Asymmetric Effects of Time Zone Related Distance on Trade

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Abstract

This paper aims to explain that distance may not always be harmful for international trade unlike the explanations provided by the gravity model. In case of service trade distance may be helpful, instead, because of the existence of non-overlapping time zones between two trading countries. So, we will try to examine this phenomenon that whether distance is always affecting adversely in case of goods trade and how distance is affecting service trade. Then we will also try to examine the effects of the trade on factor prices, output changes and the changes in sectoral composition even if the economy consists of informal segment along with the formal sectors. Our endeavour in this paper would be to try to explain this with the help of the time zones issues. In this paper we find that with an increase in distance between trading countries the wage of skilled labour will increase and the rent of the capital will decrease in case of service trade. This will also lead to the expansion for service sector and contraction for another sector. These results are exactly reversed in case for goods trade.

JEL Classification: *D24, E26, F1, J3, J31*
Key words: *Trade; Time Zone; Factor prices; Output Changes; Informality*

1. Introduction

In traditional trade theory, gravity model of international trade is a model that predicts bilateral trade flows based on the economic sizes of and distance between two countries. The model was first introduced by Walter Isard in 1954. Gravity model says that when distance between two trading countries increases then the trading cost should increase. And hence trade between these countries decline and the factor prices also change according to factor intensity assumptions. Standard literatures (Benedictis& Taglioni (2011), Gómez-Herrera (2013), Melitz (2007), Taglioni & Baldwin (2014), Rudolph (2009)) etc. says that geographical distance is really harmful for trade between two countries which are located in different parts of the world. Most of these literatures exhibit their hypotheses both theoretically and empirically. But this phenomenon may not always be true. In case of service trade distance may have some positive effect on trade. In some recent literatures like Mandal (2015), Marjit, Mandal, Nakanishi (2020), Mandal and Prasad (2021) etc., we see that distance may not have negative effect on trade. The benefit of non-overlapping time zone can be exploited in case of service trade. In case of gravity model distance is undoubtedly harmful for trading countries but in case of service trade distance may not be harmful because the existence of non-overlapping time zones between two trading countries. In this context Marjit (2007), Kikuchi (2009), Kikuchi and Marjit (2011) and Kikuchi et al. (2013) are a few notable references. All of these papers throw light on the effect of non-overlapping time zones on the patterns of trade, volume of trade, and welfare implications of such trade. So, in this paper we try to examine this phenomenon that whether distance is affecting goods trade and service trade differently or symmetrically. Then we will also try to examine the effects of the trade on factor prices, output changes and the changes in the structural composition of the informal economy. Our endeavour would be to try to explain this from the perspective of time zone difference related distance and associated costs, if any. Marjit (2007) shows that the time preference may act as a contributor to trade between two otherwise identical countries where both the countries produce both the goods, they exhibit identical taste, technology and endowments. He showed why time difference emerges as an independent driving force of international trade besides taste, technology and endowment. In line with the arguments developed in Marjit (2007) in this paper we attempt to find some interesting results in respect of the varying effects of distance on goods-trade and service- trade. In trying to do so we check if standard gravity model results hold here or not. Since service trade does not require any physical shipment, it does not bear the increasing trading cost due to distance between the trading countries. Here, only the cost of internet is required to do trading in different countries. And with distance this usually does not increase. Remaining paper is arranged as follows. Section 2 outlines the story and formulates the basic model using Heckscher–Ohlin set up. Then it examines the effects of trade across different Time Zones and shows its impact on factor prices and output both in case of goods trade and in case of service trade. In Section 3, the model is extended to a three sector-three factor economy, where we introduce informality. Finally, Section 4 concludes the paper. Mathematical derivations are shown in the Appendix for reference.

2. The Basic Model and Results

We assume that there are two countries situated in different parts of the world. Our main focus is on any one country which attempts to trade with the other country. The trade can be either in terms of goods or in service. We further assume that the countries are located in different Time Zones which are completely non-overlapping. This guarantees that there is a huge aerial distance between these two countries. Now we focus on two types of analyses: one is for trade in goods and another is for trade in services. We would unfold both these cases in due course of time. While unfolding such cases we also try to check if distance influences production and trade pattern similarly in both the cases. The countries produce two commodities X and Y. Each good is produced using skilled labour (S) and capital (K). There exist constant returns to scale (CRS) and diminishing marginal productivity (DMP) of factors. The market is in perfect competition. Markets open every 24 hours. The production of X requires 12 hours to complete, one unit of K and one unit of S are sufficient to produce one unit of X. Thus, X is ready for sell after 12 hours. The country concerned is small, and thus the commodity prices are determined in the international market and the small countries just accept the prevailing price. If there are no other issues the entire commodity price must be distributed among the factors used in production. This is guaranteed by the competitive market assumption where commodity price should be equal to the average cost of production. However, in case, the 'disposable price' – the price of the commodity after adjusting for trading cost, delaying cost, depreciation etc – should be the amount that may be distributed among various factors of production in accordance with their relative share in the production. In either of these cases price of the commodity should be multiplied with a factor that captures issues like transportation, delay, depreciation etc. Let us denote it by $\delta(D)$ where D stands for distance. We will discuss more on this later. As a result, the price that producer receives is $P_x\delta(D)$, where, P_x is the price of X and $(1-\delta)$ denotes the transportation cost where δ is the function of geographical distance (D). The discount factor $\delta(0<\delta\leq 1)$ captures both the transportation cost and time preference or time cost of the consumers. a_{sy} is the amount of skilled labour required to produce one unit of Y and a_{ky} is the amount of capital required to produce one unit of Y.P_y is the price of Y. Let us make it very clear that we will talk about two situations: One is when X is regarded as the service production; and the other is when X is regarded as the good production. The service production case is going to be discussed under case 1 whereas the good production case is discussed under case 2. Now, let us talk a little bit more about the features of the service production and associated transactions.

