FOREIGN ENCLAVES, INFORMAL SECTOR AND URBAN UNEMPLOYMENT ------ A THEORETICAL ANALYSIS.*

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ABSTRACT :- We consider a small open Harris-Todaro economy with a rural foreign enclave and urban informal sector. We introduce consumption-efficiency relation to explain the simultaneous existence of informal sector and urban unemployment. Different types of immobility and mobility of capital are assumed in different sections of this paper. We also analyse the effects of expansion of foreign enclave on urban unemployment and on domestic factor income. In many cases, we get the results opposite to that obtained in the young-Miyagiwa model.

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1. INTRODUCTION :

The recent literature on foreign enclave has enlightened the expansion of foreign enclave and its effects on unemployment and national income. The issue on foreign enclave includes the works of Young (1987, 1992), Young and Miyagiwa (1987), Miyagiwa(1993), Dutta Chaudhury and Adhikari (1993) and Gupta (1994a). All the models are basically Harris-Todaro (1970) type complementing a foreign enclave and in all the models foreign enclave uses sector-specific capital.

In the Young-Miyagiwa (1987) model, foreign enclave is located in the rural sector and capital is purely non-shiftable among all the sectors. They have shown that the expansion of foreign enclave through the reduction in tariff on intermediate inputs lowers unemployment.

Dutta Chaudhury and Adikari (1993) have considered capital mobility between the rural sector and the urban sector and have introduced supply function of foreign capital in the Young-Miyagiwa (1987) model. They have shown that tariff reduction on intermediate input raises unemployment.

In Gupta (1994a), we find DFZ in the urban area and domestic capital is shiftable between the rural sector and the urban non-DFZ. He has shown that the reduction in import duty on intermediate goods, used in the foreign sector, raises unemployment, but we get opposite result if tariff on final goods is reduced.

In this paper, we consider a small open Harris-Todaro economy with rural foreign enclave and urban informal sector. None of the existing models on foreign enclaves considers the co-existence of these two sectors. To explain the simultaneous existence of informal sector and urban unemployment we introduce consumption-efficiency relation in the informal sector.[1] We assume that foreign enclave uses sector-specific foreign capital and the other sectors use domestic capital.

We consider both the shiftable and non-shiftable capital and we examine the impact of expansion of the foreign enclaves, thru the fiscal concessions, on urban unemployment and domestic factor income.

The model is described in section[2]. In this section we assume the non-shiftability of domestic capital among the rural sector, urban formal sector and urban informal sector[2]. The basic model is extended in three ways. In section3., the basic model is extended by

introducing capital mobility between the rural sector and the urban informal sector[3], whereas the foreign enclaves uses sector specific foreign capital and the urban formal sector uses sector-specific domestic capital. Section4. extends the basic model by assuming capital mobility between the rural sector and the urban formal sector[4], while the foreign enclave uses sector-specific foreign capital and the urban informal sector uses sector-specific domestic capital. Another extension is made in section5.by assuming perfect intersectoral mobility of domestic capital among the rural sector, the urban formal sector and the urban informal sector[5], whereas the foreign enclaves uses foreign capital. Conclusions are made in Section6.

2. THE MODEL :

2.1. ASSUMPTIOMS :

We consider a small open Harris-Todaro (1970) economy complementing the rural foreign enclave and the urban informal sector. Here, the foreign enclave is a labor supplying sector, since it is located in the rural areas[6]. All the sectors produce internationally traded goods and the prices of these goods are exogenously given[7].

The production functions of all the sectors exhibit CRS and have positive and diminishing marginal productivity to each input. Each sector uses only two inputs-labor and capital. Capital is measured in physical unit, while labor is measured in efficiency unit[8].

