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## Abstract

Using a two-factor (labor and capital), two-good (shift-working and non shiftworking commodities) model with two countries (Home and Foreign) which are located in different time zones, we highlight the impact of trade in labor services (via communication networks) on the comparative advantage of countries capable of such trade. It is shown that a comparative advantage in the shift-working commodity is held by pairs of countries in different time zones and connected through a good communication network. Concerning factor prices, if the shiftworking commodity is capital (resp. labor) intensive, the wage rate for day-shift labor will decrease (resp. increase) as a result of trade in labor services. It is also demonstrated that this kind of labor services utilization is mutual: some of Home's day-shift labor will be utilized for Foreign night-shift, and vice versa. Thus, periodic trade in labor services occurs across countries.

JEL-Code: F160.

Keywords: shiftworking, time zones, trade in labor services.

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# 1 Introduction

International trade in services is an increasingly important feature of the world economy. Anecdotal evidence abounds on the rapid growth of new types of services transactions made possible by information and communications technology. Services transactions between parties can be mediated over vast distances by electronic means both instantaneously and at low cost.

Advances in electronic communication facilitate cross-border services transactions which take advantage of time zone differences between countries. For example, recent international management studies report that, by involving specialized microchip design engineers located at multiple places around the world, microchip design firms can obtain efficiency benefits by "following the sun."[1] For time-critical projects, a team in a head office completes a full day of design on the project, and at the end of the day passes the project to foreign engineers. During the night-time at the head office, engineers located in a country with a different time zone can provide their services (e.g., development of code or testing of subsystem) via the Internet. Similar to the microchip design case, many other industries (e.g., legal services, data entry, and other back-office operations) utilize these kinds of services based on time zone differences. This mode of operation provides the firms with access to high-talent workers who would otherwise have to work locally in the night shift.[2] In other words, "trade in labor services based on different time zones" is made possible by taking advantage of communications networks.

Our paper investigates some implications of this trade for the pattern of shift working and for the comparative advantage of countries that are able to conduct such trades. In a world without trade in labor services, firms have to buy the night-shift labor from domestic labor market, which usually requires a wage premium to compensate for working during inconvenient hours. When the importation of day-time labor services at the local night-time becomes possible, however, this will result in changes of the relative supplies and demands for shift working labor services, and hence in factor prices. This factor market effect may be among one of the most important consequences of the trade in labor services based on time zone differences.

While existing literature on international trade offers a number of models that highlight some important implications of time zone differences, we are not aware of any model that captures the role of time zone differences in the pattern of shift working. Our study shows

[1] See, for example, Zaheer (2000) and Gupta and Seshasai (2004).

[2] See, for example, Cairncross (1997).

that trade in labor services across time zone can result in a complete elimination of local night-time labor, with far-reaching implications for rental rate and day-time wage rate. Betancourt *et al.* (1984) was perhaps the first to investigate the role of shift working and capital utilization in an international trade context. However, they did not consider time zone differences and therefore international trade in labor services was not present in their model. The present study, in contrast, permits trade in labor services based on time zone differences and examines its influence on national factor markets.

For these purposes, we construct a simple model of two small open economies (Home and Foreign) with two production factors (labor and capital). We embed these two economies in a world economy consisting of many small open economies. Home and Foreign are assumed to be located on different time zones. The model has two goods. The first is Good $Y$, the production of which does not require shift working. The production of the other good, Good $X$, is subject to shift working. We call the latter the shift-working commodity. Following Betancourt *et al.* (1984), we assume that one day (24 hours) is divided into a day-time shift (6 a.m. to 6 p.m.) and a night-time shift (6 p.m. to 6 a.m.). Firms in the $X$ sector buy labor from two separate labor markets.

Using the model outlined above, we study the impact of trade in labor services between Home and Foreign based on time zone differences. We show that if the importation of such labor services becomes possible, it results in a decrease in the wage premium for domestic night-shift workers. Then Home and Foreign, which utilize labor services with time zone differences have a comparative advantage in the shift-working commodity, Good $X$, relative to other pair of economies for which such trade is not possible (for example, because they do not have a good communication network). This comparative advantage arises because in Home and Foreign (or, generally, in pairs of countries in different time zones and connected through a good communication network) the $X$ sector benefits from the reduction in the wage premium for night-shift workers. It is clear that this kind of labor services utilization is mutual one: some of Home's day-shift labor will be utilized for Foreign night-shift, and vice versa.

