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Abstract

The main purpose of this study is to illustrate, with a simple two-factor (skilled labor and unskilled labor) trade model, how a time-saving improvement in business-services trade benefitting from differences in time zones can have an impact on national factor markets. For these purposes, we extend Marjit's (2007) framework into the case with the night-shift work. By doing so, we intend to capture the situation where the night-shift work in one country is replaced by the day-shift work in another country. In other words, we will show that, trade with time zone differences will result in shifts of the relative supplies and demands for skilled labor around the globe.

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1 Introduction

In recent decades, trade in many kinds of intermediate goods and services has increased between developed and developing countries. In particular, the offshoring of business services such as engineering, consulting, and software development, which do not require physical shipments of products, plays a major role in today's world trade. The availability of the global high-bandwidth network infrastructure has increased the feasibility of reducing costs by going offshore.

These changes have invited new types of business-services trade which take advantage of time zone differences between countries. The semiconductor industry provides a prime example. According to Gupta and Seshasai (2004):[1]

> ...by involving specialized microchip design engineers located at multiple places around the world, a semiconductor chip design firm may create virtual "24-hour knowledge factories."... It provides the firm with access to high-talent designers who would otherwise have to move to a different country, or work at odd hours of the night... The creation of professional service teams that transcend geographic and temporal boundaries offers the potential to change the face of many industries.

As Gupta and Seshasai suggested, the creation of virtual "24-hour knowledge factory" seems to have a huge impact on production and trade structures. Related to these phenomena, Marjit (2007) examined the role of international time zone differences in a one-factor, two-country vertically integrated Ricardian framework, where production process can be divided into two stages.[2] It has been shown that, by utilizing time zone differences, two countries can

[1] See, also, Zaheer (2001), Gupta and Seshasai (2007) and Brown and Linden (2009).

[2] Findlay (1978), Dixit and Grossman (1982), Sanyal (1983), Sarkar (1985), Marjit (1987), Kohler (2004a) and Grossman and Rossi-Hansberg (2008) are important contributions toward formalizing trade under multi-stage production. The concept of multi-stage production is closely related to the concept of fragmentation, which has been studied

save time via input trade and obtain mutual trade gains. It is important to note that sources of trade gains are the realization of the quick delivery of time-sensitive products.[3]

There is one other thing that is important in the relationship between time zone differences and trade in services: its impact on factor markets, particularly *the allocation of labor between day-shift work and night-shift work.* Based on casual empiricism, we believe that time-saving technological improvement (e.g., the utilization of communications networks such as the Internet) can trigger a series of events that leads to a country-wide decline in night-shift work.[4] In the existing trade literature, however, relatively few attempts have been made to address the effect of trade with time zone differences on labor markets. The main purpose of this study is to illustrate, with a simple two-factor (skilled labor and unskilled labor) trade model, how a time-saving improvement in business-services trade benefitting from differences in time zones can have an impact on national factor markets. For these purposes, we extend Marjit's (2007) framework into the case with the night-shift work. By doing so, we intend to capture the situation where the night-shift work in one country is replaced by the day-shift work in another country. In other words, we will show that, trade with time zone differences will result in shifts of the relative supplies and demands for skilled labor around the globe.

Our study is closely related to the literature on the role of the Internet on factor markets. In a seminal contribution, Harris (1998) developed a two-sector model in which the introduction of the Internet creates "virtual mobility" of skilled labor. He showed that the wage premium for skilled labor

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within a trade-theoretic framework by Jones and Kierzkowski (1990), Jones and Marjit (2001, 2009), Deardorff (2001), Kohler (2004b), Long, Riezman and Soubeyran (2005) and Do and Long (2008).

[3]According to the importance of quick delivery of time-sensitive products, see, Hummels (2001) and Deardorff (2003).

[4]For example, Hamermesh (1999) found a sharp decline in the proportion of evening and night work in the U. S. over the last twenty years.

increases by introducing the Internet. His results crucially dependent on the assumption of the increasing-returns-to-scale technology. Contrary to that, we will show that the increased wage premium for skilled labor occurs even under constant-returns-to-scale technology.

