

# Communication Costs, Producer Services, and International Trade

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## Abstract

This paper explores a relation between communication technology and trade in producer services. A model is developed in which manufacturers incur communication costs when obtaining producer services from service providers. The model is used to examine the effects of improvements in communication technology on the volume of trade and the welfare of countries. This paper differs from the existing work on trade in producer services since it focuses on the fixed cost aspect of producer services such as design and management.

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# 1 Introduction

In recent years, the fragmentation of production processes has taken place in manufacturing industries. For example, in apparel sectors, firms in developed countries retain activities such as design and management, and outsource production to subcontractors at low wage countries (Hanson (1996) and Feenstra (1997)). In semiconductor sectors, firms in developed nations specialize in design activities, and outsource production of computer chips to contract manufacturers in newly industrialized nations (Long et al. (2001)). The recent work on international trade has shown that such fragmentation has significantly affected trade flows. In particular, the disintegration of production leads to the surge in exports from newly industrialized countries, and its impacts on wage inequality within developed and developing nations have been extensively examined (Feenstra (1997)).

Fragmentation is also closely related to trade in producer services such as design and management. For instance, in apparel sectors, designers in developed nations need to send the blueprints of clothing to cutting rooms at low-wage countries. The development of the Internet has significantly reduced communication costs across countries, and as a result, “the patterns and instructions are sent via the Internet to China, South Korea, Vietnam and elsewhere in the developing world for the needlework to be completed” (Los Angeles Times, January 1, 2003). This implies that the recent improvement in communication technology facilitates trade in producer services such as design and management, and the fragmentation of production processes is one of the driving forces for the growth of trade in producer services.<sup>1</sup>

In this paper, I examine a relation between communication technology and trade in producer services. For this purpose, I develop a factor endowment model with monopolistic competition. In manufacturing sectors, monopolistic firms produce differentiated products for consumers. Each

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<sup>1</sup>Raff and von der Ruhr (2001) stated “much of so-called trade in services is carried out via FDI.” On the other hand, Freund and Weinhold (2002) found that U.S. trade in internet-related services, which consist of services that can be transferred electronically, has grown rapidly over the period 1995 to 1999. The development of the Internet also makes it difficult to count entire trade in services. For example, in apparel sectors, “more valuable property (of design), which was created here and beamed to Asia, is not counted as a U.S. export. That’s because digital CAD-CAM (computer-aided design and manufacturing) files, unlike cartons of slacks and blouses, cannot be tallied by customs officials” (Los Angeles Times, January 1, 2003).

manufacturer requires producer services in addition to production factors. When manufacturers obtain producer services from providers, they incur communication costs. If countries are identical in communication technology, a factor endowment difference determines comparative advantage. In free trade equilibrium, the fragmentation of a production process takes place, and as a result, a skilled-labor abundant country exports producer services and imports manufactured goods. An improvement in communication technology affects comparative advantage, and thus, it changes trade flows. If communication technology improves globally at both countries, the volume of trade in producer services increases. A global improvement in communication technology also benefits consumers in both countries since it raises the varieties of manufactured products produced in a world.

This paper is closely related to the recent theoretical work on trade and communication costs. Jones and Kierzkowski (1990) and Jones (2000) emphasized the importance of service links to coordinate activities of production blocks located in different countries. They showed that a reduction in service link costs plays an important role in increasing the fragmentation of production processes. Harris (1995) developed a model in which trade in final goods requires communication costs. This paper complements their work in that it analyzes a relation between communication technology and trade in producer services.