Our study is closely related to the literature on the role of time zones in international trade. In a pioneering paper, Marjit (2007) examined the role of international time zone differences in a vertically integrated Ricardian framework under perfect competition.[3] He showed that time-difference emerges as an independent driving force of international trade besides taste, technology and endowment. Our model with shift work is complementary to

[3]See also a recent contribution by Matsuoka and Fukushima (2010).

this literature in that we shed new light on the impact of trade in labor services with time zone differences on national factor markets.[4]

The structure of this paper is as follows. In the next section we present the basic model. The impact of labor service trade with time zone differences is considered in section 3, followed by concluding remarks presented in section 4.

# 2 The Model

We have two small open economies, Home and Foreign, and the Rest-of-the-World (ROW). Each country is endowed with labor ($L$) and capital ($K$). These countries can produce two goods, the knowledge intensive Good $X$ and the traditional Good $Y$, of which only the former is subject to shift-work. We call Good $X$ the shift-working commodity. Markets are competitive and open every 24 hours. The central assumption is that one day (24 hours) is divided into a day-time shift (6 a.m. to 6 p.m.) and night-time shift (6 p.m. to 6 a.m.), the length of each shift being 12 hours.[5]

Home and Foreign are located in different time zones and there is no overlap in daytime working hours: when Home's daytime working hours end, Foreign's daytime working hours begin (Figure 1). Except for time zone differences, these two countries are identical in terms of technology and factor endowments. We assume that the price of $X$ and $Y$, $p_X$ and $p_Y$ are determined in the ROW and are beyond control of the countries we deal with. Let the outputs generated per day be denoted by $X$ and $Y$. In what follows, we concentrate on what happens in Home.

From the viewpoint of the firm, there are two pools of labor, $L^D$ and $L^N$, where $L^D$ denotes the total supply of day-shift labor and $L^N$ denotes the total supply of night-shift labor. The $X$ sector uses both day and night-shift labor while the $Y$ sector uses the former only. There is another factor of production, capital, which is used by both sectors and whose supply (in stock terms) is denoted by $K$.

[4]The present study is also related to the literature of the fragmentation of production stages and of service provision, which has been studied within a trade-theoretic framework by Jones and Kierzkowski (1990), Harris (1998), Jones and Marjit (2001), Deardorff (2001), Long *et al.* (2005) and Grossman and Rossi-Hansberg (2008). Another important related literature is the role of international factor mobility in the world economy. See, for example, Wong (1995).

[5]This assumption is taken from Betancourt *et al.* (1984).

## 2.1 Utility Function and the Supply of Labor

We shall assume that each worker has $\overline{\ell}$ units of time and supplies inelastically a *fixed* amount $\ell$ of labor. Let

$$H \equiv (\overline{\ell} - \ell) \tag{1}$$

denote the (fixed) amount of leisure. The worker must decide whether he offers the fixed amount $\ell$ in day shift, or in night shift.[6] In what follows, we normalize $\ell$ as 1. Workers are not identical in their degree of dislike for nigh-time work. We assume that there is a continuum of workers, indexed by $\Psi$, where $\Psi \in [0, \bar{\Psi}]$. Assume that they are uniformly distributed. For any level of consumption $C$ (where $C$ is the number of units of "consumption basket" he consumes), a worker of type $\Psi$ obtains the utility $U = CH$ if he works in a day shift, and the utility $U = CH/(1 + \Psi)$ if he works in a night shift. The wage rate for day labor is $w^D$ and that for night labor is $w^N > w^D$.

Assume that workers consume all their income (which consists only of wage income). Then a night shift (respectively, day shift) worker will have consumption level $C^N = w^N/P_C$ (respectively, $C^D = w^D/P_C$) where $P_C$ is the price of the consumption basket. It follows that, given the wage profile $(w^N, w^D)$, there is a "pivot worker" who is indifferent between being a night shift worker and a day shift worker (his utility level being the same for both choices). This pivot worker is the one of type $\tilde{\Psi}$, where

$$1 + \tilde{\Psi} = \frac{w^N}{w^D}, \tag{2}$$

His utility level is

$$\widetilde{U} = \frac{w^D H}{P_C} = \frac{w^N H}{P_C}\left(\frac{1}{1 + \tilde{\Psi}}\right)$$

Workers whose $\Psi$ is lower than $\tilde{\Psi}$ will choose to be night shift workers, and enjoy a utility level greater than $\widetilde{U}$. Workers whose $\Psi$ is greater than $\tilde{\Psi}$ will choose to be day shift workers, and enjoy the same utility level $\widetilde{U}$ as the pivot worker.

