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Unemployment of Unskilled Labor due to COVID-19 led Restriction on Migration and Trade

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Unemployment of Unskilled Labor due to COVID-19 led Restriction on Migration and Trade

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Abstract

To combat COVID-19 the entire world has resorted to global lockdown implying restriction on international labor migration and trade. This paper aims to check the effect of such restrictions on the unemployment of unskilled labor in the source country. In competitive general equilibrium framework with three goods and four factors restriction on migration raises unemployment for given factor intensity. The results remain same even in a slightly different structure of the economy. In case of trade restriction, however, the rise or fall in unemployment depends on both the structure of the economy and the factor intensity assumption.

JEL Classification: D5, F22, F12, J6,

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Abstract

To combat COVID-19 the entire world has resorted to global lockdown implying restriction on international labor migration and trade. This paper aims to check the effect of such restrictions on the unemployment of unskilled labor in the source country. In competitive general equilibrium framework with three goods and four factors restriction on migration raises unemployment for given factor intensity. The results remain same even in a slightly different structure of the economy. In case of trade restriction, however, the rise or fall in unemployment depends on both the structure of the economy and the factor intensity assumption.

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1. Introduction and Motivating Environment

Global outbreak of COVID-19 has unnerved the entire world in last few months. By now it is apparent that Corona virus outbreak took the corridor of physical proximity of affected countries and human beings. This corroborates the role of trade, travel and migration for transmitting Corona virus. And again since the spread of Corona virus has been showing no signs of abating, it has taken the whole world into a synchronized lockdown - complete closure of international borders. A variety of policies are also framed and international sanctions are essentially imposed to restrict international movement of goods and services, and labor. It would lead to inevitable production disruptions. Immobility of labor due to various controls would be accompanied by unnecessary economic cost as well. The impacts would be similar to the one we noticed during H1B visa sanctions imposed by the USA government or during BREXIT. Global production or trade in goods and services would be adversely impacted. When national policies like H1B Visa restriction or BREXIT are responsible for the immobility of labor, a substitute process is also made handy. In this context, production cost rises but the supply chain does not get disrupted because production still takes place (may be by domestic labor). Inability to harness the cost advantage that was possible due to availability of cheap foreign labor will also lead to a rise in the price level along with a fall in demand. This certainly has huge economic impact. However, when the root cause of all restrictions are health related and that too contagious just like the one with COVID-19, then the pathways to an alternative production process no

longer remains a viable option. When mobility of resources like labor is restrained worldwide, production in a single particular economy does not get affected alone - it affects the global economy at large. Therefore, naturally, possible sufferers of all such policies are worried about the economic upshots in their domestic fronts. In this globalized world, both benefit and ill effects spill over across the globe. And so is the perceived detrimental effects of policies mentioned to combat COVID-19. Thus, finally the issue becomes a political economic one where international relations among different trading countries are persuaded by the policy outcome.

This paper primarily attempts to focus on the effects of restriction on international migration policy which arguably has severe employment effects as this may either cause discontinuation of the stay of immigrants or does not allow new migrant. Such policy would primarily restrict the mobility of skilled workers such as IT professionals, engineers, etc. And we also know that recent economic prosperity of some countries like India has been predominantly propelled by these skilled workers and their free movement among various occupations and countries. Therefore, the concern is quite justified. What do they apprehend? Due to mobility restriction¹, domestic supply of skilled workers would rise. This is a kind of reverse migration. Naturally, this would influence prices of other factors and their employment. One possibility is that they get directly employed in the skilled sector either displacing some already employed skilled youth which moves to other sector and also pushes some unskilled workers towards unemployed pool leading to an increase in unemployment

¹Quite similar to what happens due to H1B Visa restriction.

in the economy. Alternatively, skilled workers can make room for some more capital in the skilled sector and hence return to capital goes up and that of unskilled labor falls. Another possibility is a setback for the existing skilled workers pool. When skilled wage falls, return to other factors move accordingly. Of course, there are host of other possibilities; we are primarily concerned with the state of unemployment of unskilled workers and unskilled wage where the general apprehension is an increase in unemployment and decrease in wage rate.