Workers' efficiency is positively related to the wage rate they receive. Such efficiency wage relation is more pronounced when the wage rate is low. It is assumed that the worker's efficiency is equal to one after a certain level of wage W* and is less than one below that specified level of wage. The wage rates in the urban formal sector, rural sector and the foreign enclave are higher than this specified level of wage, while the wage rate in the urban informal sector is assumed to be less than this level. Thus, for the UFS, RS and the foreign enclave, labor expressed in labor time is identical to that expressed in efficiency unit. However, for the UIS efficiency units of lobor differ from the labor time units of labor.

All the markets are assumed to be perfectly competitive. The assumptions of CRS production functions and profit maximizing behaviour of the firm imply the equality between price and unit cost in each sector and the minimisation of cost of one efficiency unit of labor.

Workers migrate from the rural sector to the urban region. Some of them are absorbed either in the UFS or in the UIS and a portion of them remains unemployed in the urban sector. The migration mechanism is of Harris-Todaro (1970) type.

Urban formal wage rate is institutionally fixed and is higher than the wage rates in all other sectors. The rural wage rate and the wage rate in the foreign enclave are equal since the workers are perfectly mobile between the RS and the foreign enclave.

We assume that the foreign enclave uses sector specific foreign capital and its supply is assumed to be exogenously given[9]. It is also assumed that the entire foreign capital income is fully repatriated[10]. Domestic capital is also assumed to be non-shiftable. Thus, we have different rate of returns on capital in different sectors. The endowment of labor and domestic capital are also exogenously given.

It is assumed that the urban formal sector is more capital intensive than the rural sector which is more capital intensive than the urban informal sector.

2.2. NOTATIONS :

j = u, i, r, F.

u = Urban formal sector.

i = Urban informal sector

r = Rural sector.

F = Foreign enclave.

X_j = Level of output in the j th sector.

L_j= Level of employment in the j th sector

k_j = Capital intensity of the j th sector.

W_j = wage rate in the j th sector.

h = Worker's efficiency.

R_j = Rental rate on capital in the j th sector.

V_i = Cost of one efficiency unit of labor in the urban informal sector.

L = Labor endowment of the entire economy.

K_j = Stock of capital in the j^{th} sector.

P_j = Producer's effective price of the j th good.

f_j = Intensive production function of the j th good.

C_j = Unit cost of production of the j th good.

U = Level of urban unemployment.

Y = Domestic factor income of the economy.

2.3 THE EQUATIONS :

The intensive production functions of the four sectors are given by :

$X_u = L_u f_u (k_u)$……(1) ;

$X_i = L_i f_i (k_i, h)$…… (2) ;

$X_r = L_r f_r (k_r)$ …… (3) ;

$X_F = L_F f_F (k_F)$……(4) ;

The efficiency-wage relation in the informal sector is given by :

$h = h (W_i)$ …… (5) ;

Following restrictions are imposed on this efficiency function :

i) $h' (W_i) > 0$ for $W_i < W^*$; ii) $h (W_i) = 1$ for $W_i \geq W^*$;

ii) and iii) $h'' (W_i) \gtreqless 0$ for $W_i \lesseqgtr W^{**} < W^*$.

The cost of one efficiency ;unit of labor in the UIS is :

$V_i = (W_i / h (W_i))$ …… (6) ;

The minimisation of efficiency unit cost of labor implies :

$(h' (W_i), W_i / h (W_i)) = 1$ ……(7) .

The long run equilibrium of a competitive firm implies that price is equal to the unit cost in each sector. Hence, we have the following equations :

$P_u = C_u (\overline{W}_u , R_u)$ ……(8) ;

$P_i = C_i (V_i , R_i)$ …… (9) ;

$P_r = C_r (W_r , R_r)$ ……(10) ; and

$P_F = C_F (W_r , R_F)$ ……..(11)

The optimum capital – labor ratios are given by :

$K_u = k_u (\overline{W}_u / R_u)$ ……..(12) ;

$k_i = k_i (V_i / R_i)$ ……..(13) ;

$k_r = k_r (W_r / R_r)$ ……(14) ;

$k_F = k_F (W_r / R_F)$ ……...(15) ;

$W_r = (L_u / (L - L_r - L_F)) \overline{W}_u + (L_i / (L - L_r - L_i)) W_i$ ……..(16) ;

Is the Harris-Todaro (1970) migration equilibrium condition.

