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## Studies on Time Zones and International Trade: An Introductory Overview\*

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### Abstract

Trade in services has become an active area in the international scene of the modern economy. In addition, recent advancement of the information-communication technology (ICT) such as the Internet has brought about revolutionary changes in the ways through which international services transactions are made. In relation to this global trend, the notion of “time zone difference” has come into play as a new driver of international transactions. In this article we give an overview of the studies concerning the time zone difference and international trade. Theoretical literature emphasizes a positive, trade-facilitating effect (i.e., “continuity effect”) of the time zone difference. In addition to the continuity effect, empirical literature finds some pieces of evidence of an opposite effect (i.e., “synchronization effect”) that suppresses trade between countries. Empirical literature also finds that the continuity effect is more important in services sector (than in goods sector) and for those countries that enjoy higher levels of ICT infrastructure.

### 1 Introduction

It is well recognized that in the course of economic development the tertiary sector, which produces various services, has expanded its size and share in an economy faster and greater than the primary and secondary sectors, which produce agricultural goods, raw materials, and manufacture goods. This is known as Petty’s law. Even within the primary and secondary sectors, inputs of various *intermediate business services* such as advertisement, product design, and management consulting services, play some important roles in production and sales of the

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goods. Extensive utilization and production of various services in diverse stages of economic activities are, among others, distinctive features of a modern economy — the services economy.

Services are not storable in nature. Then, for a service transaction to be accomplished, it is often required that the buyer and seller be close each other and the consumption and production of the service should take place in the same location at the same time — a double coincidence of the buyer–seller proximity in both time and space.<sup>1)</sup> With this traditional view on services, large parts of the services economy have been considered as domestic activities that have almost nothing to do with international transactions.<sup>2)</sup> However, the advancement of information communication technology (ICT) in recent decades has changed the situation drastically: it has reduced the communication costs as well as other transaction costs remarkably and, thereby, brought about dynamic changes in the modes of distribution of information and services. In particular, the emergence and proliferation of the “Internet” have made it possible or easier to make international transactions of various services that had been difficult or almost impossible; furthermore, it has helped to create and expand a new range of service varieties that would have not otherwise existed. Examples include education (i.e., e-learning), legal advisory, business and management consulting, medical diagnoses and health care, software programming, and so forth. For the transactions of these services, the double coincidence is no longer required. Thanks to the Internet, the buyer and seller located in distant places can make instantaneous contact and transactions at significantly lower costs.

In parallel with the general trend of the services economy, *trade in services* has become an active area in the international scene.<sup>3)</sup> Based on the data from the World Bank’s World Development Indicators and Eurostat data, Head et al. (2009) have examined the growth of trade in services from 1985 to 2005. In their study, service sectors are divided into four subcategories: (1) government, (2) travel, (3) transport, and (4) other commercial services (OCS), which is further divided into (4a) financial services, (4b) computer and information, (4c) miscellaneous business services, and (4d) others. Head et al. (2009, p. 431) have observed that the service sector has grown faster than the goods sector; trade growth outstrips growth in value added; among the subcategories they examined, OCS trade has grown the most rapidly; although OCS, transport and travel each accounted for about a third of worldwide service exports in 1985, the shares of transport, travel and government services have declined over time whereas the share of OCS has risen to reach 48.1% in 2006.

To explain the phenomenon of the rapid growth of trade in services (in particular, that in

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1) Hill (1977).

2) Of course, there are some services (such as trade finance and maritime transportation) that have been playing important roles in international transactions for a long time.

3) According to General Agreement on Trade in Services (GATS) in the World Trade Organization (WTO), trade in services are classified into four modes: (a) mode 1 (cross-border trade), which includes services supplied from the territory of one Member into the territory of any other Member, (b) mode 2 (consumption abroad), which includes services supplied in the territory of one Member to the service consumer of any other Member, (c) mode 3 (commercial presence), which includes services supplied by a service supplier of one Member, through commercial presence, in the territory of any other Member, and (d) mode 4 (presence of natural persons), which includes services supplied by a service supplier of one Member, through the presence of natural persons of a Member in the territory of any other Member. For a brief introduction of GATS, see WTO (2019).

OCS) in relation to the revolutionary advancement of communication technology such as the Internet, the notion of *time zone difference* has recently attracted a great deal of attention. Time zone difference opens a new dimension in international trade theory: it “emerges as an independent driving force of international trade besides taste, technology and endowment” (Marjit, 2007) and has important implications for the overall economic welfare and international/domestic income distributions as well as for the economic growth of the countries. In this article, I briefly survey both theoretical and empirical studies that deal with the issues of time zone differences and international trade. Then, we examine the structure of mechanisms through which the time zone difference affects trade patterns, trade gains, income distributions and economic growth.

## 2 Time Zone Differences and Economic Activities

The earth rotates on its own axis; this generates cycles of morning, daytime, evening, and nighttime in this order (i.e., “days”). Noon of a particular location on the earth is generally determined as the time at which the relative position of the sun coincides with the line of terrestrial longitude of that location (i.e., the time when the sun is at the highest angle). The time period from noon to noon is divided into 24 equal portions (i.e., “hours”). In principle, different locations with different longitudes have different time periods; a longitudinal difference of 15 degree corresponds to 1 hour difference in time. Ignoring small longitudinal differences, the surface of the earth is divided into a number of areas — *time zones* — each of which shares the same time period. For example, the time zone including London (the UK) adopts the Greenwich Mean Time (GMT, or UTC: Coordinated Universal Time) whereas the time zone including Tokyo (Japan) adopts the Japan Standard Time (JST: UTC+9); the time difference between them comes to 9 hours.<sup>4)</sup>

The earth’s rotation and the resulting time zone differences affect human activities in two (closely related, but different) ways. First, because human nature has been biologically adapted to fit cyclic changes of day and night, it naturally follows that human activities become cyclic or periodic on the daily basis: an active period of the daytime is followed by an idle period of the nighttime, which is in turn followed by the next active period of the daytime and so forth. People are awake in the daytime and sleep in the nighttime. Because of this human nature, many economic activities of which completion take longer time than a day become *intermittent* or *discontinuous*. Offices or factories open in the morning, do business in the daytime, close in the evening, and rest in the nighttime.<sup>5)</sup>

Second, even if some people in a particular location are working in their daytime, some other people in another location of a sufficiently different longitude can take rests in their own nighttime. For example, when people in London begin to work in the morning at 9 : 00 a.m., people in Tokyo have already finished their work of the day and they are getting home in the evening at 6 : 00 p.m. At any given point of time, we can find some places on the earth where people are awake to work. From a global point of view, human economic activities never

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4) We are ignoring here the summer time in the UK

5) Some people work in the nighttime. We discuss the nightshift working and the whole-day operation later.

