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# Growth with Time Zone Differences

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## Abstract

We propose a two-country growth model of intermediate business-services trade that captures the role of time zone differences. It is shown that a time-saving improvement in intermediate business-services trade involving production in different time zones can have a permanent impact on productivity.

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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.<sup>1</sup> 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 Brown and Linden (2009, p. 87):

“Some chip companies with foreign design subsidiaries value the opportunity to design on a 24-hour cycle because of the enormous pressure to reach the market ahead of, or no later than competitors. One established US chip company adopted a rolling cycle between design centers in the United States, Europe, and India.”

In other words, due to the communications revolution, time zone differences

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<sup>1</sup>In what follows, for brevity, we will refer to both Information and Communication Technology (ICT) services and Business Process Outsourcing (BPO) as “business services.”

may become a primary driving force behind business-services trade.<sup>2</sup> It is increasingly recognized that the rapid growth of India's economy is attributable to this kind of business-service trade utilizing time zone differences.<sup>3</sup> Related to these phenomena, Marjit (2007) examined the role of international time zone differences in a vertically integrated Ricardian framework. It has been shown that time zone differences emerge as an independent driving force of international trade besides taste, technology and resource endowment.<sup>4</sup>

Yet to be determined is the dynamic effect of this kind of intermediate

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<sup>2</sup>The rise of the Indian software industry provides another prime example. The programming problems of some U.S. corporations are e-mailed to India at the end of the U.S. workday. Indian software engineers work on them during their regular office hours and provide solutions. By the time the offices reopen in the U.S., the solutions have already arrived, mainly as e-mail attachments. A recent empirical study by Head, Mayer, and Ries (2009) found that in OCS (" Other Commercial Services " in the OECD's classification) trade, the continuity effect (the ability to operate around the clock) dominates the synchronization effect (the need to coordinate operations during business hours).

<sup>3</sup>According to a recent McKinsey report, India contributed about two-thirds of global ICT outsourcing and about half of global BPO offshoring in 2004 (*The Economist*, June 3-9, 2006).

<sup>4</sup>Jones, Kierzkowski and Lurong (2005) also emphasize the role of time zone differences as a determinant of the efficient worldwide division of labor. Furthermore, the fragmentation of production stages and of service provision has been studied within a static trade-theoretic framework by Jones and Kierzkowski (1990, 2001), Grossman and Helpman (2005), Long, Riezman and Soubeyran (2005), and Do and Long (2008).

business-services trade utilizing time zone differences. 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 permanent increase in productivity. In the existing literature on growth and trade, however, relatively few attempts have been made to address the effect of time zones on growth. This seems to suggest that the focus on “trade involving different time zones” should be accompanied by a focus on its effect on growth. The main purpose of this study is to illustrate, with simple growth theory, how a time-saving improvement in business-services trade benefiting from differences in time zones can have a lasting impact on productivity.

For these purposes, following Acemoglu and Ventura (2002), we propose a simple two-country AK model of intermediate services trade that captures the role of time zone differences.<sup>5</sup> Two countries (Home and Foreign) are assumed to be located in different time zones and there is no overlap in daily working hours. The key assumption is that domestic business-services production requires one workday and that products are ready for sale after one workday: the delivery of domestic business services involves significant costs in terms of delay. In contrast to this, the utilization of communications

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<sup>5</sup>Aghion and Howitt (2009) also discussed the implications of a two-country version of the AK model. See, also, Dasgupta (2005).

networks allows production in a foreign country where non-overlapping work hours and business-services trade via networks enable quick delivery and low shipping costs. For these reasons, imported services whose production benefits from time zone differences provide higher value than domestically produced services. Although this assumption is at odds with that of the standard model with trade costs, it captures the idea that final good producers would like to have services sooner rather than later.<sup>6</sup> Based on the model outlined above, this study shows that an acceleration in intermediate business-services trade using different time zones can have a permanent impact on productivity.

The structure of this paper is as follows. In the next section we present the basic model. The impact of temporary technological improvement on growth is considered in Section 3, followed by concluding remarks in Section 4.

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<sup>6</sup>Based on a model of economic geography, Harrigan and Venables (2006) argue that when the stages of the value chain are physically separated, it takes more time to complete a project. Contrary to that, we argue that it takes less time to complete a project if one utilizes time zone differentials.

## 2 The Model

There are two countries, Home and Foreign. They are located in different time zones and there is no overlap in daily working hours: when Home's daytime working hours end, Foreign daytime working hours begin (Figure 1).