Full utilisation of capital and labor implies the following equations :

$k_u L_u = K_u$ ……(17) ;

$k_i L_i = K_i$ ……...(18) ;

$k_r L_r = K_r$ ……(19) ;

$k_F L_F = K_F$ …….. (20) ; and

$$\sum_{j}^{u,i,r,F} L_j + U = L \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(21)$$

The domestic factor income is given by :

$$Y = \overline{W}_u L_u + W_i L_i + W_r L_r + W_r L_F + \sum_j R_j K_j \quad \ldots\ldots\ldots\ldots\ldots\ldots(22)$$

Using equations (16) , (21) and (22) we get,

$$Y = W_r L + \sum R_j Kj \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(22a)$$

This completes the equational structure of the model.

2.4. WORKING OF THE MODEL :

The working of the model is described as follows :

Equation (7) yields the equilibrium value of W_i. Then, we get the value of V_i from equation (6) and of h from equation (5). Given, P_u and $\overline{W}_u$, we get R_u from equation (8). Equation (9) gives the equilibrium value of R_i , given P_i and V_i.

Now , k_u and k_i are obtained from equations (12) and (13). So, we get L_u and L_i from equations (17) and (18), given K_u, K_r, k_u and k_i.

From equation (10) we find that R_r is a function of W_r. Equation (11) shows W_r as function of R_F. Thus, equations (14) and (15) show that both k_r and k_F are also functions of R_F. This implies that L_r and L_F are also functions of R_F (see equations (19) and (20)). Thus, we can determine the equilibrium value of R_F from equations (16), given L_u, L_i, $\overline{W}_u$ and W_i. Hence, we get the equilibrium values of W_r, R_r, k_r, k_F, L_r and L_F.

Equilibrium value of unemployment is obtained from equation (21), given L_j ($j = u,i,r,F$).

X_j s are obtained from equations (1) to (4). Finally, equation (22a) yields equilibrium value of Y.

2.5. COMPARATIVE STATIC EFFECTS :

2.5.1. CHANGE IN P_F ; If foreign enclave is expanded through the subsidization to this sector, P_F will rise. Appendix (A.1) shows that when P_F is raised, both Wr and RF rise. Now, equation 10 implies that Rr falls, given Pr. Thus, kr rises but kF may move in any direction.

Thus, L_r falls but L_F may change in any direction. From equation 16 we get, $(\overline{W}_u - W_r) L_u - (W_r - W_i) L_i = W_r U$. This shows that U falls if P_F rises, given $\overline{W}_u$, L_u, W_i and L_i.

Now, we examine the effect of a rise in P_F on Y. As P_F is raised, W_r rises and R_r falls, R_F fall. So we can write ,$dY = LdW_r + K_r dR_r$; or $dy = dR_r (LdW_r / dR_r + K_r) = dR_r (k_r L_r - Lk_r) = k_r dR_r (L_r - L) > 0$ (since $dR_r < 0$). So Y will rise.

The above results lead to the following proposition :

PROPOSITION 1: Expansion of foreign enclave thru the subsidization to this sector lowers urban unemployment and raises domestic factor income.

In the Y-M model, expansion of foreign enclave lowers Unemployment and in Dutta Chaudhuri it raises unemployment. However , in these two models foreign enclave expands thru the reduction in import duty on intermediate input used in this sector.

2.5.2. CHANGE IN K_f :

If the stock of foreign cpaital is increased, L_r will rise, given k_F. So, the effect of a rise in K_F on W_r, R_F and R_r are similar to those obtained in section 2.5.1.