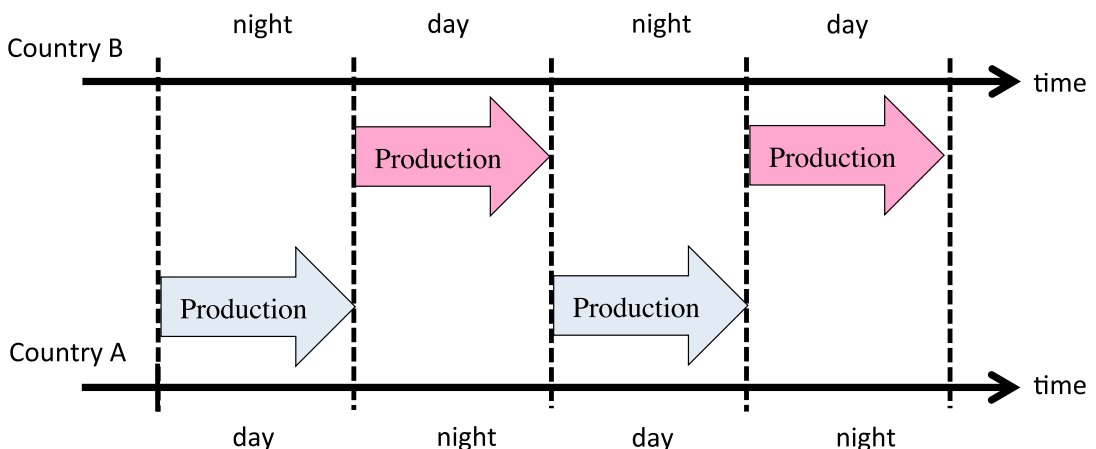
cease.

In reality, there are nearly 40 time zones on the earth and the absolute difference between a pair of different time zones varies from 1 hour to 12 hours. However, in order to clarify the roles of time zone differences, it suffices to consider a simple case where there are two time zones of which business hours do not overlap with each other.<sup>6)</sup> Let us consider two countries A and B, which are located in different time zones with no overlapping business hours as the case of London and Tokyo. Figure 1 illustrates the relation between regular business/production activities in countries A and B. In the figure, time is measured horizontally and divided into days and nights by turns. When country A is in the daytime (business hour, operating time), country B is in the nighttime (sleeping time, idle time) and vice versa.

In each country, in accordance with the human nature as a diurnal animal, regular production activities are processed only in the daytime. Therefore, if a certain production activity were to be confined in one time zone, it must be processed *intermittently* or *discontinuously*. Even if a production activity is not completed at the end of the business hour, it must be left untouched during the nighttime until the next business hour begins; the completion of the production activity is postponed. On the other hand, if we can somehow transfer or move a certain production activity from one time zone to the other quickly, it can be processed *continuously*. Suppose that a firm in country A begins to process a production activity in the morning, but cannot finish it at the end of country A's business hour. Then the firm has two options: to postpone processing the activity until the next day or to send the activity immediately to country B for further processing in the daytime of country B. If the firm chooses the latter, it can process a production activity continuously and curtail the length of time for its completion. This effect obtained by taking advantage of the time zone difference is known as *continuity effect* (Head et al., 2009).

Whether the continuity effect can be profitable or not depends on both the nature of the activity and the availability of efficient means of transferring the activity over different time

**Figure 1** Basic structure of time zone difference and production.



Source: Nakanishi (2013) with modification.

6) We take up the problem of overlapping business hours later.

zones. Not all production activities can capitalize on the time zone difference profitably. Let us, for example, consider production of a tangible good. If we want to transfer production of a tangible good from one time zone to another, it is necessary to move such items as raw materials, parts, or semi-products actually over the long distance between these time zones. The physical shipment of these bulky items, however, takes more time than what is curtailed by the continuity effect and imposes considerable transportation costs. For production of a tangible good, the continuity effect cannot (may not) be profitable.

Production of intangible services, on the other hand, can capitalize on the time zone difference profitably. Let us consider an example of a computer software industry in the US and India reported by Cairncross (1997). Engineers of a US software company work on drafting a “source cord” of a computer program. At the end of a business day, however, their task may not be completed. Instead of leaving the in-process file untouched by the beginning of the next business day, the company opts to send it to engineers in India through the Internet in order to continue the task of cord processing. The Indian engineers take over the task. During the nighttime in the US, the Indian engineers can brush up the source cord and run some preliminary tests in the daytime in India. At the end of the business day in India, the Indian engineers send the modified source cord back to the US office. Then, the US engineers can receive it in the morning and continue further processing. Note that *trade in services* occurs here: the US company *imports* the cord processing service from India. In this case, because the cord processing service is an intangible asset that does not require shipment of any physical materials and also because it can be transmitted quickly through the Internet at very low costs, the US software company can realize the continuity effect profitably by taking advantage of the time zone difference between the US and India.<sup>7)</sup>

As Marjit (2007) pointed out, for this type of services trade to be successful and profitable, two preconditions are required: (i) the time difference between trade partners’ locations is sufficiently large such that the proper division of labor is feasible and (ii) the services can be transported quickly at little costs.<sup>8)</sup> The case of the software industry in the US and India satisfies these requirements well. Other examples of trade in services with successful continuity effect include: a semi-conductor chip manufacturer that keeps 24-hour chip design systems by locating design teams separately in the US, India and Europe in order to respond to rapid changes in demand (Brown and Linden, 2009); call centers located in Ireland in order to cope with complaints and questions raised by customers in the US or in European countries (Gupta and Seshasai, 2007; Cairncross, 1997); medical diagnoses services (e.g., X-ray

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7) This cord processing offshoring can be seen as an example of “horizontal” division of labor in the sense that the same task (i.e., cord processing) is carried out in both countries. In contrast, we can think of an example of “vertical” division of labor that takes advantage of time zone differences. Let us consider the production of a computer-graphics animation movie: in one country, the original artist may draw a rough sketch for a certain plot of a story *by hand* and a scanned copy of the handwritten sketch is made at the end of the business hour of the day; then, the scanned copy is sent to the other country located in the opposite time zone in order to *digitize* the handwritten sketch and create its computer graphics during the nighttime of the former country; on the next day of the former country, the original artist starts drawing a sketch for another plot, and so forth. In this example, the original hand-drawing is carried out in one country, while the digitizing service is carried out in the other country.