There is a recent theoretical work on trade in producer services, such as Markusen (1982), Marrewijk et al. (1997), Long et al. (2001) and Kikuchi (2003). They shared a common view that producer services are differentiated intermediate inputs, and used a framework developed by Ethier (1982). As a result, services are variable inputs in that an increase in service inputs proportionally raises final good outputs for the given number of service varieties.<sup>2</sup> On the other hand, theory of industrial organization emphasized that expenses on producer services such as management and design are firm-specific fixed costs. This paper depends on this view and departs from the existing work in that manufacturers require fixed units of producer services in

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<sup>2</sup>Using a framework that is different from Ethier's, Francois (1990) analyzed the effect of trade in producer services on specialization in the production of differentiated final goods. In his formulation, producer services are variable inputs as well.

their production.<sup>3</sup>

The rest of this paper is organized as follows. In Section 2, I develop a factor endowment model with monopolistic competition. I show that monopolistic competition equilibrium achieves the first best optimum. This result is useful for the analysis in the following section. In Section 3, I extend a model to a setting with two countries and examine trade equilibrium. I show that trade patterns, trade volumes, and gains from trade in a familiar box diagram. In Section 4, I investigate the effect of an improvement in communication technology. In Section 5, I close the paper with concluding remarks.

## 2 The Model

Manufacturers produce differentiated goods,  $M$ . They require skilled labor, unskilled-labor, and producer services. Producer services such as design and management are essential inputs for manufacturers. Let  $S$  denote these producer services. For manufacturers, expenses on management and design are firm-specific fixed costs, and thus they are sources of economies of scale. For the simplification of the analysis, I assume that a manufacturer requires one unit of  $S$ . The total cost for a manufacturer is represented by the following cost function,

$$C_X = c_M(w_H, w_L)x + gp_S$$

where  $x$  is the output of  $M$  and  $c_M$  is the marginal cost that depends on wages of skilled-labor,  $w_H$  and those of unskilled-labor,  $w_L$ . Each manufacturer purchases one unit of  $S$  from service providers. Providing  $S$  to manufactures requires communication costs. Manufacturers incur  $gp_S$  to obtain one unit of  $S$ , where  $g > 1$  denotes “iceberg” communication costs and  $p_S$  is the price

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<sup>3</sup>The model in this paper is similar to a monopolistic competition model in Helpman and Krugman (1985). However, this paper differs from their work due to the following reasons. First, the model in this paper does not include a competitive consumption good. This simplification is significantly useful for the analysis in this paper. Second, and more importantly, this paper analyzes the effects of communication costs.

of  $S$ . Since the market for  $S$  is competitive, the price equals the unit production cost.<sup>4,5</sup>

$$p_S = c_S(w_H, w_L).$$

Let us turn to the condition for factor market equilibrium. I assume that the factor markets are competitive. Since sector  $M$  and  $S$  have constant returns to scale technology in the use of two types of labor, we can derive the unit requirement of factor  $i$  for  $M$  and  $S$ ,  $a_{ij}$  ( $i = H, L$ ,  $j = M, S$ ). Suppose the supplies of skilled-labor and unskilled-labor are fixed, and they are denoted by  $H$  and  $L$  respectively. We can derive their equilibrium conditions as follows,

$$a_{HM}X + ga_{HS}n = H \tag{1}$$

$$a_{LM}X + ga_{LS}n = L \tag{2}$$

where  $n$  is the number of manufacturers and  $X = nx$  is the aggregate output of  $M$ . Since each manufacturer requires one unit of  $S$ ,  $n$  is the aggregate output of  $S$  as well. Given the factor prices, these two resource constraints determine  $n$  and  $X$ . These constraints imply that *there is a negative relation between  $n$  and  $X$  for given factor supplies*. In fact, we can show that transformation schedules are bowed-out if there is a difference in the factor intensity between  $M$  and  $S$ . Using the standard procedure developed in Jones (1965), we can derive the relative change in the factor market equilibrium conditions,

$$(\lambda_{HM} - \lambda_{LM}) \left( \widehat{X} - \widehat{n} \right) = \widehat{H} - \widehat{L} + \frac{\delta_H + \delta_L}{(\theta_{HM} - \theta_{HS})} (\widehat{c}_M - \widehat{c}_S) + (\lambda_{HM} - \lambda_{LM}) \widehat{g} \tag{3}$$

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<sup>4</sup>We can consider a different scenario in which service providers outsource manufacturing to subcontractors. In this case, total costs for service providers are represented by  $C_X = p_M x + g c_S$ , which is equivalent to the original cost function as long as subcontractors are competitive and thus  $p_M = c_M$  holds. Therefore, the following analysis continues to hold under this alternative scenario.