3. CAPITAL MOBILITY BETWEEN THE URBAN INFORMAL SECTOR AND THE RURAL SECTOR ;

3.1. In this Section the basic model is extended by introducing capital mobility between the rural sector and the urban informal sector. The other two sectors use sector-specific capital.

3.2. EQUATIONS ;

Since the capital is mobile between the rural sector and the urban informal sector, we have a common rate of return on capital in these two sectors. Thus, the price equations for the rural sector become :

$$P_r = C_r (W_r , R_i) \quad \text{.....(10a)}$$

The two capital endowment equations will merge into one equation :

$$k_i L_i + K_r L_r = K_i \quad \text{.....(19a)}$$

The optimum capital intensity for the rural sector becomes :

$$K_r = k_r (W_r / R_i) \quad \text{.....(14a)}$$

The domestic factor income is now given by

$$Y = W_r L + R_u K_u + R_i K_i \quad \text{.....(22a')}$$

3.3. WORKING OF THE MODEL :

Like the model of Section 2. the optimum values of W_i , h, V_i, R_u, R_i, k_u, k_i, L_u, X_u and X_i are obtained from equations (5) to (7) , (8) , (9), (12), (13), (14), (1) and (2).

Now, equation (10a) yields the equilibrium value of W_r, given P and R_i.

Then, we get R_F from equation (11), given P_F and W_r. The equilibrium values of factor prices W_r, R_i & R_F give the optimum capital intensity K_r and K_F (see equations (14), (15)). From equation (20), we get L_F, given $k_F + K_F$

The equilibrium level of employment of the urban informal sector and the rural sector can be obtained from equations (16) and (19a). The determination of Li and Lr may be shown in a simple diagramme (see fig. 1).

SPACE FOR FIGURE 1

The LL curve is obtained from equation (16). The solve of the LL curve is given by $(dL_i / dL_r)_{LL} = - (W_r / W_i)$. Thus, the LL curve is negatively sloped and it shifts when L, L_F, $\overline{W_u}$ and L_u are changed . Equation 18a) gives the KK curve. The slope of the KK curve is given by $(dli(dlr)_{KK} = - (k_r / k_i)$. So, this curve is also negatively sloped and it shifts when K_i is changed. Here, the KK curve is steeper than the LL curve because the rural sector is more capital intensive than the urban informal sector in value terms [11]. The intersection of the two curves determine (Lr*, Li *).

Now, equilibrium level of unemployment is obtained from equation (21).

The level of output of the rural sector and the urban informal sector are obtained from equations (2) and (3). Finally, equation (22a′) yields the domestic factor income.

3.4. COMPARATIVE STATIC EFFECTS :

3.4.1. CHANGE IN P_F :

Subsidization to output in the foreign enclave raises P_F. Then, equation (11) shows that R_F will rise, given W_r. Thus, (W_r/R_F) falls and so also k_F . Hence, LF rises, given K_F (see equation (20)).

The increase in L_F leads to a leftward shift of the LL curve. Thus, in new equilibrium, L_r rises and L_i falls, given the KK curve. (See the appendix A.2)

From equation (16) we can write, $(\overline{W_u} – W_r)L_u – (W_r – W_i) L_i = W_rU$.

This shows that U rises with PF, given $\overline{W_u}$, W_r, L_u and W_i.

It is assumed that the income from foreign capital is totally repatriated. As the rise in P_F has no effect on W_r, R_u and R_i, it has also no effect on Y. Thus, we can get the following proposition :

PROPOSITION 3 : Expansion of the foreign enclave thru the output subsidy to that sector raises urban unemployment. However, its effect on Y is nil.

3.4.2. CHANGE IN K_F :

An increase in the stock of foreign capital raises K_F. As factor prices W_r and R_F do not depend upon K_F, the rise in K_F raises L_F. This rise in L_F produces the results similar to those obtained in the previous case. Thus, even if the foreign enclave is expanded thru the increase in the stock of foreign capital, urban unemployment rises and domestic factor income does not change.