Papers like Mayda (2018), Bound et al. (2017), Das et al.(2019), etc. explain the effect of the H1B Visa policy on the host country. However, the existing literature do not provide with much theoretical information or explanation about the effect on employment of the source country. Chaudhuri (2019) is an interesting piece in this line, where the consequences of an anti-immigration policy on the wage gap of the source country has been examined. So, we attempt to fill up the caveat of (un)employment effect in the backdrop of COVID-19.

We first present a competitive general equilibrium model of trade where there are three sectors and four factors. Our structure closely follows Jones (1965, 1971). We slightly deviate from these two celebrated models through introduction of unemployment. And for distinction among different labors, unemployment, and their connectedness we follow Agenor and Montiel (2015), Marjit and Acharyya (2003), Marjit and Kar (2011), Acharyya and Kar (2014), Chaudhuri and Mukhopadhyay (2010), Mandal and Mandal (2015), etc. However, we do away with any domestic migration

from informal to formal sector, and hence Harris-Todaro migration possibility is not taken into account. We assume three factors – skilled labor, unskilled labor, capital – as mobile across the sectors, and one factor as specific to the skilled-labor intensive sector. All the factor are fully employed except unskilled labor. In this backdrop, we find that there is a rise in unemployment of unskilled labors due to therestriction on labor mobility during COVID-19.The resultis found to depend onthe factor intensity assumptions. However, rise or fall in the output of different sectors does not depend on the factor intensity conditions, though the magnitude of change does.

The remaining paper is structured as follows. In the next section, we first propose a competitive trade model and check different prospects. Then we slightly modify the basic model to see how robust is the theoretical predictions of the basic model. We also check how trade control of any sort, which reflects the Corona-driven policy of restriction on international movements of goods, affects the unemployment condition. Finally, we provide some concluding remarks. The relevant mathematical details are, however, relegated to the appendices.

2. Methodological Background and the Basic Model

We consider a small open economy endowed with skilled labor (S), unskilled labour(L) and two types of capital (T and K). There are three sectors, X , Y and Z . Both goods and factor markets are perfectly competitive. X is a skilled-labor (S) intensive

sector. Production of X requires S, K and T ; T is specific to X . Equation (1) gives the equilibrium condition of X where per-unit cost is equal to the price:

$$w_S a_{SX} + R a_{TX} + r a_{KX} = P_X \quad (1)$$

Here, w_S is the wage of skilled labors; R denotes the rent of T ; r is the rent of K ; P_X is the price of X ; and a_{ij} s ($i = S, L, K, T$; $j = X, Y, Z$) refer to the input coefficients.

The production of Y requires S, L and K , with K being used intensively. Z uses unskilled labor and K . Y can be taken as a public sector whereas Z is a private sector. The wage of unskilled labor is assumed to differ in both these sectors to capture the fact that employees of the government sector receive more benefit as their job is relatively secured when compared to those engaged in the private sector. Thus, the unskilled labors engaged in Y are paid w_g whereas those engaged in Z get \bar{w} ($w_g > \bar{w}$). \bar{w} is the wage fixed through process² between the employers and the unskilled employees. Z is intensive in the use of L . The cost-price equations of Y and Z are given, respectively, as follows:

$$w_S a_{SY} + w_g a_{LY} + r a_{KY} = P_Y \quad (2)$$

$$\bar{w} a_{LZ} + r a_{KZ} = P_Z \quad (3)$$

Here P_Y is the price of Y and P_Z is the price of Z .

The relation between w_g and \bar{w} , is given as

$$w_g = \bar{w}(1 + \tau) \quad (4)$$

²The mechanism is briefly explained in Appendix A.

where, $\tau > 0$ and exogenously given as a mark up over the private sector wage. Therefore, when private sector wage rises, government sector employees also get higher wage.

We consider K , T and S to be fully employed but full employment of L is not achieved. The endowment conditions for unskilled labor, skilled labor, T and K areas follows:

$$a_{LY}Y + a_{LZ}Z = \bar{L} - L_u \quad (5)$$

$$a_{SX}X + a_{SY}Y = \bar{S} \quad (6)$$

$$a_{TX}X = \bar{T} \quad (7)$$

$$a_{KX}X + a_{KY}Y + a_{KZ}Z = \bar{K} \quad (8)$$

L_u in equation (5) denotes the amount of unemployed unskilled labors in the economy. The amount of unskilled labors who are employed is simply given as:

$$L_E = \bar{L} - L_u \quad (9)$$

This completes the framework of our model. We have nine equations and nine variables namely, $w_S, w_g, r, R, X, Y, Z, L_u$ and L_E . w_g is obtained from (4). r is determined from (3) as \bar{w} is given. With r and w_g at hand, we get the value of w_S from (2). Putting the value of w_S and r in (1), we get R . a_{ij} ($i = L, S, K, T; j = X, Y, Z$) are determined by the Constant Returns to Scale (CRS) assumption. X is calculated from (7). Using the value of X in (6) we calculate the value of Y . By substituting the value of X and Y in (8), Z is determined. Further, substituting the value of Y and Z in (5) we get L_u . Putting the value of L_u in (9), we get the value of L_E . Thus, the model is solved.

2.1. Restriction international labor mobility

With a restriction on international labor movement migration of particularly skilled labor from developing or poor countries to rich countries is stopped and/or skilled labor is forced to return from developed to developing economies. As a result, there is an increase in the supply of skilled labor in the source economy. Since there is no change in price of the goods, there will be no change in the factor prices whatsoever and consequently the input coefficients remain unchanged. However, there may be changes in the output of different sectors. From (7), we get the percentage change in X as,

$$\hat{X} = (-)\hat{a}_{TX} = 0 \quad (10)$$

From equation (10), we observe that the percentage change in X is zero as non-changing factor prices constrained the substitution possibility. Thus, in spite of being S intensive, with the increase in the supply of skilled labor because of COVID-19, X remains unaffected. Fixity of T could be another complementary reason for such result. Consequently, X producers have no further incentive to change their output level as, given the situation, they are already producing at their optimal point.

Now, using (10), from (6) we have the percentage change in the output of sector Y as

$$\hat{Y} = \frac{\hat{S}}{\lambda_{SY}} > 0 \text{ as } \hat{S} > 0 \quad (11)$$

Using the values of \hat{X} and \hat{Y} , from (8) we get the relative change in Z :

$$\hat{Z} = (-)\frac{\lambda_{KY}}{\lambda_{KZ}\lambda_{SY}}\hat{S} < 0 \text{ as } \hat{S} > 0 \quad (12)$$

The positive change in Y , as seen in equation (11), is because sector X does not absorb the skilled labors returned to the economy. Therefore, the excess skilled labor is employed in Y . Since Y also uses L , who are paid more than those engaged in Z , unskilled labors from Z will move out to get employed in Y . As a result, Z contracts. When Z contracts, along with L it also releases K which can be used in Y . Thus, there is an expansion of Y as, unlike X , it does not face any input constraints. Therefore, with a restriction on migration, X remains unchanged, sector Y expands and sector Z contracts. Note that this result is irrespective of the factor intensity conditions.

Now, when Y expands and Z contracts, Z being unskilled-labour intensive releases more unskilled labors than required in Y . Therefore, there will be a rise in unemployment level of unskilled labors. To check the mathematical effect of international lockdown related restriction on labor mobility on the employment of unskilled labor mathematically, we use equation (5) and with the help of equations (9), (11) and (12) we obtain the change in employment of unskilled labor as follows:

$$\hat{L}_E = \frac{\hat{S}}{\lambda_{SY}\lambda_{KZ}} (\lambda_{KZ}\lambda_{L_EY} - \lambda_{L_EZ}\lambda_{KY}) < 0 \quad (13)$$

Or, the change in unemployment level of unskilled labor is

$$\hat{L}_U = (-) \frac{\lambda_{L_EL}}{\lambda_{L_UL}\lambda_{SY}\lambda_{KZ}} (\lambda_{KZ}\lambda_{L_EY} - \lambda_{L_EZ}\lambda_{KY}) \hat{S} > 0 \quad (14)$$

As presumed, since Y is K intensive and Z is L intensive, from equation (13), there is a fall in the employment of unskilled labor or from (14) a rise in the unemployment level of unskilled labor. Thus, we have the following proposition:

Proposition 1: *Given the factor intensity assumptions, there is a rise in the unemployment level of unskilled labors because of international lockdown during COVID-19. ■*