Equation (2) defines the supply of night-shift labor: if the night-shift labor force is to increase, increasingly unwilling workers have to be drawn into night work and the required wage premium increases. Since the parameter $\Psi$ is distributed uniformly over the interval $[0,\ \bar{\Psi}]$, the night-shift labor supply curve will be shown as a curve $SS$ in Figure 2, where the vertical axis represents $w^N/w^D$ while the horizontal axis represents the level of night-shift labor.[7]

[6] He cannot work partly in night shift and partly in day shift.

[7] The assumption of a uniform distribution implies that $SS$ is linear. This assumption can be easily

## 2.2 Technology

Following Betancourt *et al.* (1984, 1985), we assume if a firm $i$ rents $K_i$ units of capital, it must pay capital owners $rK_i$ dollars per day, regardless of whether $K_i$ is used only for the day shift (and thus lies idle at night) or is used for both shifts. Thus there is an incentive for a firm in sector $X$ to operate two shifts (a day time shift and a night time shift) provided that the wage $w^N$ is not prohibitively expensive.[8]

The following (ex ante) production function describes equipment sharing from multishift:

$$X = \sum_{i=D,\ N} F(K_X,\ L_X^i), \tag{3}$$

where $X$ is the daily rate of output, $L_X^i$ $(i = D,\ N)$ is the distinct labor input used in $i$-shift, and $K_X$ is the common capital used in both shifts, and where $F$ is assumed to be linear homogeneous, increasing, and strictly quasi-concave in its arguments.

We also assume that firms face a zero ex-post elasticity of substitution between capital and labor services.[9] This assumption implies that firms have to maintain the same capital-services-to-labor-services ratio during the day and night shifts. Thus while this ratio can be altered in the long run in response to a change in factor prices, it cannot be altered in the short run, and thus certainly not within the same day. In other words, we require that the same number of workers be working at each machine, whether it is in day time or night time. Therefore, if the firm operates both shifts, its labor employment must satisfy

$$L_X^N = L_X^D. \tag{4}$$

In what follows, we assume that sector $X$ firms find it efficient to operate both shifts.[10] Substituting (4) into (3), the above production function assume the form

$$X = 2F(K_X,\ L_X^D). \tag{5}$$

relaxed without any change in the qualitative results.

[8]Firms in sector $Y$ cannot operate two shifts.

[9]This is a standard assumption in the capital utilization literature. See, for example, Betancourt and Clague (1981, ch. 2).

[10]We in fact are assuming that $w^N$ is not too expensive, so that it is economical for the $X$ sector firms to work both shifts rather than just the day shift. In other words, we assume the factor prices $(w^D, w^N, r)$ are such that

$$c\left(\frac{r}{2}, \frac{w^D + w^N}{2}\right) < c(r, w^D)$$

where $c(.,.)$ is the unit cost function associated with the production function $F(.,.)$. This condition implies that the average unit cost when working two shifts (LHS) is less than that when working only day shift (RHS). This assumption will be maintained throughout the paper.

Production of $Y$ is assumed to be operating during the day-shift only. Therefore we can represent its output by a conventional neoclassical production function

$$Y = G(K_Y,\ L_Y), \tag{6}$$

where $G$ is linear homogeneous in its arguments, and $K_Y$ and $L_Y$, respectively, are capital and labor employed in the $Y$ sector.

Capital market clearing requires that

$$K_X + K_Y = K. \tag{7}$$

## 2.3 Equilibrium under Communications Autarky

Now, let us consider the equilibrium conditions under communications autarky (i.e. Foreign and Home cannot engage in international trade in labor services because of lack of communications networks).[11] Denoting the rental on capital by $r$, cost minimization by firms in the $X$ sector yields the following conditions:

$$p_X(\partial X/\partial K_X) = 2p_X(\partial F/\partial K_X) = r, \tag{8}$$

$$p_X(\partial X/\partial L_X^D) = 2p_X(\partial F/\partial L_X^D) = w^D + w^N. \tag{9}$$

Optimality requires that the value of marginal product of labor in each shift be equated to the average wage in the $X$ sector, $\bar{w}$, which is defined as $(w^D + w^N)/2$.