4. CAPITAL MOBILITY BETWEEN THE UFS AND THE RS :

4.1. ASSUMPTIONS : In this Section we extend the model of Section2. by introducing capital mobility between the UFS and the RS. The other two sectors are assumed to use the sector-specific capital.

4.2. EQUATIONS :

Since the UFS and the RS use the same type of capital and there is no ditortion in this capital market, we get a uniform rate of return on capital in these two sectors ., R_u.

Thus , the price equation for the rural sector (equation (10) becomes

$$P_r = C_r(W_r, R_u) \quad \text{.....(10b).}$$

The optimum rural capital intensity is given by

$$k_r = k_r (W_r / R_u) \quad \text{.....(14a)}$$

The capital endowment equations (17) and (18) become

$$k_u L_u + k_r L_r = K_u \quad \text{.....(17a)}$$

The domestic factor income is given by

$$Y = W_r L + R_u K_u + R_i K_i \quad \text{.....(22a′)}$$

4.3 WORKING OF THE MODEL :

The equilibrium value of W_i, V_i and h are obtained from equations (5) to (7). Equation (8) gives R_U and equation (9) gives R_i. Equilibrium W_r is obtained from equation (10b), given P_r & Ru. Then, we get R_F from equation (11), given P_F. Thus, we get optimum capital intensities. So, we obtain L_i , given K_i, K_F & L_F (see equations 19 & 20)).

Now, from equations (16) and (17a) we get the equilibrium values of L_u and L_r. This may be shown graphically (see Fig. 2.) . The L′ L′ curve is obtained from equation (16) and the K′ K′ curve is obtained from equation (17a). Both the curves are negatively sloped. The K′ K′ steeper than the L′L′ curve since we assume that the urban sector is more capital intensive than the rural sector in value terms. The intersection of the two curves determines $(L_u^\star , L_R^\star)$.

SPACE FOR FIG . 2.

Now, we can determine the equilibrium U from equation (21). Thus, the equilibrium levels of output can be obtained from equations (1) to (4).

Finally, equation (22a) yields the equilibrium value of Y.

4.3. COMPARATIVE STATIC EFFECTS :

4.4.1. CHANGE IN P_F :

Output subsidy given to the foreign enclave raises P_F. This also raise R_F ; given W_r. So, (W_r/R_F) falls and so also k_F. This implies that L_F will rise, given K_F. This will shift the LL curve to the left. As a result, L_u rises and L_r falls. (See the appendix A.3) From equations (16) and (21) we find if L_u rises, U also rises given $\overline{W}_u$, W_i, W_r and L_i.

So far as Y is concerned, we find the rise in PF has no effect on Y since W_r, R_u & R_i remain frozen in this case.

Thus , we can make the following proposition :

PROPOSITION 4. If foreign enclave is expanded thru the output subsidy given to this sector, urban unemployment rises, but domestic factor income does not change at all.

4.4.2. CHANGE IN K_F :

If foreign capital is enlarged, L_F rises, given k_F. In this case, we get the similar results as obtained when P_F is raised. Thus, even if the foreign enclave is expanded thru the

increase in the stock of foreign capital, urban unemployment rises, but domestic factor income remains unchanged.

5. CAPITAL MOBILITY AMONG THE UFS, UIS, AND THE RS :

5.1 ASUMPTIONS :

In this section, we assume perfect capital mobility among the UFS, UIS and Rs, while foreign enclave uses sector-specific foreign capital. Thus, we have a common rate of return on domestic capital.

We assume that the goods produced in the UIS is non-traded. UFS is more capital intensive than the RS which is more capital intensive than the UIS in value terms.

5.2. EQUATIONS :

Since the domestic capital is mobile among the UFS, UIS and RS the three price equations become :

$P_u = C_u (\overline{W}_u, R)$ …… (8a);

$P_i = C_i (V_i, R)$ …….. (9a) ; and

$P_r = C_r (W_r, R)$ …… (10c).