8) Condition-(i) implies that the time-zone-related trade in services is possible only for a pair of countries with specific locations on the earth. This geographic condition cannot be overcome by any technological improvement and is one of the characterizing features of the time-zone-related trade in services.

reading) during the night in the US that are outsourced to other English-speaking countries in different time zones such as Australia, Malaysia, India, South Africa (Wachter, 2006).

### 3 Vertical Division of Labor and Comparative Advantage

To show how time zone difference and its continuity effect facilitate international trade, earlier theoretical contributions such as Marjit (2007), Kikuchi (2006), and Kikuchi (2009) focused on the roles of *vertical division of labor* and *outsourcing*. One important feature of offshore-outsourcing (or offshoring) taking advantage of the time zone differences should be mentioned. In the offshoring literature, it is often argued that various tasks and services are characterized by different factor intensities and that the range of offshored tasks/services is determined by the differences in the relative factor prices in the countries concerned. For example, the labor-intensive tasks/services are offshored to countries with low wage rates (i.e., to labor-abundant countries). On the contrary, the time-zone-related offshoring can occur without any differences in both factor intensity and relative factor price.

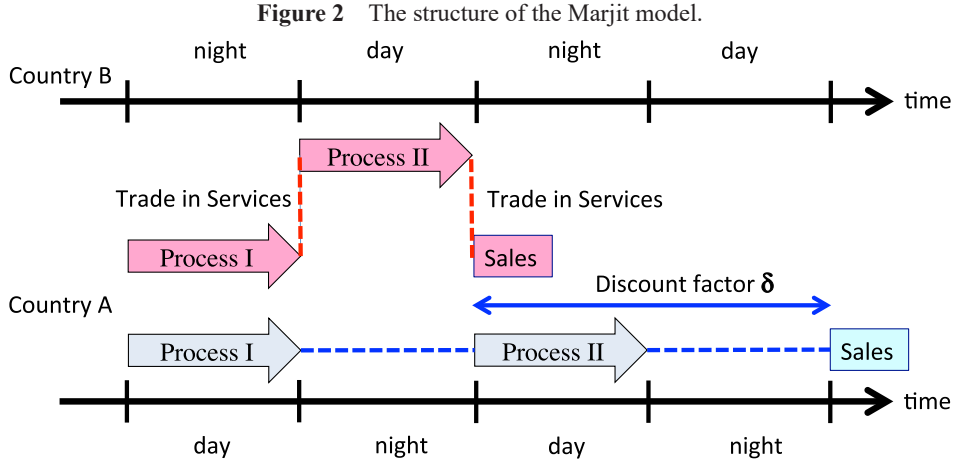
In addition to vertical division of labor and outsourcing, Marjit (2007) has emphasized the importance of *discounting*. He has constructed a simple Ricardian model with two countries (A and B) embedded in a larger world economy. Countries A and B are assumed to be *small* relative to the rest of the world and also *symmetric*, except that they are located in different time zones. Each country can produce a time-zone-related good  $X$  and a regular good  $Y$ . Production of one unit of  $X$  is divided into two vertically related stages I and II.<sup>9)</sup> Each stage requires  $1/2$  unit of labor and takes 1 working day; in addition, it is necessary to finish stage I before going into stage II. Therefore, production of one unit of  $X$  requires  $1 (= 1/2 + 1/2)$  unit of labor and takes 2 working days. Production of one unit of  $Y$  requires  $\beta$  unit of labor and takes only 1 working day. Markets of a country open every 24 hour; market transactions are made at the beginning of every day. Due to the small-country assumption, the prices of  $X$  and  $Y$  (i.e.,  $p_X$  and  $p_Y$ ) at a certain date are given exogenously. The discount factor per day is denoted by  $\delta$  ( $0 < \delta < 1$ ). The structure of Marjit (2007)'s model is illustrated in Figure 2.

Note that, because of the symmetry assumption and the Ricardian structure, inter-industry trade between countries A and B cannot occur in Marjit (2007)'s model. International trade between countries A and B (if any) must be *intra-industry trade*. Let us consider under what conditions such intra-industry trade can occur. We compare two alternative scenarios: one in which countries A and B specialize in  $Y$  and the other in which countries A and B specialize in  $X$  and engage in intra-industry trade between them.

Let us consider the first scenario. Suppose that production of  $X$  and  $Y$  start in Monday morning in country A. If 1 unit of labor is used to produce  $Y$ , then  $1/\beta$  units of  $Y$  become available by Monday evening. The cost of producing  $1/\beta$  units of  $Y$  is equal to the wage rate  $w_A$  in country A.  $1/\beta$  units of  $Y$  are sold in Tuesday morning at price  $p_Y$ ; the revenue from the sales of  $1/\beta$  units of  $Y$  amounts to  $p_Y/\beta$  (in Tuesday morning). On the other hand, if 1 unit of

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9) The argument of the time-zone-related offshoring crucially depends on the divisibility of a production process. Some portions of a production process are easily divided into several stages, while others are not; the time-zone-related offshoring is applicable only to the former.



Source: Nakanishi (2013) with modification.

labor is used to produce  $X$ , 1 unit of  $X$  become available by Tuesday evening and is sold in Wednesday morning at price  $p_X$ . The cost of producing 1 unit of  $X$  is  $w_A$ . The revenue from the sales of 1 unit of  $X$  amounts to  $\delta p_X$  (in Tuesday morning, not in Wednesday morning). Therefore, country A specializes in  $Y$  if  $\delta p_X < w_A = p_Y/\beta$  or equivalently

$$\frac{1}{\delta\beta} > \frac{p_X}{p_Y}. \quad (1)$$

By symmetry, country B also specializes in  $Y$  under the same condition.

Let us turn to the second scenario. Production of  $Y$  can be done in the same way as the first scenario. Suppose that stage I of producing 1 unit of  $X$  starts in Monday morning in country A. The cost of 1 unit stage I is  $w_A \times 1/2$  in country A, because the input coefficient of labor for stage I is  $1/2$ . After finishing stage I in Monday evening, a half-done  $X$  can be sent or *outsourced* to country B, where it is now at the beginning of (say) Monday morning — international trade in half-done  $X$  between countries A and B occurs.<sup>10)</sup> Stage II is processed during the daytime of Monday in country B. The cost of 1 unit stage II in country B is  $w_B \times 1/2$ , where  $w_B$  is the wage rate in country B. Then, 1 unit of  $X$  becomes available by Monday evening in country B. In total, the unit cost of producing 1 unit of  $X$  amounts to  $w_A/2 + w_B/2$ . A finalized  $X$  now can be sent back to country A and sold at the market in Tuesday morning in country A at price  $p_X$ . Therefore, countries A and B specialize in  $X$  and engage in intra-industry trade in  $X$  if  $w_A/2 + w_B/2 = p_X > p_Y/\beta$  or equivalently

$$\frac{p_X}{p_Y} > \frac{1}{\beta}. \quad (2)$$

10) Here, it is assumed that a half-done  $X$  can be transferred without any additional cost. In general, a transfer of production stages has to be subject to some transaction costs. In the theoretical literature, however, those transaction costs of transferring services are often assumed away in order to focus on the continuity effect of the time zone differences.