In the $Y$ sector, cost minimization along with perfect competition yields the following standard conditions:

$$p_Y(\partial G/\partial K_Y) = r, \tag{10}$$

$$p_Y(\partial G/\partial L_Y) = w^D. \tag{11}$$

As it has been mentioned, by normalization, we can suppose that each worker supplies one unit of labor [see (1)]. Then total labor supply will equal the total number of workers. We can write

$$L_X^D + L_X^N + L_Y = L. \tag{12}$$

We now proceed to determine the equilibrium values under communications autarky. We must show how, given the world relative price $p_X/p_Y$ and given Home's endowment $(K, L)$, the equilibrium values of $(K_X, K_Y, L_X^D, L_X^N, L_Y)$ are determined. (Note that $L_X^D = L_X^N$). In what follows, we use a diagrammatic approach.

[11] Note that, even under communications autarky, Good $X$ and Good $Y$ are traded internationally.

The model can be solved by utilizing a demand curve and a supply curve for night-shift labor $L_X^N$. As mentioned above, the supply curve is given in equation (2) and is represented by the curve $SS$ in Figure 2.

Next, let us derive the demand curve for night-shift labor. If we fix the level of $L_X^N$, it also implies that we fix $L_X^D$ and $L_Y$ [see, (4) and (12)]. Thus, for given levels of $L_X^N$, $L_X^D$, and $L_Y$, and of $p_X$ and $p_Y$, one can draw the value of marginal product of capital ($VMP_K$) curves [see, (8) and (10)]. These curves are drawn in the left panel of Figure 3, where we measure capital stocks on the horizontal axis and $r$ on the vertical line farthest to the left. The total capital stock is indicated by the distance from the origin to the point $\bar{K}$, and $K_X$ is measured to the right from $\bar{K}$ and $K_Y$ is measured to the left from the origin. The intersection of the two $VMP_K$ curves determines the levels of $K_X$ and $K_Y$ and the value of $r$.

Now we can draw the value of marginal product of labor ($VMP_L$) curves in the right panel of Figure 3, where the total availability of labor is indicated by the distance along the horizontal axis from the origin to the point $\bar{L}$. $L_X^N$ is measured to the right from the origin and $L_Y$ is measured to the left from point $\bar{L}$. The horizontal distance between $L_X^N$ and $L_Y$ is $L_X^D$, which equals $L_X^N$ (see (4)). On the vertical axis from the origin we measure $\bar{w}$ and on the vertical line from point $\bar{L}$ we measure $w^D$. The $VMP$ curves for $L_X^N$ and for $L^Y$, together with the values of $L_X^N$ and $L_Y$, determine $\bar{w}$ and $w^D$. Then $w^N$ can be found from

$$\bar{w} = \frac{(w^D + w^N)}{2}.$$

We have now found the values of $w^N$ and $w^D$, and hence $(w^N/w^D)$, for a given value of $L_X^N$. We repeat this process for each value of $L_X^N$ and trace out the demand curve for $L_X^N$, denoted $DD$ in Figure 2. Communications autarky equilibrium is obtained as an intersection of the curve $SS$ and the curve $DD$, point $A$.

# 3 Effects of Advances in Communications on Shiftwork and Trade in Labor Services

Now let us consider the impact of technological advances in communications networks. In our scenario, via communications networks, day-shift worker in one country can provide its labor services as the other country's night-shift labor services but is paid domestic daytime wage. In other words, the night-shift labor in one country is replaced by the day-shift labor in the other country.[12] This tends to reduce the cost to produce Good $X$: now firms in each country can import daytime labor services during local nighttime. For ease of exposition we will concentrate on the case where labor services can be imported without additional trade costs.[13]

The impact of technological advancement is represented in Figure 2, which compares Home communications autarky equilibrium, point $A$, and the one with the importation of Foreign daytime labor. The impact can be interpreted as if the disutility from night-shift labor supply vanishes, which would produce a flatter $SS'$ curve and the graph shows that $L_X^N$ (which now indicates imported Foreign daytime labor) would increase and $w^N/w^D$ would fall: the new equilibrium with the importation of Foreign daytime labor is depicted as point $N$ in Figure 2.