Case 1: When X is service, if distance (D) decreases then δ will also decrease, since δ is a function of distance(D). When the product is completely produced, i.e., ready for sell after 12 hours of production, then there will be night in the producing country and the market will be closed. If the product needs to be marketed in the country where it is produced, the product will remain idle for another 12 hours. That is why the product must be moved to some other countries where it can be marketed at that moment. If the product move to such a country where the market will be opened in less than 12 hours then the trade will be beneficial. To maximise the profit, the product needs to be exported to another country which is situated at exactly opposite direction of the world. Therefore, there is a huge geographical distance in the countries those are trying to do trade. When both the countries are situated in completely non-overlapping time zone, then the distance (D) will be maximum and δ will also be maximum, i.e., $\delta=1$ implying that the transportation cost is $(1-\delta)=0$. Then the effective price of the product (δP_x) will be maximum. The only cost of transportation requires here is the cost of the internet, which is negligible in today's world.

Case 2: Now, let us try to replicate the entire story for good. When a good is produced, the good needs to be exported to another country which is located in a non-overlapping time zone. Therefore, there is a huge geographical distance between the countries trying to do trade. Then there will be two types of costs. One is: Transportation cost. If distance (D) increases then transportation cost will also increase, therefore δ will decreases. If the cost increases, then the effective factor prices should decrease, since the contracted price is fixed. In our model transportation cost is included in the contracted price. Transportation cost is defined by $(1-\delta)$. Another is: Delaying cost. When the product reaches to the targeted country (in which the product will be marketed), there should be a delaying cost. If it takes 12 hours to reach, then there is a Travel cost, which can be summarised as the cost of Time. Opportunity cost of time is equivalent to travel cost. In our model, this travel cost is already included in δ (transportation cost). Therefore, we can say that transportation cost has two components. One is actual cost incurred to reach to another country and the second is the associated cost for delaying.

Now in this section, we try to check how the trade across time zone differences affects the changes in the factor prices when the tradable products(X) is good or service. Apart from that, we also observe the effects on output. Since, in perfect competition, per-unit cost will be equal to its price. Therefore, in a competitive framework the cost price equations will be:

$$1w_s + 1r = P_x\delta(D) \tag{1}$$

$$a_{sy}w_s + a_{ky}r = P_y \tag{2}$$

Where, w_s is skilled wage and r is rent. P_x and P_y denote prices of X and Y, respectively. The technological coefficients are fixed[1] for the production of X while a_{sy} and a_{ky} are variable. Moreover, we assume that X is a skilled labour (S) intensive good/service, whereas Y is a capital (K) intensive good.

2.A. Effect on Factor Prices

Change in effective commodity prices induces factor prices to change. To check such effects, we use equations (1) and (2) to get the following expressions

$$\theta_{sx}\widehat{w_s} + \theta_{kx}\hat{r} = \widehat{\delta(D)} + \widehat{P_x} \tag{3}$$
$$\theta_{sy}\widehat{w_s} + \theta_{ky}\hat{r} = \widehat{P_y} \tag{4}$$

Solving equation (3) and (4) by using Cramer's rule, we get the change in skilled wage ($\widehat{w_s}$) and the change in rent ($\hat{r}$) as,[2]

$$\widehat{w_s} = \frac{\theta_{ky}\widehat{P_x} + \theta_{ky}\widehat{\delta(D)} - \theta_{kx}\widehat{P_y}}{|\theta|}$$

And, $\hat{r} = \frac{-\theta_{sy}\widehat{P_x} - \theta_{sy}\widehat{\delta(D)} + \theta_{sx}\widehat{P_y}}{|\theta|}$

Where, $|\theta| = \theta_{sx}\theta_{ky} - \theta_{kx}\theta_{sy}; |\theta| > 0$[3]

Since, $\widehat{P_x} = \widehat{P_y} = 0$

$$\therefore \widehat{w_s} = \frac{\theta_{ky}\widehat{\delta(D)}}{|\theta|} \tag{5}$$

$$\text{And, } \hat{r} = -\frac{\theta_{sy}\widehat{\delta(D)}}{|\theta|} \tag{6}$$

When X is service, if geographical distance (D) increases then δ will also increase. Therefore, when there is an increase in the distance between the trading countries, then the wage for the skilled labour will increase in this type of trade. On the other hand, the rent for capital will decrease due to an increase in the distance between the trading countries.