(Note that, by symmetry, we have  $w_A = w_B$  in equilibrium.) Combining equations (1) and (2), we obtain the condition for intra-industry trade in  $X$  due to time zone difference to occur:

$$\frac{1}{\delta\beta} > \frac{p_X}{p_Y} > \frac{1}{\beta}. \quad (3)$$

Obviously, the above condition cannot be true without the discount factor  $\delta$ .

In the above argument for the second scenario, we assumed that stage I starts in country A. That is, a half-done  $X$  is exported from country A and a finalized  $X$  is exported from country B. By symmetry, however, stage I can start in country B as well. Hence, the pattern of intra-industry trade in  $X$  between countries A and B is indeterminate in Marjit (2007)'s model. On the other hand, gains from intra-industry trade in  $X$  can be shown clearly. Let  $\bar{w}_k$  be the wage rate of country  $k$  in equilibrium with no intra-industry trade (the first scenario) and  $w_k^*$  be that in equilibrium with intra-industry trade (the second scenario). As discussed above, we have

$$w_k^* = \frac{w_A^*}{2} + \frac{w_B^*}{2} = p_X > \frac{p_Y}{\beta} = \bar{w}_k, \quad k = A, B. \quad (4)$$

Under condition (3), trade liberalization (i.e., the occurrence of intra-industry trade in  $X$ ) between A and B certainly raises the wage rates of both countries and brings trade gains.

Instead of emphasizing discounting as in Marjit (2007), Kikuchi (2009) has emphasized the roles of *communication networks* through which trade in services are carried out.<sup>11</sup> His model consists of two symmetric countries (A and B), two goods (a time-zone-related good  $X$  and numéraire  $Y$ ), and an “intermediate business service”  $Z$ , which comes in differentiated varieties.  $X$  is produced under constant-returns-to-scale technology (CES production function) using only differentiated business services  $Z$  as inputs. Differentiated business services  $Z$  are supplied by monopolistically competitive service firms. Each unit of a business service requires production in two stages I and II — vertical division of labor. Each stage takes 1 working day for completion; stage II must follow the completion of stage I. Therefore, if a variety of business services  $Z$  is produced in a country, it takes 2 working days.

Business service firms in one country have two options: one is to produce their services within one country and the other, taking advantage of time zone difference, is to outsource one of the stages to the other country. Kikuchi (2009) has introduced possible gain and loss from outsourcing. The loss is related to communication networks. In order to make *international* transactions of business services, firms must get on communications network, which requires some additional fixed costs — the connection cost. The gain is related to specialization. If, for example, stage I is outsourced from country B to country A and stage II is outsourced from country A to country B, then country A can concentrate on processing stage I and country B on stage II. Such specialization in one of the stages in each country brings about *efficiency gain*, which is represented by a reduction of unit labor cost.

Based on the above setting, Kikuchi (2009) has shown several interesting results: (i) if the connection cost is sufficiently low and the efficiency gain due to specialization is sufficiently high, then it is more profitable to outsource than to maintain a communications

11) The model in Kikuchi (2006) is intrinsically the same as the model in Kikuchi (2009).

autarky; (ii) a pair of “connected” countries who are trading intermediate business services has a comparative advantage in the time-zone-related good X; (iii) if the expenditure share for good X is sufficiently small, then countries gain from trade in services.

It is easy to explain result-(i): business service firms would carry out the offshoring via communications network, simply because the net cost of offshoring is sufficiently low. Result-(ii) can be explained as follows. By the offshoring of production stages, each country can specialize in only one of two stages and realize the efficiency gain. Then, the business services available to the “connected” countries become less expensive, making the cost of the time-zone-related good X produced in these countries less expensive, too. Lastly, the intuition behind result-(iii) goes as follows. On one hand, it is well known that gains-from-trade in a trade model with increasing-returns-to-scale (IRS) is possible if the IRS sector expands after trade liberalization. On the other hand, because the good-X sector in the Kikuchi model exhibits IRS, which is consistent with the assumption of perfect competition in the good-X sector, due to increase in the range of business services, the supply curve of good X becomes downward-sloping. Therefore, in order for the good-X sector in the Kikuchi model to expand after liberalization, the price of good X has to be *lowered* after liberalization. If, contrary to result-(iii), the expenditure share for good X is large enough, the large demand for good X after liberalization induces an increase in the price of good X.

Kikuchi and Iwasa (2010) is another attempt to show how time zone difference and its continuity effect facilitate international trade. Their model is a simple variant of Krugman-type monopolistically competitive trade model with transportation costs. Their model does not rely on either vertical division of labor or outsourcing, instead it emphasizes the roles of domestic as well as international delivery costs. They assume that markets are open every 24 hour in the morning in each country and that production of 1 unit of service takes only 1 working day. If a business service firm in a country wants to supply services to its own country, it has to wait for one night after finishing services production of the day until the market of the country opens. The waiting time constitutes the *domestic delivery cost*. On the other hand, if a business service firm wants to supply services to the other country, it does not have to wait. Because the market of the other country opens when the firm has just finished the production of services at the end of business hour of the day, it can quickly serve the other country through the communications network. To get on the communications network, however, some additional costs are required; this constitutes the *international delivery cost*.