3. A Slightly Different Framework

In this section, we develop a variant of the model considered in the previous section. Here the skilled-labor intensive sector (X) uses only skilled labor and K for production. Y can be regarded as the government manufacturing sector which uses S , L and K . As in the previous model, the unskilled labors employed in Y receive higher wage than those employed in non-government sectors. To capture this we assume the wage rate in Y is w_g which is higher than \bar{w} – the wage rate in sector Z . Here, we assume T to be a type of capital that is specific to Z . Therefore, sector Z uses L and a specific factor T for production. The conditions showing the cost-price equality of X , Y and Z are given below:

$$w_S a_{SX} + r a_{KX} = P_X \quad (15)$$

$$w_S a_{SY} + w_g a_{LY} + r a_{KY} = P_Y \quad (16)$$

$$\bar{w} a_{LZ} + R a_{TZ} = P_Z \quad (17)$$

We assume full employment of K , T , and existing S , in the economy. A part of unskilled labor is, however, unemployed. The endowment equations of the factors are:

$$a_{SX}X + a_{SY}Y = \bar{S} \quad (18)$$

$$a_{LY}Y + a_{LZ}Z = L - L_u = L_E \quad (19)$$

$$a_{TZ}Z = \bar{T} \quad (20)$$

$$a_{KX}X + a_{KY}Y = \bar{K} \quad (21)$$

Equations (15)-(21) along with equations(4) and (9), represent the basic structure of the model. There are nine equations and nine variables ($w_s, w_g, r, R, X, Y, Z, L_u$ and L_E). Hence, the model is solvable.

With the given structure of the economy, if there is an increase in the supply of skilled labor due to lockdown, the following changes occur in each of the sectors:

$$\hat{X} = (-) \frac{\lambda_{KY}}{\lambda_{KX}\lambda_{SY} - \lambda_{KY}\lambda_{SX}} \hat{S} > 0 \quad (22)$$

$$\hat{Y} = \frac{\lambda_{KX}}{\lambda_{KX}\lambda_{SY} - \lambda_{KY}\lambda_{SX}} \hat{S} < 0 \quad (23)$$

$$\hat{Z} = 0 \quad (24)$$

The change in employment of unskilled labors is

$$\hat{L}_E = \frac{\lambda_{KX}\lambda_{LE}Y}{\lambda_{KX}\lambda_{SY} - \lambda_{KY}\lambda_{SX}} \hat{S} < 0 \quad (25)$$

Or, the change in unemployment of unskilled labor is

$$\hat{L}_U = (-) \frac{\lambda_{LE}L\lambda_{KX}\lambda_{LE}Y}{\lambda_{LU}L(\lambda_{KX}\lambda_{SY} - \lambda_{KY}\lambda_{SX})} \hat{S} > 0 \quad (26)$$

As in the previous model, there is no change in the price of any good so the factor prices and input coefficients remain unchanged. Now, as the skilled-labor intensive sector uses only skilled labor and K , the inflow of skilled labor will positively

affect the size of sector X (equation (22)). Non specificity of any factor in X is doing the trick. As X also uses K , additional amount of K is drawn from Y and thus there is a fall in Y (equation (23)). Y releases capital (K), skilled labor and unskilled labor. K and S get employed in X but L remains unemployed. Though Z uses L for production but the limited supply of T and unchanged factor prices restrict Z from changing the input composition, leaving Z unaffected because of restriction on international labor mobility (equation (24)). Therefore, there is excess supply of unskilled labor leading to a rise in unemployment (equations (25) and (26)) of unskilled workers. However, these results depend on the factor intensity assumption. If X was K intensive and Y was skilled-labor intensive then Y would absorb the excess supply of skilled labor and X would contract in order to supply K to Y . As Y also uses L , the employment level of unskilled labor would have risen. Therefore, when we consider a different framework, factor intensity in production plays an important role in determining the effect of an increase in the supply of skilled labors on the employment of unskilled factors. Thus, we have,

Proposition 2: *Not the structure of the economy, but the factor intensity of different sectors is fundamental in determining the level of unemployment of unskilled labor due to restriction on international labor mobility during COVID-19. ■*

Together with this, we also propose:

Proposition 3: *If a particular sector faces any resource constraint, it remains unaffected due to international lockdown.*

Proof: In the basic model, one specific factor, whose supply is limited, was used by the skilled-labor intensive sector. Even if the skilled labor is used intensively in that sector, unavailability of the specific input in the economy restricted it from expanding. In contrast to this, in the extended model when X was able to acquire inputs, we saw its expansion with increased supply of skilled labor. On the other hand, in the extended model, sector Z was unaffected because of the similar reason that led to non-changing X in the basic model.