The next section presents the basic model. In section 3, the impact of technological advance in communications networks is examined. Section 4 presents concluding remarks.

2 The Model

We have two small open economies, Home and Foreign, and the Rest-of-the-World (ROW), which endowed with skilled and unskilled labor. These countries can produce the knowledge-intensive good X and the traditional good Y. 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. Markets are competitive and open every 24 hours. The central assumption is that one day (24 hours) is divided into *two periods*: day-shift working hours and night-shift working hours, both of which are 12 hours. Home and Foreign are located in different time zones and there is no overlap in daily working hours: when Home's day-shift working hours end, Foreign day-shift working hours begin (Figure 1). Except for time zone differences, these two countries are identical in terms of technology and factor endowments.

Production of Y is instantaneous in the sense that one unit of Y can be produced within day-shift working hours. Unskilled labor is a factor input specific to Y: the Y sector is a competitive constant returns industry using unskilled and skilled labor, with a production function

$$Y = F(L,\ S_Y), \tag{1}$$

where L is the total amount of unskilled labor, while S_Y denotes the employment level of skilled labor in the Y sector.

Following Marjit (2007), we posit that the production of the knowledge-intensive good X necessarily involves two stages. Thus, to produce the good

X, skilled labor has to be applied continuously for two periods. At the end of the first period some goods-in-process are obtained and additional labor is applied to these goods in process in the second period. As noted above, the key assumption is that each day is divided into two periods. Thus, if a producer of good X utilizes both day-shift and night-shift skilled labor services continuously, whole one day is required for the preparation (see Figure 1).

2.1 Communications Autarky

First, let us consider the equilibrium conditions under communications autarky (i.e., without communications networks). The technology of the knowledge-intensive good X is simplified by assuming that at each stage only one unit of skilled labor goes into the unit production process.

We assume that each skilled worker has to choose whether day-shift work or night-shift work. To establish intra-day wage differences for skilled labor, we impose the following condition:

$$v^N = (1+\theta)v^D, \quad \theta \geq 0, \tag{2}$$

where θ, which is given as exogenous, reflects the degree of dissatisfaction from night-shift work, and v^D (resp. v^N) is the wage rate for skilled labor working at dayt (resp. night), respectively.[5] In equilibirum, the day-shift wage rate in the X sector must be equalized to the wage rate for (day-shift) skilled labor in the Y sector:

$$v^D = p_Y F_S(L,\ S_Y). \tag{3}$$

Factor market clearing requires that

$$S_X^D + S_X^N + S_Y = S, \tag{4}$$

where S_X^D (resp. S_X^N) is the employment level of day (resp. night) shift labor in X sector, and S is the total endowment of skilled labor.

[5]Hamermesh (1999) developed a model in which the value of positive θ is endogenously determined for workers' undesirable hours.

To produce one unit of output, both one unit of day-shift skilled labor services and one unit of night-shift skilled labor services must be applied. Thus, one can obtain the unit cost of the good X under communications autarky as

$$\begin{aligned} C_{AUT} &= v^D + v^N \\ &= (2+\theta)v^D. \end{aligned} \quad (5)$$

It is important to note that we ignore intra-day discounting.[6] Since the X sector is competitive,

$$P_X = C_{AUT} \quad (6)$$

must be hold.

We now proceed to determine the equilibrium values under communications autarky. In Figure 2 the two vertical axes measure the wage rate for skilled labor and the horizontal axis measures the total endowment of skilled labor, S. Given the fixed endowment of unskilled labor, one can draw a downward-sloping marginal productivity schedule for skilled labor used in the Y sector, from the left-hand origin and that in the knowledge-intensive X sector from the right-hand origin. Let us take the traditional good Y as the numeraire with its price equal to unity and start with exogenously given price P_X. Then the day-shift wage rate for skilled labor is determined from (6). Given this day-shift wage rate for skilled labor, we can determine the employment levels S_X and S_Y in the two sectors: $S_X/2$ is employed as day-shift skilled worker while the rest $S_X/2$ is employed as night-shift skilled worker.