#### 4 Shift-Working, Virtual Labor Mobility, and Income Distribution

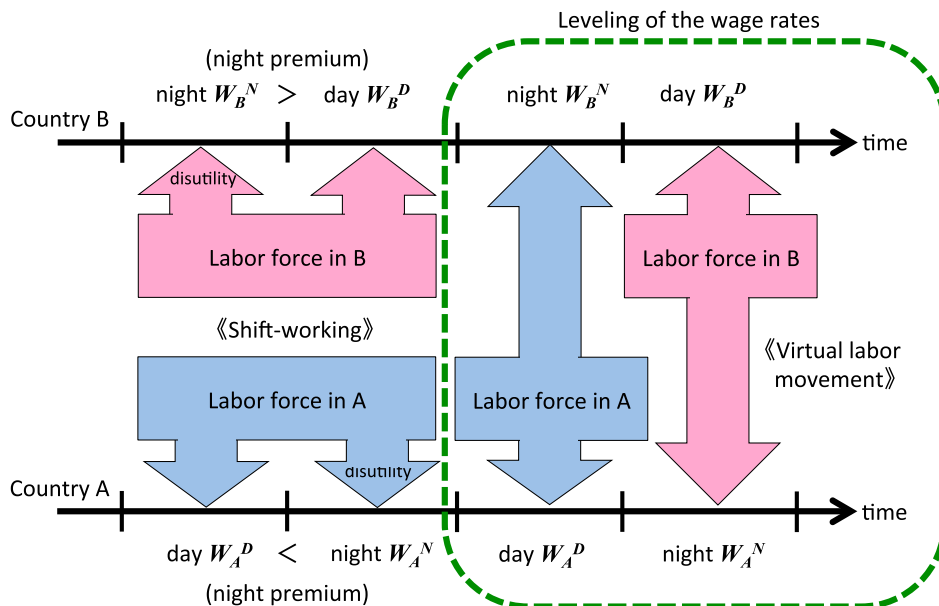
So far, we have assumed that the workers in a country works only in the local daytime. In order to complete two consecutive stages of the production of a time-zone-related good in a single country, a firm has two alternative ways of operation: one is a two-day operation, in which the firm only operates in the daytime and takes two regular working-days, and the other is an around-the-clock operation, in which the firm operates over the whole day (i.e., all day and night). To operate around the clock in a single country, the firm has to hire both the dayshift and nightshift workers. Normally, people (as a diurnal animal) do not want to work on the nightshift because the nightshift-working entails severer disutility than the dayshift-working. Therefore, the firm has to pay a higher wage rate to the nightshift workers than that

to the dayshift workers (i.e., the nightshift premium) in order to compensate the disutility from the nightshift-working. Otherwise, no labor force will be supplied to the nighttime labor market. At the same time, however, the nightshift premium wage rate causes a higher cost of production for the firm.

Suppose now that we can take advantage of the time zone difference between countries. When a country (say, country A) is in the nighttime and the local workers there are sleeping, the workers in another country (say, country B) located in the completely opposite time zone are awake and operating in their daytime with being paid a (relatively lower) daytime wage rate. Therefore, if a firm in country A can somehow make use of country B's dayshift workers instead of the nightshift workers in country A, the firm can operate continuously around the clock without hiring the nightshift workers in country A and, thereby, save the nightshift premium and reduce the cost of production. This cost reduction enabled by taking advantage of time zone difference and by replacing/substituting the nightshift workers in one country with the dayshift workers in the other country can be called the *day-night-reversal effect*. The concepts of shift-working and virtual labor mobility are illustrated in Figure 3.

Matsuoka and Fukushima (2010) have examined the implications of time-zone-related trade in services on 24-hour continuous operation and nightshift-working. They assumed that intermediate business services, which are inputs to the production of the time-zone-related good, are produced by using only labor and traded internationally through the communications network. The production process of intermediate business services is divided into two consecutive stages, each of which takes one regular working day (i.e., 12 hours), but these stages have to be carried out without any interruption. That is, the production of intermediate

Figure 3 Shift-working and virtual labor mobility.



Source: Nakanishi (2013) with modification.

business service requires contiguous 24 hours. Then, without trade in intermediate business services through the communications network, the business service firms have to incur the extra cost of the nightshift premium wage rate to complete the production of intermediate business service within one full day. In the Matsuoka-Fukushima model, the gains from liberalization of trade in intermediate business services stem from the reduction of the nightshift workers due to the day-night-reversal effect.

When the firms in one country are using the intermediate business services produced in the other country, we can say that the firms are *indirectly* employing the labor forces used to produce the intermediate business services in the latter country. In effect, trade in intermediate business services enables the labor forces to move across countries — the *virtual labor mobility*. If the nightshift workers in one country is completely replaced with the dayshift workers in the other country located in the opposite time zone through the virtual labor mobility, then the nighttime wage rate in the former country will be equalized to the daytime wage rate in the latter. In other words, the nighttime labor market in the former and the daytime labor market in the latter are virtually integrated into a single market. This observation suggests that the liberalization of time-zone-related goods/services may have significant effects on the income distribution in the countries concerned. However, because labor is the only factor of production in the models of Marjit (2007), Kikuchi (2006), Kikuchi and Iwasa (2010), and Matsuoka and Fukushima (2010) taken up so far, these models cannot be used to delve further into the problem of income distribution.

Kikuchi and Long (2011) were the first to examine the implications of shift-working and virtual labor mobility on income distribution and on some other problems. To this end, they have constructed a model with two countries (Home and Foreign) and two goods (X and Y) along the lines with the standard Heckscher-Ohlin-Samuelson (HOS) model. In the Kikuchi-Long model, Home and Foreign are identical in every aspect except that they are located in the completely opposite time zones. In both countries, X and Y are produced by using both capital and labor under constant-returns-to-scale technology. Capital is not mobile across countries, while labor can become virtually mobile across countries if the advancement of the ICT technology makes it possible to supply labor services in one country to the other via the communications network. We shall use the term “communications liberalization” to refer to trade in services or in labor force made possible by the reduction of the communication cost due to the advancement of ICT. Good X can be produced both in the daytime and in the nighttime, while good Y is produced only in the daytime. Then, the capital employed in the good-Y production lies idle in the nighttime. In contrast, the capital employed in the good-X production can operate both in the daytime and in the nighttime. Kikuchi and Long (2011) have assumed that the capital/labor ratio (i.e., capital intensity) of the daytime production of good X is the same as that of the nighttime, which is, of course, different from the capital intensity of the good-Y production.

As discussed above, if the good-X firms in one country want to operate throughout the night by employing the local nightshift workers (i.e, without virtual labor mobility), they have to pay a higher wage rate to the nightshift workers. If, on the other hand, the good-X firms in one country become able to employ the dayshift workers in the other country during the firms’ own local nighttime, then the nightshift premium wage rate will be equalized to the daytime wage rate in the other country. Further, if the local nightshift workers are completely replaced

with the foreign dayshift workers after the communications liberalization, in other words, if the local workers work only in the local daytime, the nightshift premium vanishes. In this case, the local daytime wage rate, the local nighttime wage rate, and the foreign daytime wage rate converge to a certain level. It should be noted that the convergence of these wage rates does not mean that the lower daytime wage rate increases and the higher nighttime wage rate decreases. Kikuchi and Long (2011) have shown that if the good-X sector is more capital intensive than the good-Y sector, the virtual labor mobility due to the communications liberalization brings about a decrease in the daytime wage rate (also, a decrease in the nighttime wage rate) and an increase in the rental rate.