In Home, the final good,  $Y$ , and the Home intermediate business services,  $X$ , are both produced under perfect competition. The final good is produced with capital,  $K$ , Home intermediate business services,  $X$ , and Foreign-produced intermediate business services,  $\tilde{X}$ , according to

$$Y = K^\alpha (X)^{\frac{(1-\alpha)}{2}} (\tilde{X})^{\frac{(1-\alpha)}{2}}. \quad (1)$$

There is trade in intermediate business services and no trade in the final good or capital. Home intermediate business services are produced with the final good one for one.

The key assumption is that there are positive time costs for the delivery of intermediates. In order to capture this point, we assume that shipments of intermediates incur the "iceberg" effect of delivery costs: to sell one unit of Foreign intermediates in the Home market,  $\tilde{t}$  units must be shipped. Thus, the price of Foreign intermediates becomes  $\tilde{t}$  times higher than its original price. One can interpret  $\tilde{t}$  as a measure of the inverse of the "delivery timeliness" of Foreign intermediate business services in the *Home* market: a lower



value of  $\tilde{t}$  implies a quicker delivery.

As mentioned above, domestic intermediates' production are ready for sale after one workday, whereas imported intermediates whose production benefits from time zone differences are available sooner (see Figure 1). To parametarize the timing of delivery, we treat the utilization of communications networks (i.e., technological improvement) as a reduction in the delivery time of imported intermediates (i.e., a decrease in  $\tilde{t}$ ). Let us denote the Foreign intermediates' delivery timeliness before technological change as  $\tilde{t}^1$  and that after change as  $\tilde{t}^2$ . Then the following condition holds:

$$\tilde{t}^1 > 1 > \tilde{t}^2. \tag{2}$$

Note that this effect comes not from lower production costs in Foreign, but from faster delivery.

Let the final good,  $Y$ , be the numeraire. Then the unit price of good  $Y$  is equal to one, and this is also the unit cost of producing the Home intermediates. Since markets are perfectly competitive, the price of Home intermediates,  $X$ , is equal to its unit cost; thus it is also equal to one. In contrast to this, the price of Foreign intermediate business services is given by  $\tilde{p}$ . Given these assumptions, the demand for intermediate business services is determined by profit maximization in the final-goods sector. That is, the

optimal  $X$  and  $\tilde{X}$  maximize final-sector profits:

$$K^\alpha (X)^{\frac{(1-\alpha)}{2}} (\tilde{X})^{\frac{(1-\alpha)}{2}} - X - \tilde{p}\tilde{X}.$$

The first-order conditions for this problem are

$$X = \left( \frac{1-\alpha}{2} \right) Y,$$

$$\tilde{p}\tilde{X} = \left( \frac{1-\alpha}{2} \right) Y.$$

Substituting back into equation (1) we obtain

$$Y = (\tilde{p})^{-\frac{(1-\alpha)}{2\alpha}} \left( \frac{1-\alpha}{2} \right)^{\frac{(1-\alpha)}{\alpha}} K. \quad (3)$$

So even though the production function (1) has a diminishing marginal product of capital, we still have an AK model, with  $Y = AK$ , where the marginal product of capital,  $A$ , is given by

$$A = (\tilde{p})^{-\frac{(1-\alpha)}{2\alpha}} \left( \frac{1-\alpha}{2} \right)^{\frac{(1-\alpha)}{\alpha}}. \quad (4)$$

Note that  $A$  depends negatively on the relative price of Foreign intermediate business services.<sup>7</sup>

Now, let us assume a constant saving rate so that we can obtain the capital accumulation equation, namely,<sup>8</sup>

$$\dot{K} = sY - \delta K.$$

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<sup>7</sup>This implies that  $A$  depends positively on Home's terms of trade:  $1/\tilde{p}$ .

<sup>8</sup>To simplify the argument, we assume the constant saving rate. An optimal growth framework yields the same result.