In this case, the night-shift workers in one country are completely replaced by the day-shift workers in the other country, and the night-shift wage premium vanishes. It is important to note that, due to symmetric setting between countries, half of workers in the $X$ sector work as the Home day-shift worker during Home daytime, while the other half work as Foreign night-shift worker and receiving the same wage rate ($\tilde{w}^D$ in Figure 3). Since the wage premium vanishes, both $L_X^N$ and $L_X^D$ would rise. This change would shift up the $VMP_{KX}$ curve so that $K_X$ would rise. Hence the supply of Good $X$ would rise. Analogously, $L_Y$ and $K_Y$ must fall, and thus the supply of Good $Y$ must fall. Thus, comparing a pair of communications autarky countries with time zone differences and a pair of connected countries with time zone differences, other things being equal, the latter pair would have a comparative advantage in the shift-working commodity $X$. This is because, in these countries, the $X$ sector works efficiently through the reduction in extra labor costs for night-shift workers.

**Proposition 1 (Comparative Advantage):** *Other things being equal, a pair of connected (i.e., labor trading) countries with time zone differences would have a comparative advantage in the shift-working commodity relative to a pair of communications autarky countries with time zone differences.*

What happens to factor prices? The answer depends on factor intensities. If $K_X/L_X > K_Y/L_Y$, then as the $Y$ sector releases labor and capital at given factor prices, the $X$ sector

[12] It is important to note that this condition comes from one more basic assumption: when exporting its labor services, workers in one country does *not* utilize its domestic capital. Although this assumption is rather strong, to keep matters simple, we posit this condition.

[13] The case of importing labor services with additional trade costs will be discussed in the end of this section.

tries to absorb the factors at a higher ratio of capital to labor than they are being released, and consequently there is upward pressure on $r$ and downward pressure on $w^D$.

A graphical representation of this case is shown in Figure 3. $L_X^N$ rises to $\tilde{L}_X^N$. $VMP_{KX}$ shifts up and $VMP_{KY}$ shifts down in such a way that their intersection occurs at a higher level of $r$. $VMP_{LY}$ shifts down and $VMP_{LX}$ shifts up in a such a way that at the new levels of $L_Y$ and $L_X^N$, $w^D$ goes down.[14]

**Proposition 2 (Factor Prices):** *Suppose that $K_X/L_X > K_Y/L_Y$ holds. Then a technological advance in communications networks that enables trade in labor services across time zones would result in a decrease in wages to day-shift labor, and an increase in rental for both countries.*

Let us consider this proposition more precisely. Utilization of communications networks and time zone differences imply that the avoidance of the domestic night-shift labor. Thus, given factor prices, firms in the $X$ sector have an incentive to expand its production. Then, via traditional Heckscher-Ohlin mechanism, relative factor price changes due to factor intensity rankings.[15] The point is that, without information on factor intensity rankings, one cannot predict the impact of trade in labor services with time zone differences on national factor markets.

Next let us move to trade patterns of labor services. As it has been mentioned, during Home's daytime, half of the day-shift labor in the $X$ sector is exported to Foreign as the night-shift labor services. During Home's nighttime, the patterns will be reversed: Firms in the $X$ sector imports Foreign day-shift labor. Thus, due to communications breakthroughs, *two-way trade in labor services with time zone differences* occurs across countries. These patterns are summarized in Figure 4.

Interestingly, these kinds of trade in labor services with time zone differences can be interpreted as a (new) form of *periodic intra-industry trade*. Traditionally, trade in perishable agricultural products, electricity and similar goods has been based on predictable, periodic fluctuations in countries' production of, or demand for, these commodities. As for agricultural products, for example, the cycle is seasonal, based on the differences in climatic zones. The present study emphasizes that, due to communications revolutions, similar kinds

[14] Recall that under international trade in labor services between Home and Foreign, Home would pay $w^D$ for the local (Home) night shift operated by Foreign workers who are working in Foreign day time.

[15] It is clear that, if Good $X$ is labor intensive, the above argument is reversed and there is downward pressure on $r$ and upward pressure on $w^D$.

of trade in labor services based on the differences in time zones emerge.

**Proposition 3 (Periodic Trade in Labor Services):** *Due to a technological advance in communications networks, periodic trade in labor services occurs. Each country becomes an exporter of labor services during its local daytime, while it becomes an importer of labor services during its local nighttime.*

It is important to note that this periodic trade in labor services, which makes the $X$ sector more efficient, boosts trade in final goods. In that sense, trade in labor services (i.e., a version of factor movements) and trade in final goods are complements in the present setting.

Before closing this section, let us briefly consider the case of labor importation with additional trade costs. In this case, the domestic night-shift labor is not completely wiped out: some domestic night-shift labor and some imported day-shift labor coexists and the wage premium for the night-shift remains.[16] Still, an importation of daytime labor services implies that there are downward pressure on $w^N$, which works to expands to the supply of Good $X$. Thus, our propositions still hold under the cases of additional (but not prohibited) costs with labor importation.