The effects of the time-zone-related virtual labor mobility on income distribution (in particular on the wage rates) in the Kikuchi-Long model are ambiguous in the sense that they depend crucially on the assumption on the difference in capital intensities (which is given somewhat ad hoc), but not on the very nature of the virtual labor mobility. To obtain much clearer results on income distribution, Nakanishi and Long (2015) have constructed a model with two countries (Home and Foreign) and two goods (X and Y) along the lines with the standard Specific-Factors model with two specific factors (i.e., capital and land) and one general factor (i.e., labor). The outline of the Nakanishi-Long model is almost the same as the Kikuchi-Long model except that capital is specific to the time-zone-related good X; land is specific to the traditional good Y; and labor is general for both goods. Nakanishi and Long (2015) have examined two cases: one where both countries are completely identical and the other where Home is proportionally larger than Foreign in terms of the factor endowments.<sup>12)</sup>

In the case of identical countries, Nakanishi and Long (2015) have shown that the virtual labor mobility due to the communications liberalization brings about an increase in the daytime wage rate in Home (i.e.,  $w_H^D$ ) and a decrease in the nighttime wage rate in Foreign (i.e.,  $w_F^N$ ). Consequently, both the daytime and nighttime wage rates converge to a certain common value, that is,  $w_H^D = w_F^N$ . Similarly, we obtain the equalization of the nighttime wage rate in Home (i.e.,  $w_H^N$ ) and the daytime wage rate in Foreign (i.e.,  $w_F^D$ ). In this case, the nightshift workers are completely replaced with the dayshift workers in the other country — Every worker in each country works in its own daytime, but do not work on the nightshift. This implies both  $w_H^D \geq w_H^N$  and  $w_F^D \geq w_F^N$ . Eventually, we obtain the full convergence of various wage rates:  $w_H^D = w_H^N = w_F^D = w_F^N$ . Further, because the daytime wage rate increases, the land rent in the good-Y sector decreases. Under certain plausible conditions on the production function of good X, we can show that the virtual labor mobility results in an increase in the capital rental rate in the good-X sector. Furthermore, the full convergence of various wage rates implies the equalization of capital rental rates and that of land rents in both Home and Foreign. In this case, the factor price equalization obtains.

In the standard Specific-Factors model, as well as the HOS model, the scale of an economy in terms of the factor endowments does not affect the determination of the factor

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12) There are other papers that deal with the relation between income distribution and trade in time-zone-related goods/services. For example, Kikuchi et al. (2013) have examined the implication of the time-zone-related trade in services on income distribution by using a hybrid model of Ricardian and Specific-Factors models. They have paid special attention to the inequality between the skilled and unskilled labor. By using a model similar to Kikuchi (2013), Mandal et al. (2018) have also examined the effects of time-zone-related trade on the wage inequality by focusing on the roles of educational capital.

prices. Quite interestingly, in the Nakanishi–Long model featuring shift-working and virtual labor mobility, the difference in the sizes of countries brings about significant consequences on the income distribution in the countries. Suppose that Home is sufficiently larger than Foreign. Then, the demand for the nighttime labor in Home becomes very large and, therefore, cannot be fully met by the (small) supply of the dayshift labor via the virtual labor mobility from Foreign. Accordingly, some Home workers have to work on the nightshift even under the communications liberalization. To induce the Home residents to work on the nightshift in Home, the Home nighttime wage rate  $w_H^N$  must be higher than the Home daytime wage rate  $w_H^D$ , that is,  $w_H^N > w_H^D$ . In contrast, due to the virtual labor mobility, the Home daytime wage rate  $w_H^D$  is equalized to the Foreign nighttime wage rate  $w_F^N$ . Similarly, the Home nighttime wage rate  $w_H^N$  is equalized to the Foreign daytime wage rate  $w_F^D$ . Eventually, we obtain  $w_F^D = w_H^N > w_H^D = w_F^N$ . Because we have  $w_F^D > w_F^N$ , no Foreign resident works on the nightshift. Instead, the Foreign demand for the nightshift workers will be completely met by the dayshift workers supplied from Home via the communications network.

The effects of the virtual labor mobility on the income distribution in a smaller country (i.e., Foreign) are different from those in a larger country (i.e., Home). In Foreign, the virtual labor mobility due to the communications liberalization brings about a decrease in the nighttime wage rate and an increase in the daytime wage rate as naturally expected. Further, the nighttime wage rate becomes lower than the daytime wage rate. The increase in the Foreign daytime wage induces a decrease in the Foreign land rent in the Y-sector. Similar to the case of identical countries, the Foreign capital rental in the X-sector increases.

In Home, on the other hand, because the Foreign dayshift workers, who have been paid a lower wage rate, becomes available to the Home X-producers as the nightshift workers in Home via the communications network, the Home nighttime wage rate definitely decreases. Then, some of the Home nightshift workers move away from the Home nighttime labor market toward the Home daytime labor market. In effect, the virtual labor mobility increases the labor supply to the Home daytime labor market. The demand for labor in the Home daytime labor market comes from the Home Y-producer in Home, the Home X-producer, and the Foreign X-producer. Facing the decrease in the nighttime wage rate in Home, the Home X-producers shift the share of production toward the nightshift production in Home and, therefore, decrease the daytime demand for labor to the Home daytime labor market. In sum, the virtual labor mobility gives rise to a tendency of excess supply in the Home daytime labor market. Accordingly, unlike the case of identical countries, it may be the case that the Home daytime wage rate would decrease — This somewhat unusual case is possible when Home is sufficiently larger than Foreign. The Home land rent in the Y-sector will decrease if and only if the Home daytime wage rate under the virtual labor mobility increases. Further, we can show that if the marginal product of capital is concave in labor, the virtual labor mobility results in an increase in the Home capital rental in the X-sector.<sup>13)</sup>

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13) Both Kikuchi and Long (2011) and Nakanishi and Long (2015) have examined the implications of shift-working and virtual labor mobility not only on income distribution but also on the structure of production and comparative advantages of the countries. They have shown that a pair of countries, which are connected by the communications network and engaging in the mutual trade in virtual labor services, has a comparative advantage on the time-zone-related shift-working good X.

## 5 Economic Growth

Liberalization of the time-zone-related goods/services has significant influence not only on the static efficiency of the world production but also on the long-run growth of the world economy.