<sup>5</sup>In the present setting, an improvement in communication technology is identical to a technical progress in producer services. In fact, it is hard to separate these two effects because they are closely related with each other. In apparel sectors, the development of the Internet complements the use of CAD (computer-aided design) for the improvement of the overall efficiency of design. For example, “the electronic tools have now gotten so good - making it possible not only to design a garment on a computer screen but to bring that design to production - that most designers are at least beginning to take the plunge” (Los Angeles Times, February 17, 1997).

where  $\widehat{z} = dz/z$ ,  $\lambda_{ij}$  is the fraction of the total supply of factor  $i$  ( $i = H, L$ ) used in  $j$  ( $j = M, S$ ), and  $\theta_{ij}$  is the share of factor  $i$  in the marginal cost  $c_j$ .<sup>6</sup> Some empirical evidences suggest producer services are highly skilled-labor intensive in their production.<sup>7</sup> Thus, suppose that  $S$  is relatively more skilled-labor intensive than  $M$ .

$$\frac{a_{HS}}{a_{LS}} > \frac{a_{HM}}{a_{LM}}$$

The factor intensity ranking implies that both  $\lambda_{HM} - \lambda_{LM}$  and  $\theta_{HM} - \theta_{HS}$  are negative. Since the aggregate elasticity  $\delta_H + \delta_L$  is positive, there is a positive relation between  $X/n$  and  $c_M/gc_S$  given factor endowments and communication technology. This relation implies smoothly bowed-out transformation schedules.

Turning to the demand side, we expect to draw indifference curves in the space of  $n$  and  $X$ . If each manufacturer produces a differentiated product, consumers would have preferences for diversity and they could choose the best mix between diversity and quantity in manufactured goods. Let us consider the following CES utility function that is well-known as a Dixit and Stiglitz type,

$$u = \left( \sum_{i=1}^n d_i^{\frac{\sigma_X - 1}{\sigma_X}} \right)^{\frac{\sigma_X}{\sigma_X - 1}}, \quad \sigma_X > 1$$

where  $d_i$  is the demand for a manufactured good  $i$  and  $\sigma_X$  is the elasticity of substitution. Assuming consumers demand the same amount of each good, we can rearrange the utility function as follows,

$$u = n^{\frac{1}{\sigma_X - 1}} D \tag{4}$$

where  $D = nd$  is aggregate consumption. This functional form implies that consumers value diversity since the number of varieties raises the level of utility for the given aggregate con-

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<sup>6</sup>See Appendix A for the derivation.

<sup>7</sup>For example, Mincer (1991) stated “service industries are the major employer of educated workers,” and OECD (2001) noted “among services subsectors, educational attainment is highest in producer and social services and lowest in personal services.” In a recent theoretical work on trade, Findlay (1997) assumed that services are relatively more skilled-labor intensive than manufacturing, but unlike the present paper, he used a competitive model and considered only consumer services.

sumption. Another important property, which has rarely been emphasized, is that there is a substitutability between variety and quantity. In fact, indifference curves in the space of  $D$  and  $n$  are convex toward an origin since the marginal rate of substitution (MRS) is decreasing.

$$\frac{u_D}{u_n} = (\sigma_X - 1) \frac{n}{D} \quad (5)$$

Using indifference curves and transformation schedules, we can easily show the first best optimum, at which an indifference curve is tangent to a transformation schedule in the space of  $D$  (or  $X$ ) and  $n$  (see Figure 1). In general, monopolistic competition does not attain the first best optimum.<sup>8</sup> However, I show that it does in the present setting.<sup>9</sup>

**Proposition 1** *The marginal rate of substitution equals the relative marginal costs in monopolistic competition equilibrium. Thus, market equilibrium is the first best optimum.*

*Proof:* In market equilibrium, the zero profit condition for manufacturers holds,

$$p_X X = c_M X + g c_S n \quad (6)$$

where  $p_X$  is the price of a manufactured product. The profit maximization leads to the first order condition for manufacturers.

$$p_X (1 - 1/\sigma_X) = c_M \quad (7)$$

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<sup>8</sup>Dixit and Stiglitz (1977) considered two different types of social optima, the first best optimum and the second best optimum. The first best optimum requires pricing below average cost because lump sum transfers that cover losses are available. The second best optimum requires each firm must have nonnegative profits since lump sum subsidies are not available. They showed that monopolistic competition equilibrium is identical to the second best optimum, but it does not achieve the first best optimum under the CES subutility function.