Case 1 When, X is service, if D increases, $\delta(D)$ will increase. Therefore, $\widehat{\delta(D)} > 0$. Hence, $\widehat{w_s} > 0$ and $\hat{r} < 0$

Now, if we try to see the entire story for good production instead of service, we will witness some different results. When the good is produced, the goods need to be exported to another country which is situated at exactly opposite direction of the world. So, if distance (D) increases, transportation cost will also increase, therefore δ will decrease. If the cost increases,

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[1]The co-efficients are fixed as per the assumptions of this model. One unit of capital (K) and one unit of skilled labour wage (S) are required to produce one unit of X.

[2] Detailed calculations for all these values are given in the Appendix 1

[3]If, X is S (Skilled labour) intensive and Y is K (capital) intensive, then, $\theta_{sx} > \theta_{sy}$ and $\theta_{ky} > \theta_{kx}$

$\therefore \theta_{sx}\theta_{ky} > \theta_{kx}\theta_{sy}$ Or, $(\theta_{sx}\theta_{ky} - \theta_{kx}\theta_{sy}) > 0$ Or, $|\theta| > 0$

then the effective factor prices should be decreased, since the contracted price is fixed. Therefore, when there is an increase in the distance between the trading countries, then the wage for the skilled labour will decrease in case of goods trade. On the other hand, the rent for capital will increase due to an increase in the distance between the trading countries.

Case 2 When, X is a tangible good, if D increases, $\delta(D)$ will decrease. Therefore, $\widehat{\delta(D)} < 0$. Hence, $\widehat{w_s} < 0$ (as δ signifies transportation cost), and $\hat{r} > 0$.

Therefore, the following Proposition is immediate.

Proposition I: An increase in distance between trading countries leads to an increase in wage of skilled labour(w_s) and a fall in rent (r) if the product is a service, whereas the same reason leads to a decrease in skilled wage(w_s) and a rise in rent (r) if the product is a good.
Proof: See discussion above.

2.B. Effect on Output

Now, we examine the effects on output changes in case of service trade and good trade. Both skilled labour (S) and capital(K) are fully employed. Hence, the endowment constraints are given as (we also assume that S and K endowment are fixed)

$$1\,X + a_{sy}Y = \bar{S} \quad (7)$$
$$1\,X + a_{ky}Y = \bar{K} \quad (8)$$

In order to calculate the effects on output of X and Y we need to use the concept of elasticity of substitution in Y (σ_Y). This is given by,

$$\sigma_Y = -\frac{\widehat{a_{sy}} - \widehat{a_{ky}}}{\widehat{w_s} - \hat{r}}$$

Thus,

$$\therefore \widehat{a_{ky}} = \sigma_Y \theta_{sy} \frac{\widehat{\delta(D)}}{|\theta|} \quad (9)$$
$$\widehat{a_{sy}} = -\sigma_Y \theta_{ky} \frac{\widehat{\delta(D)}}{|\theta|} \quad (10)$$

Differentiating totally equation (7) we get,

$$\lambda_{sx}\hat{X} + \lambda_{sy}\hat{Y} = \lambda_{sy}\sigma_Y \theta_{ky} \frac{\widehat{\delta(D)}}{|\theta|} \quad (11)$$

Similarly, from equation (8),

$$\lambda_{kx}\hat{X} + \lambda_{ky}\hat{Y} = -\lambda_{ky}\sigma_Y \theta_{sy} \frac{\widehat{\delta(D)}}{|\theta|} \quad (12)$$

Solving equation (11) and (12) by using Cramer's rule, we get the change in the output of X and the change in the output of Y as,[4]

$$\hat{X} = \frac{1}{|\lambda||\theta|}\left(\lambda_{ky}\lambda_{sy}\theta_{ky} + \lambda_{sy}\lambda_{ky}\theta_{sy}\right)\sigma_Y \widehat{\delta(D)} \quad (13)$$

And, $\hat{Y} = -\frac{1}{|\lambda||\theta|}\left(\lambda_{kx}\lambda_{sy}\theta_{ky} + \lambda_{sx}\lambda_{ky}\theta_{sy}\right)\sigma_Y \widehat{\delta(D)}$ (14)

[4] Detailed calculations for all these values are given in the Appendix 2

If, X is S (Skilled labour) intensive and Y is K (capital) intensive, then,

$(\lambda_{sx}\lambda_{ky} - \lambda_{kx}\lambda_{sy}) > 0$; $|\lambda| > 0$

Therefore, when there is an increase in the distance between the trading countries, then the output for service X will increase while the output for good Y will decrease due to the increase in the distance between the trading countries.