3 Technological Advancement

Now let us consider the impact of technological advances in communications networks. In our scenario, via communications networks, product-in-process

[6] See Hamermesh (1999, p. 39) on this point. Since timeleness of delivery is an important issue, incorporating intra-day discounting needs further consideration.

at the end of one country's daytime will be sent to the other country and day-shift skilled labor will be applied (Figure 3). There are three possible cases:[7] (a) Home specializes in the first stage while Foreign specializes in the second stage, (b) Foreign specializes in the first stage while Home specializes in the second stage, and (c) in each country, half of the workers in the X sector work in the first stage, while the rest half work in the second stage. Although trade patterns are different in each case, factor market implications are qualitatively same. Thus, we concentrate on the first case.

This technological advancement reduces the labor cost to produce the knowledge-intensive good: now each country does not have to utilize night-shift workers. In this case, since technology is identical among countries, production technology exhibits as if the same day-shift wage rate $\tilde{w}^D$ will be applied two times. The unit cost with communication networks can be written as

$$C_{NET} = 2\tilde{w}^D. \tag{7}$$

In this case, the equilibrium wage rate for day shift skilled labor $\tilde{w}^D$ is determined from the condition $P_X = C_{NET}$.

The impact of technological advancement is represented in Figure 4, which compares the communications autarky equilibirum (point A) and the one with communications networks. The impact can be interpreted as if the disutility from night-shift labor supply, θ, vanishes.[8] This raises the day-shift skilled wage and increases the resources devoted to the X sector: the new equilibrium is depicted as point N in Figure 4. At the same time, the wage of unskilled labor is reduced as skilled labor is pulled out of the Y sector as a consequence of the "time zone difference" effects of communications networks. The present model predicts an increase in wages to day-shift skilled labor, a decrease in unskilled wages and an increase in the skill premium as a

[7] According to the indeterminacy of trade patterns with time zone differences, see Marjit (2007).

[8] According to the impact of utilization of time zone differences, Zaheer (2000) emphasizes the productivity gains from the entrainment or synchronization of individual circadian rhythms, the social rhythms, and work rhythms.

result of this particular form of technological advancement.[9] It is important to note that the sources of these changes can be divided into (1) switchings from the night-shift work toward the day-shift work within the X sector, and (2) inter-sectoral labor reallocation due to utilization of time zone differences. It must be also emphasized that the utilization of time zone differences can be interpreted as a creation of "virtually connected good X sector between countries," where "24-hour knowledge factories" operate.[10] These changes result in an increase in relative demands (and therefore supplies) for skilled labor around the globe.

Proposition 1: *Due to a technological advance in communications networks, there is an increase in wages to day-shift skilled labor, while a decrease in unskilled wages for both countries.*

Let us briefly compare the present results with Harris's (1998). Based on increasing-returns-to-scale technology, Harris has shown that the introduction of communications networks raises the wage premium for skilled labor. Sources of these changes are the realization of aggregate returns to scale via Smithian division of labor. Contrary to that, the present results derived from constant-returns-to-scale technology: increased productivity simply arises from utilization of time zone differences (i.e., avoidance of the night-shift work).[11]

Next, let us consider trade gains. The effect on national income of each country is unambiguously provided that skilled wage increases. The national income is equal to factor income given by $wL + vS$. The increases in returns to skilled labor is more than offset by the losses to unskilled labor. Trade with time zone differences, provided that it raises skilled wages, therefore raises aggregate real income and productivity.

[9]Harris (1998) emphasizes this kind of impact of the introduction of communications networks on labor markets.

[10]Gupta and Seshasai (2004, 2007).

[11]See Marjit (2007) on this point.