<sup>9</sup>Why does the present setting lead to the result that was not obtained by Dixit and Stiglitz (1977)? This is related to the existence of a competitive consumption good. In Yomogida (2004), I discuss the details of this point.

Solve (7) for  $p_X$  and substitute it to the zero profit condition (6). Then we have

$$\frac{\sigma_X}{\sigma_X - 1} c_M X = c_M X + g c_S n. \quad (8)$$

Rearranging the zero profit condition (8), we can derive

$$\frac{c_M}{g c_S} = (\sigma_X - 1) \frac{n}{X}. \quad (9)$$

Clearly, the marginal rate of substitution (5) equals the right hand side of (9) since  $D = X$  holds in market equilibrium. Thus, we have the desired result. Q.E.D.

Now, let us turn to the effects of an improvement in communication technology.<sup>10</sup> Suppose communication costs  $(g - 1)c_S$  fall due to an improvement in technology, which is represented by  $g$ . A reduction in  $g$  shifts a transformation schedule as it is shown in Figure 2. Intuitively, a fall in communication costs leads to a decline in costs for manufacturers to obtain producer services. The reduction in expenses on producer services promotes the entry of new manufacturers, and thus the number of varieties available for consumers rises. This point is confirmed by (3). For the given relative output  $X/n$ , the relative marginal cost  $c_M/gc_S$  is higher at the new transformation schedule than that at the original one. Since varieties are relatively less expensive as compared to aggregate quantity, consumers demand more varieties and thus the equilibrium number of manufacturers rises.

Whether aggregate outputs increase or not depends on the size of the marginal rate of substitution between  $n$  and  $D$ . The utility function (4) implies that the marginal rate of substitution equals one. With this property, a reduction in  $g$  does not affect aggregate outputs since the negative substitution effects exactly offset the positive income effects. Thus, new equilibrium is determined at point  $E'$  in Figure 2. We can easily show that relative wages do not change either.

A reduction in  $g$  has a negative effect on the relative wages for skilled-labor since it reduces

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<sup>10</sup>One recent example is the development of broadband technology for the Internet. “Broadband’s particular promise is in its capacity to enable multiple applications over a single network, and the related economic gains - meaning greater access at lower cost” (International Telecommunication Union (2003)).

a relative marginal cost of  $S$ . On the other hand, a fall in the costs of  $S$  leads to the entry of new manufacturers, which expands the relative demand for  $S$  and thus the relative demand for skilled-labor. This positive effect is exactly offset by the negative impact if the elasticity of substitution equals one. Thus, an improvement in communication technology does not affect relative wages in the closed economy.

**Proposition 2** *A improvement in communication technology benefits consumers by allowing more varieties of manufactured goods. In the Dixit-Stiglitz CES utility function, the elasticity of substitution between varieties and aggregate consumption equals one, and thus an improvement in communication technology does not affect aggregate outputs and relative wages.*

*Proof:* See Appendix B.

### 3 Trade Equilibrium

In this section, I examine trade equilibrium by developing a box diagram. Countries are assumed to have identical communication technologies, and thus they have the same size of  $g$ .<sup>11</sup> Comparative advantage is determined by a difference in factor endowments. In free trade equilibrium, vertical trade in producer services and manufactured goods takes place. I show how trade benefits countries and affects a wage gap between skilled and unskilled-labor. In the next section, I shall examine how an improvement in communication technology influences the pattern of trade, the volume of trade, and the welfare of countries.