Case 1 When, X is service, if D increases, $\delta(D)$ will increase. Therefore, $\widehat{\delta(D)} > 0$. Hence, $\hat{X} > 0$ and $\hat{Y} < 0$

Now, if we try to see the entire story for good production instead of service, we will witness some different results. If X is a good then, the good needs to be exported to another country which is situated far away from the producing country. Therefore, there is a huge geographical distance between the countries those are trying to do trade. If distance (D) increases then transportation cost will also increase for the goods trade, therefore δ will decreases. Therefore, when there is an increase in the distance between the trading countries, then the output for good X will fall. On the other hand, the output for good Y will expand.

Case 2 When, X is a tangible good, if D increases, $\delta(D)$ will decrease. Therefore, $\widehat{\delta(D)} < 0$. Hence, $\hat{X} < 0$ and $\hat{Y} > 0$

Hence, we have the following Proposition.

Proposition II: An increase in distance between trading countries leads to$\hat{X} > 0$ and $\hat{Y} < 0$ if X is a service and leads to$\hat{X} < 0$ and $\hat{Y} > 0$ if X is a good.

Proof: See discussion above.

3. Extended Model with Informal Sector

In this section, we extend the basic model by introducing an informal sector Z, which we observe in developing and even in developed countries. (Mandal, Marjit, and Beladi (2018), Mandal (2011), and Mandal and Chaudhuri (2011)). Therefore, beside X and Y, we have a new sector Z. X and Y are formal sectors, Z is an informal sector. We assume that there are three factors of production. These are: skilled labour (S), capital (K) and unskilled labour (L). X is produced using S and K as before, Y is also produced using S and K and Z uses L and K as factors of production. Further, sector Z is assumed to be unskilled labour intensive. In this section, we try to check how the trade across time zone difference related distance affects the size of informal sector when one of the formal products (X) is good or service. However, the effects on factor prices and wage difference between skilled and unskilled labours will also be checked. Therefore, along with the previous price equations here we have a new price equation for sector Z, which is given as:

$$a_{lz}w + a_{kz}r = P_z \tag{15}$$

Where, w is unskilled wage and r is rent. P_z denotes the price of Z. a_{lz} is the amount of unskilled labour required to produce one unit of Z and a_{kz} is the amount of capital required to produce one unit of Z.

3.A. Effect on Factor Prices

From equation (15) we can obtain the wage for unskilled labour (w). To determine this, we need tototally differentiate equation (15) and we get the change in the wage rate for unskilled labour ($\widehat{w}$) as,

$$\theta_{lz}\widehat{w} + \theta_{kz}\hat{r} = \widehat{P_z} \tag{16}$$

$$And, \widehat{w} = \frac{\theta_{kz}\theta_{sy}\widehat{\delta(D)}}{\theta_{lz}|\theta|} \tag{17}$$

Since, all the component in $\widehat{w}$ is positive (except $\widehat{\delta(D)}$) therefore the value of $\widehat{w}$ cannot be determined unambiguously whether it is positive or negative. Because this depends solely on the value of $\widehat{\delta(D)}$. When $\widehat{\delta(D)}$ is positive then the value of $\widehat{w}$ is positive, and when the value of $\widehat{\delta(D)}$ is negative, then the value of $\widehat{w}$ will be negative.

Since, informal wage is usually less than the formal wage where minimum wage rule is followed, then we can see that;[5]

$$(\widehat{w_s} - \widehat{w}) = \widehat{\delta(D)}\frac{\theta_{lz}\theta_{ky} - \theta_{kz}\theta_{sy}}{\theta_{lz}|\theta|} \tag{18}$$

When X is a service, then if the geographical distance (D) increases then δ will also increase. And hence the wage difference between skilled labour and unskilled labour increases. On the other hand, if X is a good, the wage difference between skilled labour and unskilled labour decreases when the distance between two trading countries increases.

Hence, we have the following Proposition.

Proposition III: If distance increases $(\widehat{w_s} - \widehat{w}) > 0$; if the product (X) is a service and$(\widehat{w_s} - \widehat{w}) < 0$; if the product (X) is a good.
Proof: See Appendix 3

3.B. Effect on Output

In this section, we will try to see the effects of output changes in case of service trade and good trade also. Both skilled labour (S), unskilled labour (L) and capital (K) are fully employed. The modified set of full employment conditions are:

$$1\,x + a_{sy}y = \bar{S} \tag{19}$$
$$1\,x + a_{ky}y + a_{kz}z = \bar{K} \tag{20}$$
$$a_{lz}z = \bar{L} \tag{21}$$

In order to calculate the effects on changes in output of X, Y and Z we need to use the concept of elasticity of substitution in Z (σ_Z). This is primarily because Z uses unskilled labour as a specific factor of production. The elasticity of substitution in Z is mathematically expressed as,

$$\sigma_z = -\frac{\widehat{a_{lz}} - \widehat{a_{kz}}}{\widehat{w} - \hat{r}}$$