4. Restriction on Trade and Unemployment of Unskilled Labors

In the basic model, suppose countries impose restriction on its imports. If X is the importable good, there must be a decline in the demand for X from the rest of the world (ROW) and since the country concerned is assumed as small compare to the ROW, the price of X would decline. A fall in the price of X will cause its output to fall releasing some of the factors employed in it. As T is specific to X , the rent of T , R falls and T would be used more intensively in X . On the other hand, assuming no change in the requirement of K , there will be a fall in per-unit requirement of S (though the factor intensity assumption would not be changed). Thus, T remains fully employed in X but some K and S are released³. S and K gets employed in Y . Since Y is K intensive it requires more K than released from X . This extra demand for K is met by a fall in Z . When Z falls, L is also released which is used in Y . However, as Z is unskilled labor intensive

³Here, except R , all the factor prices remain unchanged. As \bar{w} is fixed, from equation (3) r does not change and from equation (4) w_g remains constant. Moving to equation (2), since P_Y is unaltered, w_s also remains the same. Thus, only R is affected by trade restriction.

more L is released than demanded for the expansion of Y leading to an increase in unemployment of unskilled labors⁴.

Now if we consider the extended version of the basic model, restriction in imports by the ROW again leads to a fall in the price of X discouraging its production. There is a reduction in the output of X and consequently S and K are released. These S and K can get employed in Y . Also, following Stolper-Samuelson's argument there is a fall in the price of the factor used intensively in X i.e., w_S , and there is a rise in the price of less intensively used factor i.e., a rise in r . In what follows, there will be substitution of factors in production. Again, as Y also requires L , additional L is acquired from the unemployed pool of the economy thereby reducing the level of unemployment.⁵ Sector Z remains unaltered as it uses a specific factor, T .

Therefore, unlike the case of restriction on international labor migration, when the ROW opts for restriction on trade, the effect on unemployment of unskilled labors depends on the specific structure of the economy.

Thus, we propose that:

Proposition 4: *Unlike restriction on labor migration, the effect of trade restriction on unskilled unemployment depends on specific structure of the economy.*

Proof: *See discussion above.*

⁴Mathematical details are given in Appendix B.

⁵Mathematical calculations are provided in Appendix C.

5. Conclusions

In this paper, we consider two slightly different general equilibrium frameworks to check the effect of international lockdown which has been adopted by all countries across the globe to control the spread of COVID-19. First we analyze the case of restriction on labor migration on employment of unskilled labor. Though having different structures of the economy, we see that unemployment of unskilled labor rises in both the frameworks. But the factor intensity assumption is important irrespective of specific economic setup. In the next section, we check the employment effect of another protectionist policy, trade restriction. It is found that in case of restriction on international trade, the effect on unemployment depends on the type of economy; though as in the case migration control, the factor intensity here also plays an important role in arriving at the results.

Appendices

Appendix A

Determination of wage in sector Z

The wage is determined by the labor unions by maximizing their utility function subject to the labor demand. We assume the firms to be price takers. Let the utility function of the union be: $U = U(w, L_Z, p_Z)$; where w is the wage rate, L_Z is the employment in Z, p_Z is the relative price of Z. U is quasi-concave and increasing in w and L_Z .

The labor demand function is $L_Z = Zc_w = L_Z(w, r)$, here r is the rent of K , c_w is the partial derivative of the cost function, $c(w, r)$, and Z is the output. The demand for labor is negatively related to wage.