Kikuchi and Marjit (2011) have examined the implications of time-zone-related trade on the long-run growth rate. They have focused on the roles of intermediate business services, which can be traded internationally over different time zones via communications network. They constructed a variant of so-called “AK growth model” with two countries (Home and Foreign) and two goods (Home good and Foreign good). Each good is produced under constant-returns-to-scale technology by using capital, domestic intermediate business service, and imported intermediate business service. The production function of Home good is represented by

$$Y = K^\alpha (X)^{\frac{1-\alpha}{2}} (X^*)^{\frac{1-\alpha}{2}}, \quad 0 < \alpha < 1, \quad (5)$$

where  $Y$  is the quantity of Home good,  $K$  is the input of capital,  $X$  is the input of domestic intermediates, and  $X^*$  is the input of imported intermediates. Trade in intermediate business services (in either direction) is subject to transaction costs, which can be regarded as the “time costs” for the delivery of intermediates. The conditions for the profit maximization yield the derived demand functions for both domestic and imported intermediates. By substituting the derived demand functions for the intermediates back into the production function, we obtain the reduced production function  $Y = AK$ , which is linear in the capital input  $K$  as in the standard AK growth model. The productivity parameter  $A$  depends negatively on the transaction costs of intermediate business services. By assuming a constant saving rate (i.e.,  $0 < s < 1$ ), the equation of motion for capital in Home becomes

$$\dot{K} = sY - \delta K, \quad (6)$$

where  $\delta > 0$  denotes the depreciation rate. Taking account of the reduced production function  $Y = AK$ , we obtain

$$\frac{\dot{K}}{K} = sA - \delta. \quad (7)$$

Similar relations can be obtained for Foreign. Since  $A$  is negatively dependent on the transaction costs, we can conclude that trade liberalization of intermediate business services enhanced by the reduction in the transaction costs raises the permanent long-run growth rate. Marjit and Mandal (2017) have extended a simple AK model of Kikuchi and Marjit (2011) to an optimal growth model, in which the saving rate is determined endogenously through intertemporal consumption-smoothing by the household sector, and shown that liberalization of the time-zone-related business services gives rise to both an increase in the *level* of GDP and an increase in the *growth rate*. The expanded availability of the intermediate business services due to communications liberalization is the driving force of the growth in the

Kikuchi-Marjit and Marjit-Mandal models.

In contrast to the AK-type models by Kikuchi and Marjit (2011) and Marjit and Mandal (2017), which focused on the roles of intermediate business services, Nakanishi and Long (2018) have constructed a Schumpeterian quality-ladder model of endogenous growth with two countries (North and South) located in the opposite time zones.<sup>14)</sup> They have paid special attention to the roles of outsourcing of research and development (R&D) activities conducted by employing skilled workers. In the Nakanishi-Long growth model, it is assumed that research firms are located only in North; that each R&D project is divided into a number of steps, which must be conducted consecutively in order; and that the fruit of an R&D project is *uncertain* in the sense that the R&D productivity is a stochastic variable drawn from a certain distribution function. Because the researchers (i.e., skilled workers) in North work in their own daytime, there is a limit of the number of R&D projects that can be completed within a certain period of time (i.e., a year) only in North. If some steps of an R&D project are outsourced from North to South (i.e., R&D offshoring) during the nighttime of North by taking advantage of time zone difference, the total number of R&D projects that can be completed in a year will be doubled. With this setting, Nakanishi and Long (2018) have shown that the R&D offshoring brings about an immediate decrease in the Northern *skilled* wage rate, an immediate increase in the Northern *unskilled* wage rate, and an increase in the long-run growth rate along the balanced growth path. In their model, the increased access to the pool of Southern skilled workers due to the virtual labor mobility via communications network is the driving force of economic growth.<sup>15)</sup>

## 6 Empirical Studies

Comparing to theoretical literature, there are only a limited (though growing) number of empirical researches that directly address the time-zone-related trade and investment. In this section, I briefly review some of those empirical studies.

Almost all of the empirical studies concerning the time zone issues are based on the “gravity equation,” which associates the volume of bilateral trade or other bilateral transactions between two countries with the *magnitudes* of these countries and the *distance* between them. The magnitude of a country can be identified with its GDP, while the distance between two countries may include not only the physical distance but also other impediments to trade such as transportation costs, trade taxes, differences in languages and/or cultural backgrounds, and so forth. In this article, *time zone difference* comes into play as the most important component of the distance variables.

Let  $Y_{ij}$  be the volume of bilateral transaction between countries  $i$  and  $j$ ; let  $X_i$  and  $X_j$  be the magnitudes of countries  $i$  and  $j$ , respectively; and let  $D_{ij}$  be the distance variable between countries  $i$  and  $j$ . Then, the basic equation for estimation based on the gravity equation becomes as follows:

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14) For a standard Schumpeterian endogenous growth model, see Aghion and Howitt (1992), Aghion and Howitt (2009).

15) Nakanishi and Long (2018) have also examined the implications of R&D offshoring on the skilled and unskilled wage rates in South and the Southern growth rate.



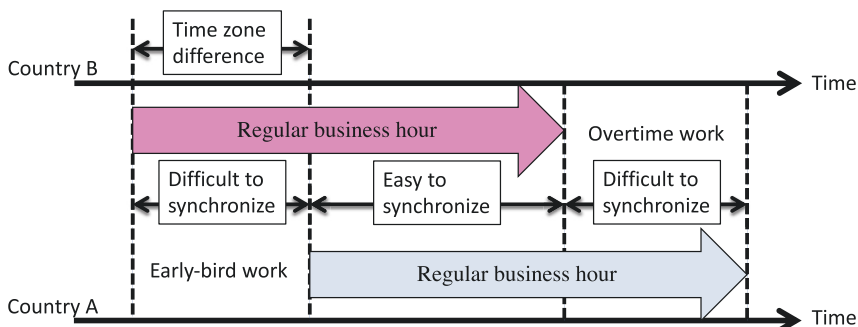
$$\ln Y_{ij} = \beta_0 + \beta_1 \ln X_i + \beta_2 \ln X_j + \beta_3 \ln D_{ij} + \varepsilon_{ij}, \quad (8)$$

where  $\beta_0$  is a constant term and  $\varepsilon_{ij}$  is an error term. Bilateral transactions between countries are considered to get more active when the income levels of the countries become higher on one hand, less active when the distance between them becomes larger on the other. Naturally, the following sign patterns of the coefficients are expected:  $\beta_1, \beta_2 > 0$  and  $\beta_3 < 0$ .