There are two countries, Home and Foreign. The countries are identical except for relative factor endowments. Without the loss of generality, we assume that Home is relatively more skilled-labor abundant than Foreign. For given factor prices, the ratio of the aggregate output to the number of manufacturers  $X/n$  in Home is smaller than that in Foreign due to the Rybczynski theorem. This suggests that, in the state of autarky, Home's relative marginal costs of  $S$  are

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<sup>11</sup>Even though countries have identical technologies, communication costs could be different between countries since they depend on relative wages.

smaller than Foreign's, and thus Home has a comparative advantage in producing  $S$ . This point is easily shown by constructing a box diagram. Consider free trade equilibrium in which countries incompletely specialize in production and thus factor prices are equalized between countries.<sup>12</sup> In the free trade equilibrium, the output of each manufacturer is also equalized. (Otherwise, the free entry conditions would be violated.) Keeping these points in mind, we can construct a box diagram in Figure 3. The vertical axis measures the number of varieties or the aggregate output of  $S$ . The horizontal axis measures the aggregate output of  $M$ . Point  $O$  is the origin for Home and point  $O^*$  is the one for Foreign. In the free trade equilibrium, production for each country is determined at point  $E$  where the transformation schedules are tangent to each other.

In the free trade equilibrium, the aggregate output of  $M$  produced at Home is  $OG$ . Notice that the slope of the diagonal equals  $1/x$ , which is the inverse of the output of each manufacturer in the free trade equilibrium. Thus,  $FG$  is the output of  $S$  used for the home production of  $M$ . In other words, the number of varieties produced at Home equals  $FG$ . Since  $FG$  is smaller than  $EG$  that is the total output of  $S$  produced at Home,  $EF$  is the volume of home exports of  $S$ . In Foreign, the aggregate output of  $M$  is given by  $O^*D$ . Foreign manufacturers require  $S$  by  $DF$  to produce the manufacturing output  $O^*D$ . Foreign demand for  $S$  is met by imports from Home,  $EF$ , in addition to the foreign supply,  $DE$ .

Now we turn to consumption patterns. The line that is tangent to each country's transformation schedule at point  $E$  determines the level of each country's GDP. Thus,  $OI / OO^*$  is the relative size of Home in terms of GDP. Home's aggregate consumption of  $M$  is given by  $OJ$  since each country's expenditure on  $M$  is proportional to its GDP due to the homotheticity of preferences. Aggregate consumption  $OJ$  is greater than aggregate output  $OG$  and thus Home imports  $M$  by  $GJ$ . Foreign exports  $M$  by  $DH$  since aggregate output  $O^*D$  is greater than aggregate consumption  $O^*H$ .

**Proposition 3** *In free trade equilibrium, the fragmentation of production processes takes place.*

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<sup>12</sup>We implicitly assume that there are no additional communication costs when services are traded between countries. Thus, communication costs  $(g - 1)c_S$  are also equalized between countries at free trade equilibrium.

*A skilled-labor abundant country exports producer services and imports manufactured goods.*

It is easy to show gains from trade. Remember that the vertical axis measures the number of varieties as well as the output of  $S$ . Since consumers in both countries demand the total varieties produced in a world, the consumption point of Home is point  $H$  and that of Foreign is point  $J$  at the free trade equilibrium. The indifference curve that goes through point  $H$  ( $J$ ) indicates the level of utility for Home (Foreign) consumers at the trade equilibrium. Since countries have identical preferences, indifference curves are tangent with each other at point  $I$  on the diagonal  $OO^*$ . This implies that, in the state of autarky, the Home (Foreign) equilibrium is determined at point  $A$  ( $A^*$ ). Thus, the upward (downward) shift of the indifference curve shows gains from trade for Home (Foreign).<sup>13</sup>

It is also possible to explore the impact of trade on income distribution within countries. The slope of the transformation schedule is flatter at point  $E$  than that at point  $A$ . Thus, free trade reduces the relative marginal costs  $c_M/gc_S$  at Home. This leads to a rise in the wage premium for skilled-labor because of the Stolper-Samuelson theorem. In Foreign, the relative wages for unskilled-labor rise since the relative marginal costs of  $M$  go up.