The optimum capital intensities for the three domestic capital using sectors become :

$k_u = k_u (\overline{W}_u/R)$ ……. (12′) ;

$k_i = k_i (W_i/R)$ …….. (13′); and

$k_r = k_r (W_r/R)$ …… (14′).

The three capital endowment equations (17), (18) and (19) become :

$K_uL_u + k_iL_i + k_rL_r = K_D$ …….. (17′).

The demand for the goods produced in the UIS is given by :

$D_i = D_i (P_i)$, $D_i' < O$

Thus, the market equilibrium for the UIS's product is given by :

$X_i = D_i (P_i)$ ……. (23)

The domestic factor income will be :

$Y = W_rL + RK_D$ ……. (22′)

5.3. WORKING OF THE MODEL :

The equilibrium values of W_i, V_i and h are obtained from equations (5), (6), (7). All the factor prices R, W_r & R_F can be determined from equations (8′) and (10′) an (11), given $\overline{W}_u$. Thus, we get optimum capital intensities k_u, k_i, k_r and k_F from equations (12′) to (14′) and (15) . Now, equation (11) yields equilibrium P_i, given V_i and R. We get equilibrium L_i from equation (20) and L_F from equation (23).

Now, equilibrium L_u and L_r can be determined from equations (16) an (17′). This is shown in figure –3. The MM curve is obtained from equation (16). Its slope is given by $(dL_r/ dL_u)_{MM} = - (\overline{W}_u/W_r)$. Thus, the MM curve is negatively sloped and it shifts when W_u, W_r, L, L_F, W_i & L_i are changed. Equation (17′) gives the NN curve, whose slope is given by $(dL_r/ dL_u)_{NN} = - (k_u/k_r)$. This is also negatively sloped and shifts when K_D, K_i, L, L_i are changed. The NN curve is steeper than the MM curve as we assume that the UFS is more capital intensive than the RS in value terms[12]. The intersection of the two curves determines equilibrium (L_u*, L_r*).

Now, the equilibrium level of urban unemployment is obtained from equation (21). The level of output X_u, X_r, X_F are obtained from equations (1) to (3) and (4). Finally, Y is determined from equation (22′).

5.4. COMPARATIVE STATIC EFFECTS ;

5.4.1. CHANGE IN P_F :

Output subsidization to the foreign enclave raises P_F. As a result, R_F rises, given W_r (See equation (11). Thus, (W_r/R_F) falls and so also k_F. Equation (20) shows that L_F rises, given K_F. Thus, the MM curve shifts downward. This leads to a rise in L_u and fall in L_r. (See the appendix A.3) Now, equation (16) implies that U must rise when L_u rises, given $\overline{W}_u$, W_i, L_i & W_r.

Equation (22′) shows that there is no effect on Y since rise in P_F does not affect W_r and R.

The above result leads to the following proposition :

PROPOSITION 5 : Expansion of the foreign enclave thru output subsidy leads to a rise in urban unemployment. However, its effects on domestic factor income is nil.

5.4.2. CHANGE IN K_F

If foreign capital stock is increased, K_F will rise. This raises L_F, given k_F. Thus, we get the same effect on unemployment and on Y, as obtained in proposition 5.

6. CONCLUSION.

This paper presents a model with special emphasis on foreign enclove, informal sector and urban unemployment. The simultaneous existence of the urban informal sector and urban unemployment is explained interms of the efficiency wage theory. Like, Young-Miyagiwa (1987), we assume a rural foreign enclave, implying this as a labour supplying sector. This paper examines the impact of expansion of foreign enclave on urban unemployment and domestic factor income. Our model differs form the existing models on foreign enclave in two respects : here, foreign enclave expands either thru the output subsidy given to this sector or thru the enlargement of foreign capital ; and different types of capital mobility among the sectors are assumed in this paper.