Proposition 2: *If shipment cost of goods-in-process is negligible, there are always gains from trade across different time zones.*

It is important to note that this proposition is a version of the basic proposition obtained by Marjit (2007, Proposition 1).

According to trade patterns, in particular case (c), we obtain an interesting result (See Figure 3). At the end of Home's day-shift working hours, all goods-in-process (i.e., stage 1 products) is exported to Foreign. Similarly, at the end of Foreign's day-shift working hours, all goods-in-process is exported to Home. Thus, due to communications breakthroughs, *intra-industry trade with time zone differences* occurs across countries. It is important to note that these kinds of trade with time zone differences can be interpreted as new versions of *periodic intra-industry trade*. Traditionally, trade in perishable agricultural products, electricity and similar goods has been based on predictable, periodic fluctuation 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 of trade based on time zone differences emerge.

4 Concluding Remarks

This study highlights the role of business-services trade benefiting from time zone differentials and its impact on national factor markets. It is shown that an acceleration in intermediate business-services trade involving production in two time zones can have a huge impact on factor markets: switching from night-shift work toward day-shift work and an increased wage premium for skilled labor. Even more noteworthy is the finding that, via increased specialization, aggregate real income will be increased by trade with time zone differences. Although these results are derived under the specific assumptions that markets are perfectly competitive and the dissatisfaction from night-shift work is exogenously given, it appears that a more general setting would yield similar results.

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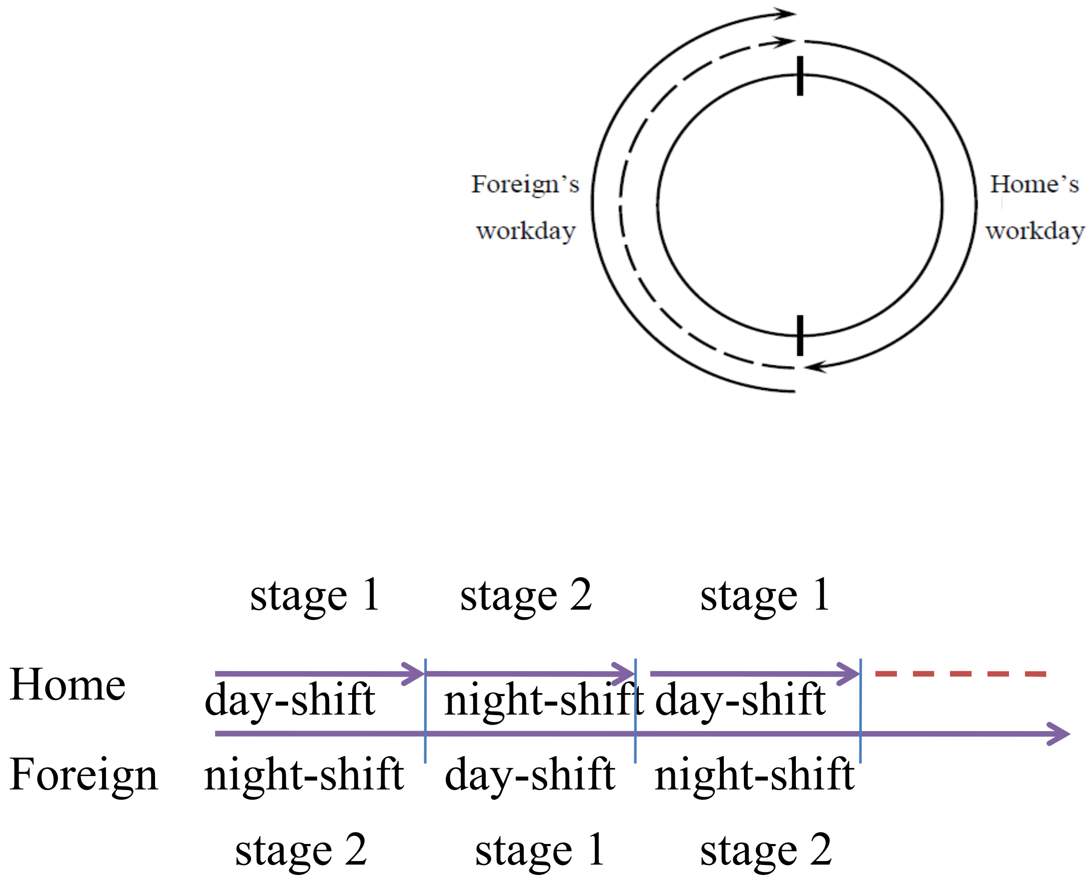
Figure 1