## 4 Communication Technology and Trade

In this section, I investigate the effect of an improvement in communication technology. First, I focus on the case in which communication technology improves only in one country. A country having advanced communication technology has comparative advantage in producer services. Next, I proceed to the case in which communication technology improves globally. I examine the impact of an improvement in communication technology on the volume of trade in producer services and the welfare of countries.

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<sup>13</sup>The slope of the Home indifference curve at point  $H$  does not equal that of the Foreign indifference curve at point  $J$ . Thus, countries' indifference curves do not have the same slope at the free trade equilibrium. At first glance, this seems to be unusual because two countries have identical preferences. However, this is not. In Appendix C, I show that the free trade equilibrium meets the optimum condition for an economy with a public good.

## 4.1 Local Improvements in Communication Technology

Suppose that two countries are identical. In free trade equilibrium, trade in differentiated manufactured products takes place but trade in producer services does not occur since countries have identical factor endowments and preferences. If communication technology improves in one country, what will happen to the trade equilibrium? Without the loss of generality, we assume that there is a fall in  $g$  at Home. An improvement in communication technology shifts out the transformation schedule of Home as in Figure 2. In the state of autarky, the relative marginal costs of  $S$  at Home are lower than those at Foreign, and thus Home has a comparative advantage in producer services. An improvement in communication technology creates a Ricardian comparative advantage in producer services.

If trade is opened up between countries, Home exports producer services and imports manufactured goods. Relative output of  $S$  expands at Home and thus relative wages for skilled-labor rise. In Foreign, relative wages for unskilled-labor increase since the relative output of  $M$  rises. Eventually, the relative costs of  $S$  would be equalized between countries. Nonetheless, the relative wages would not be equalized due to a difference in communication technology. This implies a difficulty of illustrating a free trade equilibrium in a box diagram such as Figure 3. If relative wages are not equalized, a price of a manufactured product produced at Home does not equal to that produced at Foreign, and thus, the symmetry in consumption of each variety fails to hold. This implies that we cannot draw indifference curves in the space of variety and quantity, and thus we cannot illustrate the allocation of a world economy as a box diagram.

## 4.2 Global Improvements in Communication Technology

Let us examine the effect of an improvement in communication technology at both countries. Suppose countries are identical except for factor endowment ratios. Home is relatively more skilled-labor abundant than Foreign. If there is an improvement in communication technology in either country, a transformation schedule of each country shifts out as in the case of the closed

economy (see Figure 2). At the free trade equilibrium, a world indifference curve is tangent to a world transformation schedule. The outward shift of the transformation schedule raises the equilibrium number of varieties in the world but it does not affect the world production of  $M$  at the equilibrium.<sup>14</sup> Thus, a technological progress in communication leads to a vertical expansion of the box diagram (see Figure 4).

The new origin for Foreign is  $O^{*'}$ . The pattern of production is determined at point  $E'$  where transformation schedules are tangent with each other. The aggregate output of  $S$  at Home is  $E'G$ . Home exports  $S$  by  $E'F'$  and they are used by foreign manufacturers.  $F'G$  is the output of  $S$  that is purchased by manufacturers producing at Home. The aggregate output of  $M$  at Home is  $OG$  and the output of each manufacturer equals the inverse of the diagonal  $OO^{*'}$  at the trade equilibrium. In Foreign, the output of  $S$  is  $D'E'$  that is used as inputs for foreign manufacturers. The foreign output of  $M$  is  $O^{*'}D'$ , which is produced by using  $S$  imported from Home as well as  $S$  purchased from foreign service providers.

Let us turn to the consumption pattern at the new trade equilibrium. In the equilibrium of the closed economy, I have shown that the relative wages are independent of  $g$ . This result is preserved in the free trade equilibrium and an improvement in communication technology does not affect wages in either country. This implies that the relative GDP of each country does not change either.<sup>15</sup> Thus, the common tangency line that determines the relative size of each country intersects with the diagonal  $OO^{*'}$  at point  $I'$ . The aggregate consumption of Home is  $OJ$  that exceeds its aggregate output of  $M$ , and thus Home imports  $M$  by  $GJ$ . Foreign exports  $M$  by  $D'H'$  because its aggregate consumption is smaller than its aggregate output. Thus, a global improvement in communication technology does not change the pattern of trade.