The comparative static analysis shows that if foreign enclave expands either thru the price subsidy or thru the increase in the stock of foreign capital, urban unemployment falls when capital is purely non-shiftable and it rises it capital is shiftable perfectly or imperfectly. This is opposite to that of YM (1987). We get the same result in Dutta Chowdhury (1993) and Gupta (1994). However, our model differs from them with respect to the mode of expansion of foreign enclave and nature of capital mobility. The paper also shows that domestic factor income does not change even if foreign enclave expands when capital is perfectly or imperfectly mobile. Only when capital is purely non-shiftable, such expansion has expansionary effect on domestic factor income.

Foot Notes :

This is related to the research work of the Author who is registered for Ph.D. Degree in the University of Calcutta.

1. Fields (1987) explains urban unemployment in a framework where unemployed are more efficient in job search than those employed in the urban informal sector. Gupta (1993) explains this in a frame work where price is fixed and quantity adjusts to clear the market for RS's product.
2. Young-Miyagiwa (1987) also consider the non-shiftable capital among the UFS, Rs and Foreign enclave.
3. Gupta (1997) considers this type of capital mobility.
4. Grinols (1991) considers this type of capital mobility.
5. Chandra & Khan (1993) have considered this type of capital mobility.
6. Both Y-M (1987) an Tamal Dutta Chowdhury(1989) consider rural Foreign enclave, whereas Gupta (1994) considers urban Foreign enclave.
7. Chandra & Khan (1993), Grinols (1991) and Gupta (1997) have made this type of assmption.
8. The efficiency-wage theory implies that physical unit of labour differs from efficiency unit of labour.
9. Dutta Chowdhury and Adhikari (1989) have introduced the supply function of foreign capital.
10. If entire foreign capital income is repatriated, domestic factor income does not include the rental income on foreign capital.
11. This implies that $W_i k_r > W_r k_i$.
12. This implies that $W_r k_u > \overline{W}_u k_r$.

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APPENDIX

A.1 The total differentials of equations (16) and (11) are given by :

$$(L-L_r-L_F)\,dw_r - w_r(L'_r+L'_F)\,dR_F = 0 \quad \text{.....(B . 1)}$$

$$C_{FL}\,dw_r + C_{FK}dR_F = dP_F \quad \text{..... (B . 2)}$$

In the Matrix Form we can write,

$$\begin{bmatrix} (L - L_r - L_F) & - w_r (L'_r + L'_F) \\ C_{FL} & C_{FK} \end{bmatrix} \begin{bmatrix} dw_r \\ dR_F \end{bmatrix} = \begin{bmatrix} 0 \\ dP_F \end{bmatrix}$$

Here, $\Delta_1 = (L - L_r - L_F)C_{FK} + w_r C_{FL}(L'_r + L'_F) \rangle 0$ (Since, $L'_r \rangle\ 0$, $L'_F \rangle\ 0$)

$$dw_r = 1/\Delta\,[\,w_r\,(L'_r + L'_F)\,dP_F] \rangle\ 0$$

and $dR_F = 1/\Delta\,[(L - L_r - L_F)\,dP_F] \rangle\ 0$

A. 2

Total differentials of equations (16) and (17a) are

$$W_i dL_i + W_r dL_r = - W_r dL_F \quad \text{.....(B . 3)}$$

$$k_i dL_i + k_r dL_r = 0 \quad \text{.....(B . 4)}$$

In the matrix form we can write,

$$\begin{bmatrix} W_i & W_r \\ k_i & k_r \end{bmatrix} \begin{bmatrix} dL_i \\ dL_r \end{bmatrix} = \begin{bmatrix} -W_r dL_F \\ 0 \end{bmatrix}$$