And hence,

$$\widehat{a_{kz}} = \sigma_z\theta_{lz}\frac{\theta_{sy}\widehat{\delta(D)}}{\theta_{lz}|\theta|} \tag{22}$$

[5] Detailed calculations for all these values are given in the Appendix 3

And, $\widehat{a_{lz}} = -\sigma_z \theta_{kz} \frac{\theta_{sy}\widehat{\delta(D)}}{\theta_{lz}|\theta|}$ (23)

Totally differentiating equation (21) we get the change in the informal output ($\hat{Z}$), as,

$$\hat{Z} = \sigma_z \theta_{kz} \frac{\theta_{sy}\widehat{\delta(D)}}{\theta_{lz}|\theta|} \quad (24)$$

Differentiating totally equations (19) and (20) we get,

$$\lambda_{sx}\hat{X} + \lambda_{sy}\hat{Y} = \lambda_{sy}\sigma_Y\theta_{ky}\frac{\widehat{\delta(D)}}{|\theta|} \quad (25)$$

$$\lambda_{kx}\hat{X} + \lambda_{ky}\hat{Y} = -\lambda_{ky}\sigma_Y\theta_{sy}\frac{\widehat{\delta(D)}}{|\theta|} - \lambda_{kz}\sigma_z\theta_{sy}\frac{\widehat{\delta(D)}}{\theta_{lz}|\theta|} \quad (26)$$

From solving equation (25) and (26) by using Cramer's rule, we get,as,[6]

$$\hat{X} = \frac{\widehat{\delta(D)}}{|\lambda||\theta|\theta_{lz}}\left(\lambda_{ky}\lambda_{sy}\sigma_Y\theta_{ky}\theta_{lz} + \lambda_{sy}\lambda_{ky}\sigma_Y\theta_{sy}\theta_{lz} + \lambda_{sy}\lambda_{kz}\sigma_z\theta_{sy}\right) \quad (27)$$

And,$\hat{Y} = -\frac{\widehat{\delta(D)}}{|\lambda||\theta|\theta_{lz}}\left(\lambda_{kx}\lambda_{sy}\sigma_Y\theta_{ky}\theta_{lz} + \lambda_{sx}\lambda_{ky}\sigma_Y\theta_{sy}\theta_{lz} + \lambda_{sx}\lambda_{kz}\sigma_z\theta_{sy}\right)$ (28)

And from equation (24), we get $\hat{Z} = \sigma_z \theta_{kz} \frac{\theta_{sy}\widehat{\delta(D)}}{\theta_{lz}|\theta|}$

In the first case, where, X is a service, an increase in the distance between the trading countries leads to expansion of the output for service X and the output of informal sector Z. On the other hand, the output for good Y will contract.

Thus, When, X is service, if D increases, $\delta(D)$ will increase. Therefore, $\widehat{\delta(D)} > 0$. Hence, $\hat{X} > 0$, $\hat{Y} < 0$ and $\hat{Z} > 0$

And When, X is a tangible good, if D increases, $\delta(D)$ will decrease. Therefore, $\widehat{\delta(D)} < 0$. Hence, $\hat{X} < 0$, $\hat{Y} > 0$ and $\hat{Z} < 0$

So, we propose that,

Proposition IV: An increase in distance between trading countries leads to an expansion of X and Z and a fall in Y if X is considered as a service. Whereas in case when X is a good, distance leads to$\hat{X}, \hat{Z} < 0$ and$\hat{Y} > 0$.

Proof: See discussion above.

[6] Detailed calculations for all these values are given in the Appendix 4

4. Concluding Remarks

In this paper we started by constructing a basic model with two countries. The important assumption here is that the countries are located in different time zones. We see that, the utilization of geographical distance may have a positive effect on trade in case of service trade. Therefore, distance may not be always harmful for trade unlike gravity model arguments. Though the goods trade is negatively affected in such a situation. Here we see that an increase in distance between trading countries leads to an increase in wage of the skilled labour and a fall in the rent of capital if the product is a service and a decrease in wage of the skilled labour and a rise in the rent of capital if the product is a good. Then we extend the basic model with inclusion of informal sector and we have unskilled labour as an extra factor of production. If distance increases then the wage inequality between skilled and unskilled labour will increase if the product is a service and will decrease if the product is a good. Hence, in brief, our model has successfully proved that there are different results of aerial distance on trade. This depends on whether the product is good or service. It has been explained in a competitive structure. Our basic results hold true even in the presence of the informal sector.