Then, Home's growth rate depends positively on its saving rate according to

$$\dot{K}/K = sA - \delta.$$

Next let us consider Foreign. Foreign's production function for the final good is given by

$$Y_f = K_f^\alpha (X_f)^{\frac{(1-\alpha)}{2}} (\tilde{X}_f)^{\frac{(1-\alpha)}{2}}. \quad (5)$$

Suppose that  $\tilde{t}_f$  measures the inverse of the "delivery timeliness" of Home intermediates in the *Foreign* market: to sell one unit of Home intermediates in the Foreign market,  $\tilde{t}_f$  units must be shipped from Home. And as with Home, Foreign will import the amount  $\tilde{t}_f \tilde{X}_f$  of Home's intermediates, where  $\tilde{t}_f \tilde{X}_f$  is given by

$$\frac{1}{\tilde{p}} \tilde{t}_f \tilde{X}_f = \left( \frac{1-\alpha}{2} \right) Y_f. \quad (6)$$

By analogy to (3) we have

$$Y_f = (\tilde{t}_f)^{\frac{(1-\alpha)}{2\alpha}} (\tilde{p})^{\frac{(1-\alpha)}{2\alpha}} \left( \frac{1-\alpha}{2} \right)^{\frac{(1-\alpha)}{\alpha}} K_f. \quad (7)$$

Same as Home, Foreign's production function becomes  $Y_f = A_f K_f$ , where the marginal product of capital,  $A_f$ , is given by

$$A_f = (\tilde{t}_f)^{\frac{(1-\alpha)}{2\alpha}} (\tilde{p})^{\frac{(1-\alpha)}{2\alpha}} \left( \frac{1-\alpha}{2} \right)^{\frac{(1-\alpha)}{\alpha}}. \quad (8)$$

From (6) and (7):

$$\tilde{t}_f \tilde{X}_f = (\tilde{t}_f)^{-\frac{(1-\alpha)}{2\alpha}} (\tilde{p})^{\frac{1+\alpha}{2\alpha}} \left( \frac{1-\alpha}{2} \right)^{\frac{1}{\alpha}} K_f. \quad (9)$$

From the Home export's value condition ( $\tilde{t}\tilde{p}\tilde{X}$ ), we have

$$\tilde{t}\tilde{p}\tilde{X} = (\tilde{t}\tilde{p})^{-\frac{(1-\alpha)}{2\alpha}} \left(\frac{1-\alpha}{2}\right)^{\frac{1}{\alpha}} K. \quad (10)$$

Trade balance implies that  $\tilde{t}\tilde{p}\tilde{X} = \tilde{t}_f\tilde{X}_f$  holds. Then, by equating the right-hand sides of (9) and (10), we can solve for the equilibrium relative price of Foreign intermediates:

$$\tilde{p} = \left(\frac{\tilde{t}_f}{\tilde{t}}\right)^{\frac{1-\alpha}{2}} k^\alpha, \quad (11)$$

where  $k$  is the relative capital stock:  $k \equiv K/K_f$ .

Now let us consider the steady state. From Home's growth equation, we have

$$\begin{aligned} \dot{K}/K &= s(\tilde{t}\tilde{p})^{-\frac{(1-\alpha)}{2\alpha}} \left(\frac{1-\alpha}{2}\right)^{\frac{(1-\alpha)}{\alpha}} - \delta \\ &= s\left(\frac{1-\alpha}{2}\right)^{\frac{(1-\alpha)}{\alpha}} (\tilde{t})^{-\frac{(1-\alpha^2)}{4\alpha}} (\tilde{t}_f)^{-\frac{(1-\alpha)^2}{4\alpha}} k^{-\frac{1-\alpha}{2}} - \delta. \end{aligned} \quad (12)$$

From the analogous Foreign growth equation, we have

$$\begin{aligned} \dot{K}_f/K_f &= s_f\left(\frac{\tilde{p}}{\tilde{t}_f}\right)^{\frac{(1-\alpha)}{2\alpha}} \left(\frac{1-\alpha}{2}\right)^{\frac{(1-\alpha)}{\alpha}} - \delta \\ &= s_f\left(\frac{1-\alpha}{2}\right)^{\frac{(1-\alpha)}{\alpha}} (\tilde{t}_f)^{-\frac{(1-\alpha^2)}{4\alpha}} (\tilde{t})^{-\frac{(1-\alpha)^2}{4\alpha}} k^{\frac{1-\alpha}{2}} - \delta. \end{aligned} \quad (13)$$