Here, $\Delta_2 = W_i k_r - W_r k_i \rangle\ 0$ (Assumed)

$$dLi = -1/\Delta\,[\,k_r W_r dL_F] \langle 0$$

and $dL_r = 1/\Delta\,[\,W_r k_i dL_F] \rangle\ 0$

A.3 The total differentials of equations (16) and (17a) are given by :

$$\overline{W}_u dL_u + W_r dL_r = - W_r dL_F$$
$$k_u dL_u + k_r dL_r = 0$$

Here, $\Delta_3 = \overline{W}_u k_r - W_r k_u \langle 0$ (Assumed)

$$dL_u = 1/\Delta \begin{vmatrix} -W_r dL_F & W_r \\ 0 & k_r \end{vmatrix} = - 1/\Delta\,[\,k_r W_r dL_F] \rangle\ 0$$

$$dL_r = 1/\Delta \begin{vmatrix} \overline{W}_u & -W_r dL_F \\ k_r & 0 \end{vmatrix} = 1/\Delta\,[\,WrkudL_F] \langle 0$$

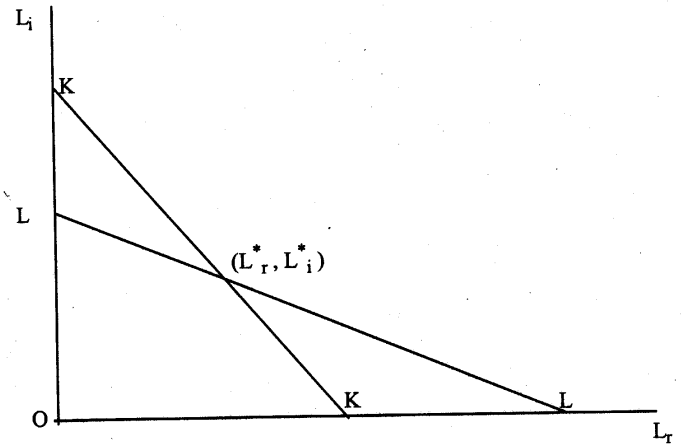

Figure - 1

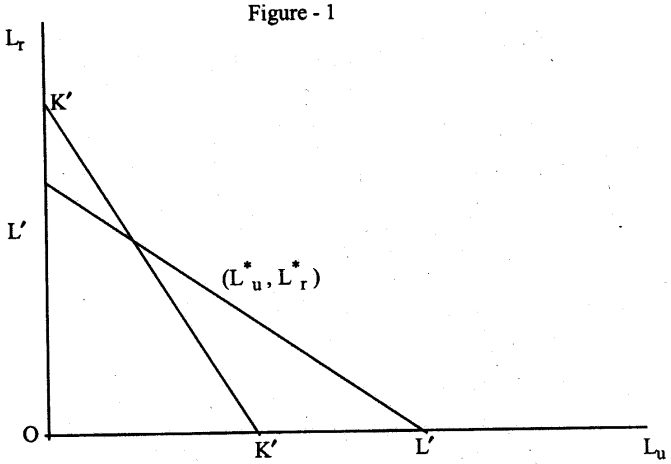

Figure - 2

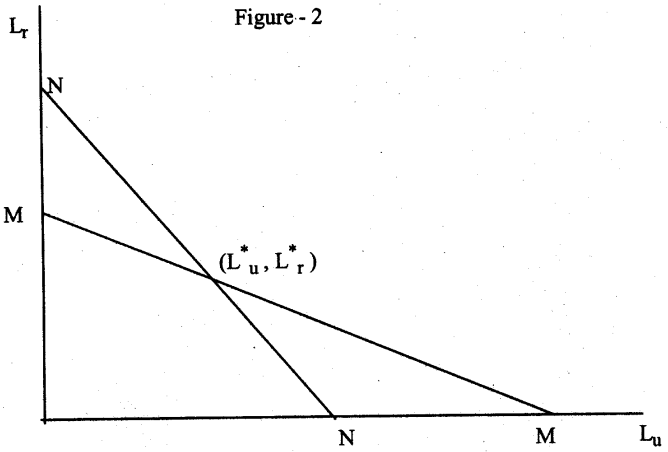

Figure - 3