The first order condition implies $\frac{\delta u / \delta w}{\delta u / \delta L_Z} = -\frac{\delta L_Z}{\delta w}$

$\Rightarrow MRS_{w, L_Z} = \text{Slope of the labor demand curve}$

The wage rate is determined from the above condition. The second order condition of the maximization problem also holds:

$$\frac{\delta^2 u}{\delta w^2} + 2 \frac{\delta^2 u}{\delta w \delta L_Z} \frac{\delta L_Z}{\delta w} + \frac{\delta^2 u}{\delta L_Z^2} \left(\frac{\delta L_Z}{\delta w} \right)^2 + \frac{\delta u}{\delta L_Z} \frac{\delta^2 L_Z}{\delta w^2} < 0$$

Appendix B

Expressing relative change by “ $\hat{}$ ” notation, from equations (1)-(3) we get,

$$\widehat{w}_S \theta_{SX} + \widehat{R} \theta_{TX} + \widehat{r} \theta_{KX} = \widehat{P}_X \quad (\text{B. 1})$$

$$\widehat{w}_S \theta_{SY} + \widehat{r} \theta_{KY} = 0 \quad (\text{B. 2})$$

$$\widehat{r} = 0 \quad (\text{B. 3})$$

Putting the value of \widehat{r} in (B.2), $\widehat{w}_S = 0$. Following this, from (B.1), $\widehat{R} = \frac{\widehat{P}_X}{\theta_{TX}}$.

As $\widehat{w}_S = \widehat{r} = 0$, the input coefficients of Y and Z remains unchanged. However, because of change in R , there will be changes in factor requirements of X . For simplicity, we assume $\widehat{a}_{KX} = 0$. Then, using the Envelope condition and the elasticity of substitution we get, $\widehat{a}_{SX} = \frac{\sigma_X}{(1-\theta_{KX})} \widehat{P}_X < 0$ and $\widehat{a}_{TX} = -\frac{\sigma_X \theta_{SX}}{(1-\theta_{KX}) \theta_{TX}} \widehat{P}_X > 0$

Using (5)-(8) we have

$$\lambda_{LEV} \widehat{Y} + \lambda_{LEZ} \widehat{Z} = \widehat{L}_E \quad (\text{B. 4})$$

$$\lambda_{SX} \widehat{X} + \lambda_{SX} \widehat{a}_{SX} + \lambda_{SY} \widehat{Y} = 0 \quad (\text{B. 5})$$

$$\widehat{X} = -\widehat{a}_{TX} < 0 \quad (\text{B. 6})$$

$$\lambda_{KX} \widehat{X} + \lambda_{KY} \widehat{Y} + \lambda_{KZ} \widehat{Z} = 0 \quad (\text{B. 7})$$

Substituting the value of \widehat{X} in (B.5)

$$\widehat{Y} = -\frac{\lambda_{SX}}{\lambda_{SY}} (\widehat{a}_{SX} - \widehat{a}_{TX}) \Rightarrow \widehat{Y} = -\frac{\lambda_{SX} \sigma_X \widehat{P}_X}{\lambda_{SY} \theta_{TX}} > 0 \quad (\text{B. 8})$$

Using the value of \widehat{X} and \widehat{Y} in (B.7)

$$\widehat{Z} = \frac{\lambda_{KX}}{\lambda_{KZ}} \widehat{a}_{TX} - \frac{\lambda_{KY}}{\lambda_{KZ}} \left\{ -\frac{\lambda_{SX}}{\lambda_{SY}} (\widehat{a}_{SX} - \widehat{a}_{TX}) \right\} \quad (\text{B. 9})$$

$$\Rightarrow \hat{Z} = \frac{\sigma_X \hat{P}_X}{\theta_{TX} \lambda_{SY} \lambda_{KZ}} \{ \theta_{SX} (\lambda_{SX} \lambda_{KY} - \lambda_{SY} \lambda_{KX}) + \lambda_{KY} \lambda_{SY} \theta_{TX} \}$$

Here, following the factor intensity assumptions of the model, $(\lambda_{SX} \lambda_{KY} - \lambda_{SY} \lambda_{KX}) > 0$.

Therefore, as $\hat{P}_X < 0$, $\hat{Z} < 0$.

From (B.4),

$$\hat{L}_E = - \frac{\sigma_X \hat{P}_X}{\theta_{TX} \lambda_{SY} \lambda_{KZ} (1 - \theta_{KX})} \{ (\lambda_{LEY} \lambda_{KZ} - \lambda_{LEZ} \lambda_{KY}) \lambda_{SX} (1 - \theta_{KX}) + \lambda_{LEZ} \lambda_{KX} \theta_{SX} \lambda_{SY} \} < 0$$

Since Z is L intensive and Y is K intensive, a fall in P_X reduces the level of employment of unskilled labors.