It follows that the growth rate of the relative capital stock,  $k$ , is just the differential growth rate  $\dot{K}/K - \dot{K}_f/K_f$ . Equations (12) and (13) imply

$$\begin{aligned} \dot{k}/k &= \left(\frac{1-\alpha}{2}\right)^{\frac{(1-\alpha)}{\alpha}} \\ &\left[ s(\tilde{t})^{-\frac{(1-\alpha^2)}{4\alpha}} (\tilde{t}_f)^{-\frac{(1-\alpha)^2}{4\alpha}} k^{-\frac{1-\alpha}{2}} - s_f(\tilde{t}_f)^{-\frac{(1-\alpha^2)}{4\alpha}} (\tilde{t})^{-\frac{(1-\alpha)^2}{4\alpha}} k^{\frac{1-\alpha}{2}} \right] \end{aligned} \quad (14)$$

This is a stable, ordinary differential equation with the unique steady state

$$k^* = \left( \frac{s}{s_f} \right)^{\frac{1}{1-\alpha}} \left( \frac{\tilde{t}_f}{\tilde{t}} \right)^{\frac{1}{2}}, \quad (15)$$

where an asterisk is used to denote the steady-state value of a variable. Substituting this back into (11), one can obtain the steady-state relative price of foreign intermediates:

$$\tilde{p}^* = \left( \frac{s}{s_f} \right)^{\frac{\alpha}{1-\alpha}} \left( \frac{\tilde{t}_f}{\tilde{t}} \right)^{\frac{1}{2}}. \quad (16)$$

Substituting (15) and (16) into (4) and (8), one can obtain the steady-state marginal productivity of capital:

$$A^* = \left( \frac{s_f}{s} \right)^{\frac{1}{2}} (\tilde{t}\tilde{t}_f)^{-\frac{1-\alpha}{4\alpha}}, \quad (17)$$

$$A_f^* = \left( \frac{s}{s_f} \right)^{\frac{1}{2}} (\tilde{t}\tilde{t}_f)^{-\frac{1-\alpha}{4\alpha}}. \quad (18)$$

### 3 The Impact of a Technological Advance in Communications Networks

Now let us consider the impact of a time-saving technological advance in communications technologies, which is captured by a reduction in *one country's* delivery cost. Suppose that the value of  $\tilde{t}$  decreases from  $\tilde{t}^1$  to  $\tilde{t}^2$  [see (2)], while  $\tilde{t}_f$  remains unchanged. This implies that the final good producers in Home could utilize imported intermediates,  $\tilde{X}$ , more quickly. From

(17) and (18), it can be shown that, in the new steady state, both countries experience an increase in the marginal productivity of capital *at the same rate*.

**Proposition:** *A decrease in one country's delivery cost for imported intermediates increases both countries' marginal product of capital.*

Let us consider this proposition more precisely. From (4), other things being equal, a lower  $\tilde{t}$  will tend to cause faster capital-stock growth in Home. Since Home final good producers can use imported Foreign intermediates more quickly, the demand for them rises. On the contrary, the Foreign demand for Home intermediates,  $\tilde{X}_f$ , will not grow as fast as the Home demand for Foreign intermediates. Thus, the relative price of Foreign intermediates,  $\tilde{p}$ , must increase so as to preserve the trade balance. This “terms-of-trade effect” will tend to bring Home's growth rate down [Acemoglu and Ventura (2002)]. In Foreign, this “terms-of-trade improvement” triggers faster capital stock growth: via changes in the terms-of-trade, the effect of one country's technological improvement will be transmitted to the other country. This effect works to stabilize world growth: growth rates of  $K$  and  $K_f$  will approach each other. Our result suggests that one country's time-saving technological improvement, which induces firms to take advantage of time zone differences, will also boost the other country's *permanent* growth.

Let us suppose that Home is a developed country, while Foreign is a developing country. Our result suggests that a time-saving technological improvement in the developed country, which then requires more intermediates made with the benefit of time zone differences, triggers faster growth in the developing country via improved terms-of-trade. Jones and Marjit (2001) argue that, in a world in which the costs of service links are falling drastically, fragmentation of production process offers new opportunities to developing countries. The present results on growth via time-saving technological improvement provide some theoretical grounds for such a development process.

## 4 Concluding Remarks

This study highlights the role of business-services trade benefiting from time zone differentials as a driving force behind growth. It is shown that an acceleration in intermediate business-services trade involving production in two time zones can have a permanent impact on productivity. Even more noteworthy is the finding that, via terms-of-trade improvements, the country without technology improvement will also attain faster economic growth. Although these results are derived under the specific assumptions that markets are perfectly competitive and the range of intermediate business services is

exogenously given, it appears that a more general setting would yield similar results.

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# Figure 1