# 4 Concluding Remarks

In this study we highlight the impact of trade in labor services with time zone differences on the nature of shift working, on the pattern of comparative advantage, and on factor prices. It is shown that a comparative advantage in the shift-working commodity is held by the connected (i.e., labor trading) countries. Concerning factor prices, given that the shift-working commodity is capital (resp. labor) intensive, the wage rate for day-shift labor will be decreased (resp. increased) due to technological advancement. It is also demonstrated that this kind of labor services utilization is mutual: some of Home's day-shift labor will be utilized for Foreign night-shift, and vice versa. Thus, periodic trade in labor services occurs across countries. Although these results are derived under the assumption that there are no additional trade costs on labor, it seems to provide a new perspective on the offshore outsourcing and wage debate.[17] Inclusion of both shift-working and time zone differences aspects shed new light on the impact of offshoring services.

[16] One way to include this aspect is to assume the iceberg trading costs. In that case, Home wage rate for night-shift work will be equalized to Foreign day-shift wage rate with trading costs in equilibrium.

[17] See Marjit and Acharyya (2003) for discussion.

These results have some importance for economic policy. If one country could provide its daytime labor as the night-shift work for the other country via communications networks, then one of the first effects of such trade in labor services will be a drastic change in factor prices. Further research should focus on these policy implications. The model could be enriched with the inclusion of additional trade costs of labor importation.

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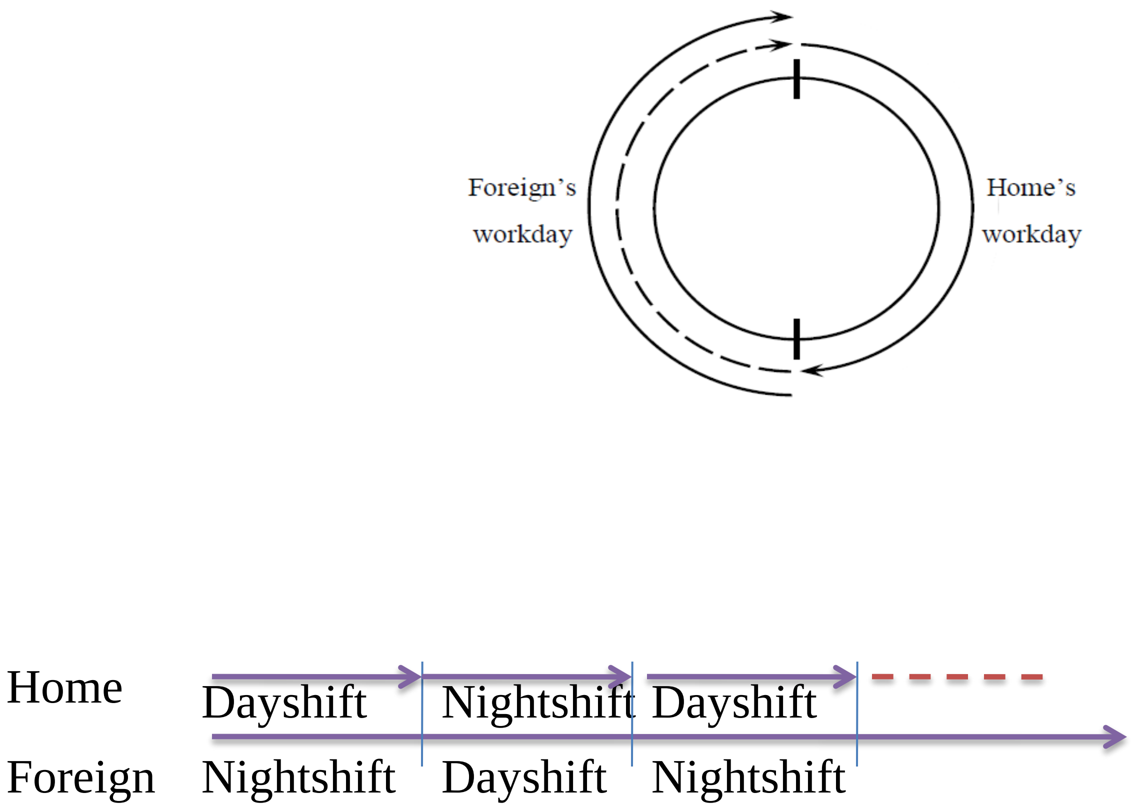