Appendix C

From equations (15)-(17) we get,

$$\hat{w}_S \theta_{SX} + \hat{r} \theta_{KX} = \hat{P}_X \quad (C.1)$$

$$\hat{w}_S \theta_{SY} + \hat{r} \theta_{KY} = 0 \quad (C.2)$$

$$\hat{R} = 0 \quad (C.3)$$

From (C.2), $\hat{r} = -\hat{w}_S \frac{\theta_{SY}}{\theta_{KY}}$. Putting this in (C.1) we get, $\hat{w}_S = \left(\frac{\theta_{KY}}{\theta_{SX} \theta_{KY} - \theta_{SY} \theta_{KX}} \right) \hat{P}_X < 0$, as

$\hat{P}_X < 0$, and X and Y are S and K intensive, respectively. Using the obtained value of \hat{w}_S ,

we calculate $\hat{r} = -\frac{\theta_{SY}}{\theta_{SX} \theta_{KY} - \theta_{SY} \theta_{KX}} \hat{P}_X > 0$.

With changes in the w_S and r there are changes in the per unit factor requirements of X and Y. Using the Envelope condition and the elasticity of substitution between S and

K in X, σ_X , we get

$$\hat{a}_{SX} = - \frac{\theta_{KX} (1 - \theta_{LY}) \sigma_X}{\theta_{SX} \theta_{KY} - \theta_{SY} \theta_{KX}} \hat{P}_X > 0$$

$$\hat{a}_{KX} = \frac{\theta_{SX}(1 - \theta_{LY})\sigma_X}{\theta_{SX}\theta_{KY} - \theta_{SY}\theta_{KX}} \hat{P}_X < 0$$

Similarly, assuming $\hat{a}_{LY} = 0$, we obtain

$$\hat{a}_{SY} = -\frac{\theta_{KY}\sigma_Y}{\theta_{SX}\theta_{KY} - \theta_{SY}\theta_{KX}} \hat{P}_X > 0$$

$$\hat{a}_{KY} = \frac{\theta_{SY}\sigma_Y}{\theta_{SX}\theta_{KY} - \theta_{SY}\theta_{KX}} \hat{P}_X < 0$$

Following this, using equations (18)-(21)

$$\lambda_{SX}\hat{X} + \lambda_{SY}\hat{Y} + \lambda_{SX}\hat{a}_{SX} + \lambda_{SY}\hat{a}_{SY} = 0 \quad (C.4)$$

$$\lambda_{LEY}\hat{Y} + \lambda_{LEZ}\hat{Z} = \hat{L}_E \quad (C.5)$$

$$\hat{Z} = 0 \quad (C.6)$$

$$\lambda_{KX}\hat{X} + \lambda_{KY}\hat{Y} + \lambda_{KX}\hat{a}_{KX} + \lambda_{KY}\hat{a}_{KY} = 0 \quad (C.7)$$

Using Cramer's rule, from (C.4) and (C.7) we get the following values

$$\hat{X} = \frac{\lambda_{SY}(\lambda_{KX}\hat{a}_{KX} + \lambda_{KY}\hat{a}_{KY}) - \lambda_{KY}(\lambda_{SX}\hat{a}_{SX} + \lambda_{SY}\hat{a}_{SY})}{\lambda_{SX}\lambda_{KY} - \lambda_{SY}\lambda_{KX}} < 0$$

$$\hat{Y} = \frac{\lambda_{KX}(\lambda_{SX}\hat{a}_{SX} + \lambda_{SY}\hat{a}_{SY}) - \lambda_{SX}(\lambda_{KX}\hat{a}_{KX} + \lambda_{KY}\hat{a}_{KY})}{\lambda_{SX}\lambda_{KY} - \lambda_{SY}\lambda_{KX}} > 0$$

From (C.5), $\hat{L}_E = \lambda_{LEY}\hat{Y}$

$$\Rightarrow \hat{L}_E = \frac{\lambda_{LEY} \{ \lambda_{KX}(\lambda_{SX}\hat{a}_{SX} + \lambda_{SY}\hat{a}_{SY}) - \lambda_{SX}(\lambda_{KX}\hat{a}_{KX} + \lambda_{KY}\hat{a}_{KY}) \}}{\lambda_{SX}\lambda_{KY} - \lambda_{SY}\lambda_{KX}} > 0$$

NOTE: There is no conflict of interest.

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