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Appendix 1

In a competitive framework the cost price equations will be:

$1w_s + 1r = P_x\delta(D)$ (1.1)

$a_{sy}w_s + a_{ky}r = P_y$ (1.2)

Differentiating totally equation (1.1) we get,

$\theta_{sx}\widehat{w_s} + \theta_{kx}\hat{r} = \widehat{\delta(D)} + \widehat{P_x}$ (1.3)

[Where $\theta_{sx} = \frac{1\,w_s}{P_x\delta(D)}$ and $\theta_{kx} = \frac{1\,r}{P_x\delta(D)}$ and $\theta_{sx} + \theta_{kx} = 1$]

Differentiating totally equation (1.2) we get,

$\theta_{sy}\widehat{w_s} + \theta_{ky}\hat{r} = \widehat{P_y}$ (1.4)

[Where $\theta_{sy} = \frac{a_{sy}w_s}{P_y}$ and $\theta_{ky} = \frac{a_{ky}r}{P_y}$ and $\theta_{sy} + \theta_{ky} = 1$]

[We have used envelop theorem, i.e.,$\theta_{sy}\widehat{a_{sy}} + \theta_{ky}\widehat{a_{ky}} = 0$]

Solving equation (1.3) and (1.4) by using Cramer's rule, we get,

$$\theta_{sx}\widehat{w_s} + \theta_{kx}\hat{r} = \widehat{P_x} + \widehat{\delta(D)}$$

$$\theta_{sy}\widehat{w_s} + \theta_{ky}\hat{r} = \widehat{P_y}$$

$$\widehat{w_s} = \frac{\theta_{ky}\widehat{P_x} + \theta_{ky}\widehat{\delta(D)} - \theta_{kx}\widehat{P_y}}{|\theta|}$$

And, $\hat{r} = \frac{-\theta_{sy}\widehat{P_x} - \theta_{sy}\widehat{\delta(D)} + \theta_{sx}\widehat{P_y}}{|\theta|}$

Where,$|\theta| = \theta_{sx}\theta_{ky} - \theta_{kx}\theta_{sy}$;$|\theta| > 0$

Since, $\widehat{P_x} = \widehat{P_y} = 0$

$\therefore \widehat{w_s} = \frac{\theta_{ky}\widehat{\delta(D)}}{|\theta|}$ (1.5)

And, $\hat{r} = -\frac{\theta_{sy}\widehat{\delta(D)}}{|\theta|}$ (1.6)

Appendix 2

$$\sigma_Y = -\frac{\widehat{a_{sy}} - \widehat{a_{ky}}}{\widehat{w_s} - \hat{r}}$$

$\therefore \widehat{a_{sy}} = \widehat{a_{ky}} - \sigma_Y(\widehat{w_s} - \hat{r})$ (2.1)

And, $\widehat{a_{ky}} = \widehat{a_{sy}} + \sigma_Y(\widehat{w_s} - \hat{r})$ (2.2)

Envelop theorem states that,

$$\widehat{a_{sy}}\theta_{sy} + \widehat{a_{ky}}\theta_{ky} = 0$$

$\therefore \widehat{a_{sy}} = -\widehat{a_{ky}}\frac{\theta_{ky}}{\theta_{sy}}$ (2.3)

And, $\widehat{a_{ky}} = -\widehat{a_{sy}}\frac{\theta_{sy}}{\theta_{ky}}$ (2.4)

Comparing Equation (2.1) and (2.3) we get,

$$\widehat{a_{ky}} = \sigma_Y(\widehat{w_s} - \hat{r})\theta_{sy}$$

Using equation (2.5) and (2.6) we get, $(\widehat{w_s} - \hat{r}) = \frac{\widehat{\delta(D)}}{|\theta|}$

$\therefore \widehat{a_{ky}} = \sigma_Y\theta_{sy}\frac{\widehat{\delta(D)}}{|\theta|}$ (2.5)

Similarly, comparing Equation (2.2) and (2.4) we get,

$$\widehat{a_{sy}} = -\sigma_Y(\widehat{w_s} - \hat{r})\theta_{ky}$$

$\therefore \widehat{a_{sy}} = -\sigma_Y \theta_{ky} \frac{\widehat{\delta(D)}}{|\theta|}$ (2.6)

The endowment constraints are given as (since we assume that S and K endowment are fixed)

$1\, X + a_{sy}Y = \bar{S}$ (2.7)

$1\, X + a_{ky}Y = \bar{K}$ (2.8)

Differentiating totally equation (2.7) we get,

$$\lambda_{sx}\hat{X} + \lambda_{sy}\hat{Y} = -\lambda_{sy}\left(-\sigma_Y \theta_{ky} \frac{\widehat{\delta(D)}}{|\theta|}\right)$$

Or, $\lambda_{sx}\hat{X} + \lambda_{sy}\hat{Y} = \lambda_{sy}\sigma_Y \theta_{ky} \frac{\widehat{\delta(D)}}{|\theta|}$ (2.9)

$$\text{Where, } \lambda_{sx} = \frac{1\, X}{S} \; and \; \lambda_{sy} = \frac{a_{sy}Y}{S} \; and \; \lambda_{sx} + \lambda_{sy} = 1$$

$$\left[\text{Since, } \hat{S} = 0 \text{ and } \widehat{a_{sy}} = -\sigma_Y \theta_{ky} \frac{\widehat{\delta(D)}}{|\theta|}\right]$$