# Figure 1
# Working hours

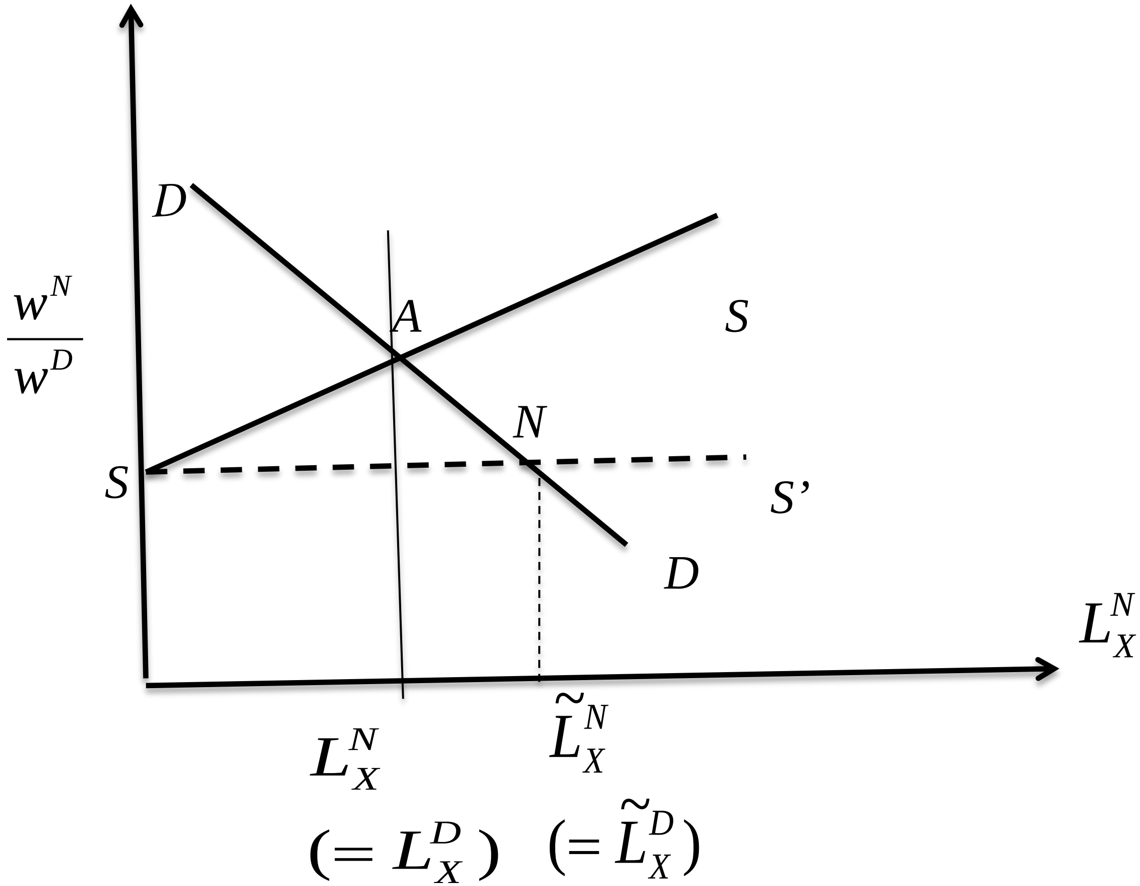


Figure 2
Night-shift labor market

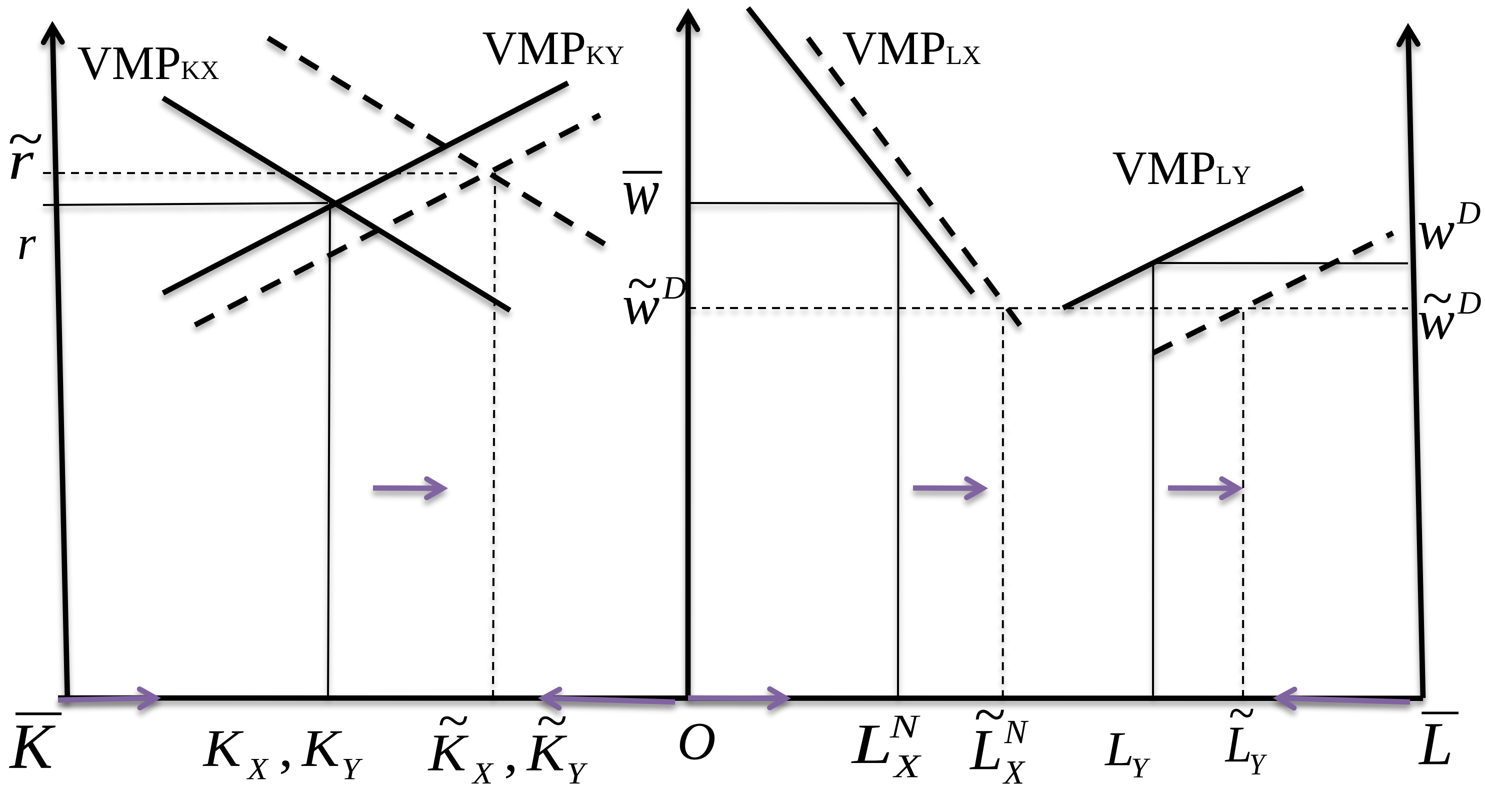