When we estimate the gravity equation including time zone difference, we have to be careful about the distinction between the notions of physical distance and time zone difference between countries. Although these notions are closely related, a larger physical distance does not imply nor is implied by a larger time zone difference. Usually, the physical distance between two countries is measured by the great-circle distance between the capital cities of the countries. When the time zone difference were to be incorporated into estimation, the physical distance will be decomposed into two elements: the *longitudinal* element, which measures the East-West distance, and the *latitudinal* element, which measures the North-South distance. The time zone difference can be identified with the longitudinal element.

The motivation of early empirical studies concerning the time zone difference was to find factors (other than the “transportation cost”) that hinder international transactions. Then, these early empirical studies presupposed that the time zone difference is nothing but a cost-augmenting factor. The story behind this presupposition goes as follows. Consider a multinational enterprise that has the headquarter and a foreign subsidiary, which are located in different time zones with some (but, not completely) overlapping regular business hours. If the headquarter wants to keep close and frequent communication with the subsidiary, the length of the overlapping regular business hour affects the overall cost of the enterprise. If the overlap is large (i.e., the time zone difference is small), people in the headquarter and the subsidiary can exchange information between them frequently via e-mail, telephone, or other swift electronic means of communication during their respective regular business hours — For the headquarter and the subsidiary, it is easy to synchronize their jobs. In contrast, if the overlap is small (i.e., the time zone difference is large), some people (either in the headquarter or in the subsidiary or both) have to come to the office earlier or stay longer than the regular business hours. (See Figure 4.) Those early-bird and/or overtime works require extra payments to the workers and, thereby, bring about a burden of higher labor cost. Head et

**Figure 4** Synchronization effect.



Source: Nakanishi (2015) with modification.

al. (2009) called this negative impact of the time zone difference the *synchronization effect*.

Stein and Daude (2007) were one of the earliest empirical studies that take explicit account of the time zone issues. They considered the stock of FDI as the indicator of the volume of bilateral transaction. Using the data from the OECD direct investment statistics, which include 17 source countries and 58 host countries, they estimated a gravity equation incorporating time zone difference by following Tobit approach. They found that the estimate of coefficient for the time zone difference is *negative* ( $-0.303$ ) and statistically *significant* at 1% level. Their result implies that a 1-hour increase in the time zone difference reduces the bilateral FDI stock by around 26% ( $-0.261 \approx \exp[-0.303] - 1$ ).

Hattari and Rajan (2008) have focused on the bilateral FDI flows into developing Asian countries and examined the roles of distance and time zone difference. They have constructed a balanced panel data set from the UNCTAD FDI/TNC and EIU's World Investment Services databases and, following the two-step Tobit approach, estimated a gravity equation incorporating both time zone difference and physical distance. They found that the estimate of coefficient for the time zone difference is *negative* ( $-0.176$ ) and statistically *significant* at 1% level. Further, they found that the estimate of coefficient for the physical distance, which is negative, becomes larger in absolute value by the factor of two when the time zone difference is excluded from the estimation. Then, they argued that part of the effects of the physical distance is attributable to the time zone difference.

Time zone difference may affect (tangible) merchandise and (intangible) services differently. Moreover, because services are composed of a wide range of heterogeneous functionings, the effects of time zone difference may vary across different services. In view of this, Head et al. (2009) have classified various international transactions into several different categories such as merchandise, the total services, OCS (Other Commercial Services), finance, IT (Information Technology), MBS (Miscellaneous Business Services) and, then, examined each category separately. They considered the flow of export as the dependent variable. In every specification, they found that the estimate of coefficient for the physical distance is *negative* and statistically *significant* at 1% level, which is consistent with other studies. At the same time, however, they found an unusual result: in the case of merchandise, the estimate of coefficient for the time zone difference is *positive* and statistically *significant* at 1% level. This unusual result contradicts the findings by Stein and Daude (2007) and, also, it is against the intuition behind the theoretical consideration.

As the theoretical literature suggests, some *positive* effects of time zone difference become more likely in the "service" sector, in particular, those services that can be transacted quickly through the communications network such as the Internet. Dettmer (2011) has focused on bilateral export in services and emphasized the roles of the ICT infrastructure and its interconnectivity between countries. Using the OECD Statistics on International Trade in Services database, she estimated a gravity equation including the time zone term, the interaction term of the ICT terms of countries, and the interaction term of the time zone and ICT terms.<sup>16)</sup> She found that in the case of commercial and other business services, both the estimates of coefficients for the time zone difference and for the interaction term of time zone and ICT are *posi-*

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16) The ICT infrastructure is measured by the per capita number of cell phones, fixed-line phones, and personal computers or by the per capita expenditure on those items.

tive and both are statistically *significant* at 1% level.

Tomasik (2013) has introduced a dummy variable that indicates the “service” sector and the interaction term of time zone and services into the estimation. She considered export (in both merchandise and services) as the indicator of volume of bilateral transactions. She found that the estimate of coefficient for the time zone alone is *negative* (−56.048) and statistically *significant* at 1% level, while the estimate of coefficient for the interaction term is *positive* (+50.571) and statistically *significant* at 1% level. From her findings, we can confirm that the synchronization effect is dominant for over all trade, but the continuity effect comes into play for trade in services.

## 7 Remarks

We have briefly reviewed both theoretical and empirical studies that deal with the issues of time zone differences and international trade and other transactions.<sup>17)</sup> Time-zone-related international trade is a relatively new, promising arena to explore, but it still needs to be elaborated.

On the theoretical side, the literature so far has been mainly concerned with the production of the time-zone-related goods/services. However, little attention has been paid to the consumption side. Of course, there are some time-zone-related consumer services: for example, the call center located on the opposite time zone (Gupta and Seshasai, 2007; Cairncross, 1997). How do people generate the demand for time-zone-related services and how do producers of services respond to those demand from the consumers? We need more sophisticated theory of consumption/production of services, which captures intrinsic characteristics of services.

On the empirical side, the literature so far has examined whether the time zone difference affects international transactions positively (i.e., continuity effect) or negatively (i.e., synchronization effect). As indicated by the theoretical literature, the time zone difference has significant effects not only on international trade in goods/services and FDI but also on the income distribution and economic growth of countries. Unfortunately, as far as I know, there is no empirical study that examines the time-zone-related income distribution or growth directly. Progress of empirical studies in this direction would be desirable.<sup>18)</sup>

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18) An article by Bøler et al. (2018) is an interesting attempt to find empirical evidence that associates the systematic difference in the gender wage gap between exporting firms and non-exporters with time zone differences.

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