Similarly, from equation (2.8),

$\lambda_{kx}\hat{X} + \lambda_{ky}\hat{Y} = -\lambda_{ky}\sigma_Y \theta_{sy} \frac{\widehat{\delta(D)}}{|\theta|}$ (2.10)

$$\text{Where, } \lambda_{kx} = \frac{1\, X}{K} \; and \; \lambda_{ky} = \frac{a_{ky}Y}{K} \; and \; \lambda_{kx} + \lambda_{ky} = 1$$

$$\left[\text{Since, } \hat{K} = 0 \text{ and } \widehat{a_{ky}} = \sigma_Y \theta_{sy} \frac{\widehat{\delta(D)}}{|\theta|}\right]$$

Solving equation (2.9) and (2.10) by using Cramer's rule, we get,

$\hat{X} = \frac{1}{|\lambda||\theta|}\left(\lambda_{ky}\lambda_{sy}\theta_{ky} + \lambda_{sy}\lambda_{ky}\theta_{sy}\right)\sigma_Y \widehat{\delta(D)}$ (2.11)

And, $\hat{Y} = -\frac{1}{|\lambda||\theta|}\left(\lambda_{kx}\lambda_{sy}\theta_{ky} + \lambda_{sx}\lambda_{ky}\theta_{sy}\right)\sigma_Y \widehat{\delta(D)}$ (2.12)

If, X is S (Skilled labour) intensive and Y is K (capital) intensive, then,

$$(\lambda_{sx}\lambda_{ky} - \lambda_{kx}\lambda_{sy}) > 0$$

$$|\lambda| > 0$$

Appendix 3

Here we have a new price equation for sector Z, which is given as:

$a_{lz}w + a_{kz}r = P_z$ (3.1)

Differentiating totally equation (3.1) we get,

$\theta_{lz}\hat{w} + \theta_{kz}\hat{r} = \widehat{P_z}$ (3.2)

Where, $\theta_{lz} = \frac{a_{lz}w}{P_z} \; and \; \theta_{kz} = \frac{a_{kz}r}{P_z} \; and \; \theta_{lz} + \theta_{kz} = 1$

[Application of envelop theorem guarantees that, $\theta_{lz}\widehat{a_{lz}} + \theta_{kz}\widehat{a_{kz}} = 0$]

Since, $\widehat{P_z} = 0$ and $\hat{r} = -\frac{\theta_{sy}\widehat{\delta(D)}}{|\theta|}$ [From equation (1.6)]

$\therefore \theta_{lz}\hat{w} + \theta_{kz}\frac{-\theta_{sy}\widehat{\delta(D)}}{|\theta|} = 0$

Or, $\hat{w} = \frac{\theta_{kz}\theta_{sy}\widehat{\delta(D)}}{\theta_{lz}|\theta|}$ (3.3)

Since, informal wage is less than the formal wage where minimum wage rule is followed, then we can see that;

$$(\widehat{w_s} - \hat{w}) = \frac{\theta_{ky}\widehat{\delta(D)}}{|\theta|} - \frac{\theta_{kz}\theta_{sy}\widehat{\delta(D)}}{\theta_{lz}|\theta|}$$

Or, $(\widehat{w_s} - \hat{w}) = \frac{\theta_{lz}\theta_{ky}\widehat{\delta(D)} - \theta_{kz}\theta_{sy}\widehat{\delta(D)}}{\theta_{lz}|\theta|}$

Or, $(\widehat{w_s} - \widehat{w}) = \widehat{\delta(D)} \frac{\theta_{lz}\theta_{ky} - \theta_{kz}\theta_{sy}}{\theta_{lz}|\theta|}$ (3.4)

$$|\theta| > 0 \; and \; (\theta_{lz}\theta_{ky} - \theta_{kz}\theta_{sy}) > 0$$

Appendix 4

The full employment conditions are,

$1\,x + a_{sy}y = \bar{S}$ (4.1)

$1\,x + a_{ky}y + a_{kz}z = \bar{K}$ (4.2)

$a_{lz}z = \bar{L}$ (4.3)

In order to calculate the effects on output of X, Y and Z we need to use the concept of elasticity of substitution in Z (σ_Z). This is given by,

$$\sigma_z = -\frac{\widehat{a_{lz}} - \widehat{a_{kz}}}{\widehat{w} - \hat{r}}$$

$\therefore \widehat{a_{lz}} = \widehat{a_{kz}} - \sigma_z(\widehat{w} - \hat{r})$ (4.4)

And, $\widehat{a_{kz}} = \widehat{a_{lz}} + \sigma_z(\widehat{w} - \hat{r})$ (4.5)

Envelop theorem says that,

$$\theta_{lz}\widehat{a_{lz}} + \theta_{kz}\widehat{a_{kz}} = 0$$

$\therefore \widehat{a_{lz}} = -\widehat{a_{kz}} \frac{\theta_{kz}}{\theta_{lz}}$ (4.6)

And, $\widehat{a_{kz}} = -\widehat{a_{lz}} \frac{\theta_{lz}}{\theta_{kz}}$ (4.7)