Figure 3
Factor allocation

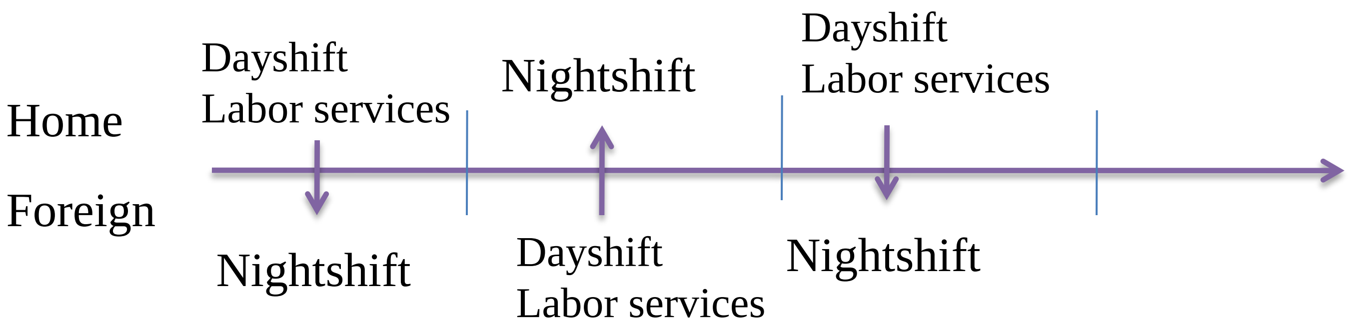


Figure 4
Periodic trade in labor services