b) this implies the assertion. ∎

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