Foreign's workday
Home's workday
stage 1
stage 2
stage 1
Home
day-shift
night-shift
day-shift
Foreign
night-shift
day-shift
night-shift
stage 2
stage 1
stage 2

Figure 2 : Communications Autarky

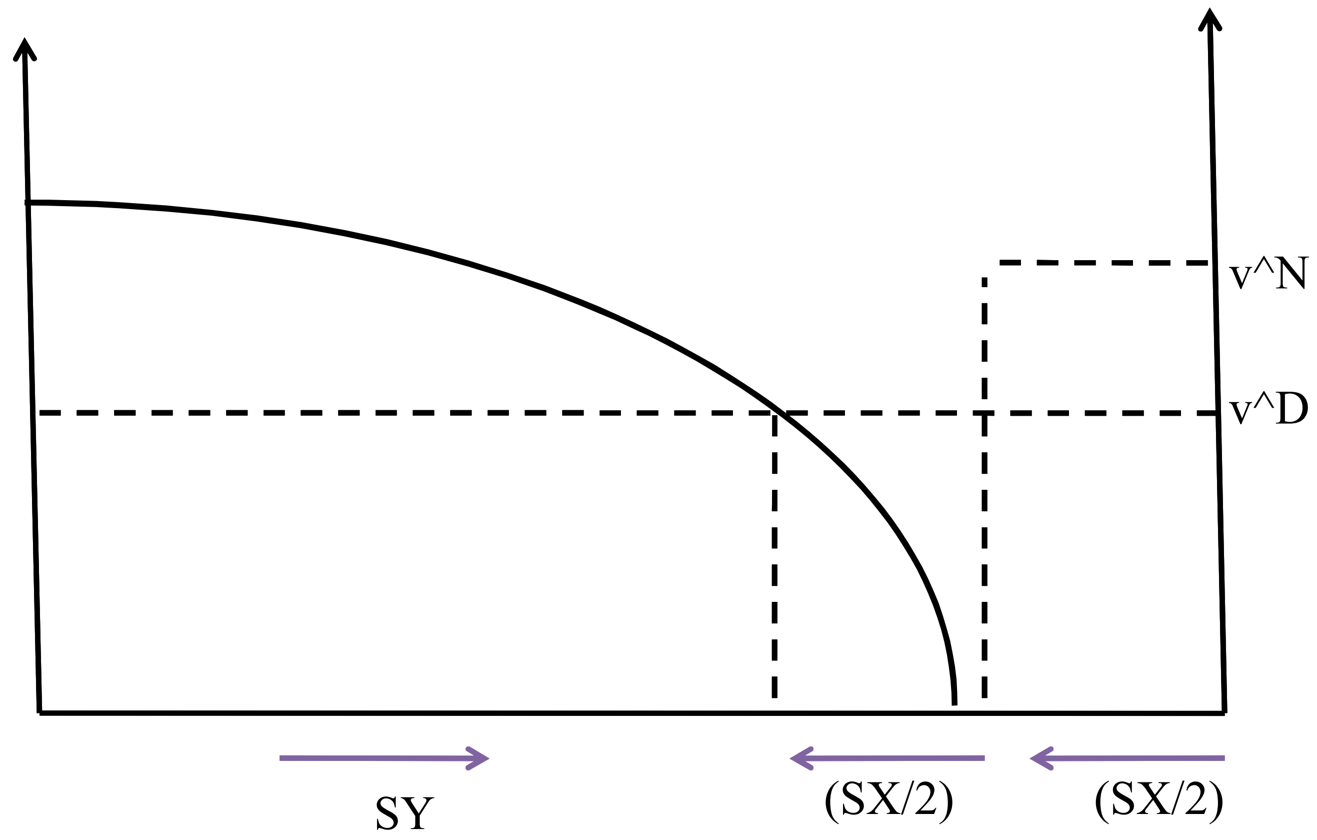
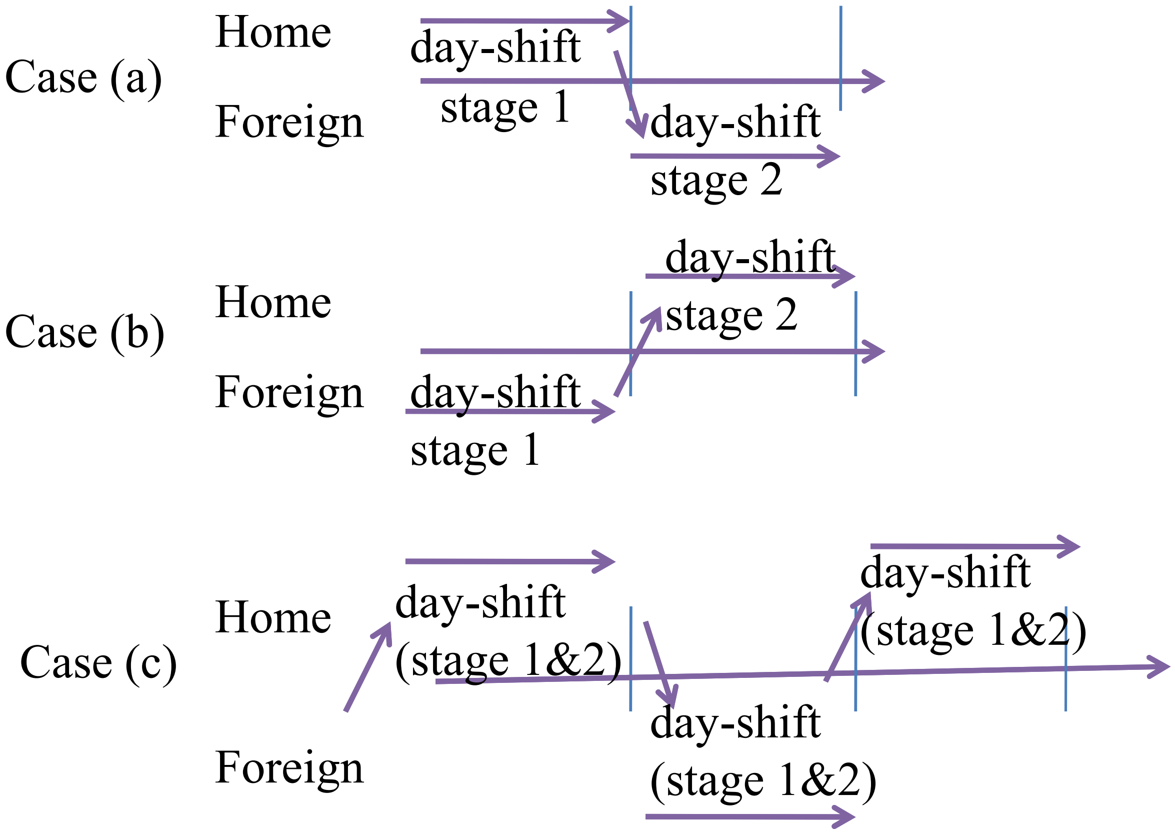


Figure 3



Case (a)
Home
Foreign
day-shift
stage 1
day-shift
stage 2
Case (b)
Home
Foreign
day-shift
stage 2
day-shift
stage 1
Case (c)
Home
Foreign
day-shift
(stage 1&2)
day-shift
(stage 1&2)
day-shift
(stage 1&2)

Figure 4 : Technological Advancement