Comparing Equation (4.4) and (4.6) we get,

$$\widehat{a_{kz}} = \sigma_z(\widehat{w} - \hat{r})\theta_{lz}$$

Using equation (1.6) and (3.3) we get, $(\widehat{w} - \hat{r}) = \frac{\theta_{sy}\widehat{\delta(D)}}{\theta_{lz}|\theta|}$

Or, $\widehat{a_{kz}} = \sigma_z\theta_{lz} \frac{\theta_{sy}\widehat{\delta(D)}}{\theta_{lz}|\theta|}$ (4.8)

Similarly, from Equation (4.5) and (4.7) we get,

$$\widehat{a_{lz}} = -\sigma_z(\widehat{w} - \hat{r})\theta_{kz}$$

Or, $\widehat{a_{lz}} = -\sigma_z\theta_{kz} \frac{\theta_{sy}\widehat{\delta(D)}}{\theta_{lz}|\theta|}$ (4.9)

Differentiating totally equation (4.3) we get,

$$\hat{Z} + \widehat{a_{lz}} = \hat{L}$$

Since, $\hat{L} = 0$ and $\widehat{a_{lz}} = -\sigma_z\theta_{kz} \frac{\theta_{sy}\widehat{\delta(D)}}{\theta_{lz}|\theta|}$

$\hat{Z} = \sigma_z\theta_{kz} \frac{\theta_{sy}\widehat{\delta(D)}}{\theta_{lz}|\theta|}$ (4.10)

Differentiating totally equation (4.1) we get,

$$\lambda_{sx}\hat{X} + \lambda_{sy}\hat{Y} = -\lambda_{sy}\left(-\sigma_Y\theta_{ky}\frac{\widehat{\delta(D)}}{|\theta|}\right)$$

Or, $\lambda_{sx}\hat{X} + \lambda_{sy}\hat{Y} = \lambda_{sy}\sigma_Y\theta_{ky}\frac{\widehat{\delta(D)}}{|\theta|}$ (4.11)

$$\text{Where, } \lambda_{sx} = \frac{1\,X}{S} \; and \; \lambda_{sy} = \frac{a_{sy}Y}{S} \; and \; \lambda_{sx} + \lambda_{sy} = 1$$

$$\left[\text{Since, } \hat{S} = 0 \text{ and } \widehat{a_{sy}} = -\sigma_Y\theta_{ky}\frac{\widehat{\delta(D)}}{|\theta|}\right]$$

Differentiating totally equation (4.2) we get,

$$\lambda_{kx}\hat{X} + \lambda_{ky}\hat{Y} = -\lambda_{ky}\sigma_Y\theta_{sy}\frac{\widehat{\delta(D)}}{|\theta|} - \lambda_{kz}\sigma_z\theta_{kz}\frac{\theta_{sy}\widehat{\delta(D)}}{\theta_{lz}|\theta|} - \lambda_{kz}\sigma_z\theta_{lz}\frac{\theta_{sy}\widehat{\delta(D)}}{\theta_{lz}|\theta|}$$

Or, $\lambda_{kx}\hat{X} + \lambda_{ky}\hat{Y} = -\lambda_{ky}\sigma_Y\theta_{sy}\frac{\widehat{\delta(D)}}{|\theta|} - \lambda_{kz}\sigma_z\theta_{sy}\frac{\widehat{\delta(D)}}{\theta_{lz}|\theta|}$ (4.12)

Where, $\lambda_{kx} = \frac{1\,X}{K}$, $\lambda_{ky} = \frac{a_{ky}\,Y}{K}$, $\lambda_{kz} = \frac{a_{kz}\,z}{K}$ $and\ \lambda_{kx} + \lambda_{ky} + \lambda_{kz} = 1$

[Using equation (2.6), (4.8)and (4.10) and $\theta_{kz} + \theta_{lz} = 1$ and assuming $\widehat{K} = 0$]

Solving equation (4.11) and (4.12) by using Cramer's rule, we get,

$\hat{X} = \frac{\widehat{\delta(D)}}{|\lambda||\theta|\theta_{lz}}\left(\lambda_{ky}\lambda_{sy}\sigma_Y\theta_{ky}\theta_{lz} + \lambda_{sy}\lambda_{ky}\sigma_Y\theta_{sy}\theta_{lz} + \lambda_{sy}\lambda_{kz}\sigma_z\theta_{sy}\right)$ (4.13)

And, $\hat{Y} = -\frac{\widehat{\delta(D)}}{|\lambda||\theta|\theta_{lz}}\left(\lambda_{kx}\lambda_{sy}\sigma_Y\theta_{ky}\theta_{lz} + \lambda_{sx}\lambda_{ky}\sigma_Y\theta_{sy}\theta_{lz} + \lambda_{sx}\lambda_{kz}\sigma_z\theta_{sy}\right)$ (4.14)

And from equation (4.10), we get $\hat{Z} = \sigma_z\theta_{kz}\frac{\theta_{sy}\widehat{\delta(D)}}{\theta_{lz}|\theta|}$