Home consumption shifts to point  $H'$ . The upward shift of the Home indifference curve indicates gains from a technological progress in communication. Similarly, foreign consumers benefit from it since its origin  $O^*$  shifts to  $O^{*'}$ . In fact, the advance of communication technology

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<sup>14</sup>This point is confirmed in Proposition 2 by regarding a world economy as a “closed economy.”

<sup>15</sup>At the trade equilibrium, the relative GDP of Home is  $(wH + L)/(w\bar{H} + \bar{L})$  where  $\bar{H} = H + H^*$  and  $\bar{L} = L + L^*$ . Clearly, it is constant if there is no change in the relative wages  $w = w_H/w_L$ .

benefits both countries equally, since it expands the equilibrium varieties of manufactured goods consumed in either country without affecting each country's aggregate consumption.

**Proposition 4** *A global advance of communication technology benefits both countries equally by expanding varieties of manufactured goods produced at free trade equilibrium.*

Finally, let us examine the effect on the volume of trade in  $S$ . A reduction in  $g$  raises the aggregate output of  $S$  at Home. In Figure 4,  $E'E$  is the increase in the supply of  $S$ . At the same time, demand for  $S$  increases at Home due to the entry of new manufacturers. In Figure 4,  $F'F$  is the rise in demand for  $S$ . Whether the volume of trade in  $S$  rises or not depends on the relative size of changes in supply and demand. Thus, we need to examine the balance of trade equation. The balance of trade for Home is

$$EX_S = (p_X/gp_S)IM_M,$$

where  $EX_S$  is the export volume of  $S$  and  $IM_M$  is the import volume of  $M$ .<sup>16</sup> A fall in  $g$  does not affect the volume trade in  $M$  since aggregate consumption and aggregate supply do not change. Hence, whether the volume of trade in  $S$  rises or not depends on the terms of trade for Home,

$$\frac{gp_S}{p_X} = \frac{\sigma_X - 1}{\sigma_X} \frac{gc_S}{c_M},$$

Since the relative wages are independent of communication technology, a fall in  $g$  worsens the terms of trade for Home. This result leads to the following proposition.

**Proposition 5** *A global progress in communication technology increases the volume of trade in producer services at free trade equilibrium.*

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<sup>16</sup>In free trade equilibrium, the budget constraint for Home is derived as  $np_Xd+n^*p_Xd = np_Xx+n_h^*gp_S$  where  $n_h^*$  denotes the number of Foreign varieties produced by using producer services exported by Home. Rearranging the constraint, we have  $p_X [n^*d - n(x - d)] = gp_S n_h^*$ , and we obtain  $p_X IM_M = gp_S EX_S$  where  $IM_M = n^*d - n(x - d)$  and  $EX_S = n_h^*$ .

## 5 Concluding Remarks

In this paper, I investigated a relation between communication technology and trade in producer services. Expenses on producer services such as management and design are firm-specific fixed costs. In addition, these producer services are relatively skilled-labor intensive activities. Focusing on these two aspects of producer services, I developed a factor endowment model with monopolistic competition. Using the model, I have shown that the fragmentation of production processes leads to trade in producer services. Since trade in producer services requires communication between service providers and manufacturers, a reduction in communication costs is a key to a change in trade flows of producer services. I have examined the effects of an improvement in communication technology and have shown that a global progress in communication technology leads to an increase in the volume of trade in producer services.

Most existing work views producer services as differentiated intermediate inputs. In this view, the size of market plays an important role in determining the pattern of trade because producer services are produced with increasing returns to scale technology. Focusing on the skill-intensity of producer services, this paper has provided a factor endowment explanation for the pattern of trade in producer services and manufactured goods. In contrast to the existing trade models with monopolistic competition, the present model does not include a competitive consumption good. This simplification allows to focus on a factor intensity difference between production stages. This paper assumes that communication costs proportionally increase with the quantity of trade in producer services. One important aspect of communication costs is that they are fixed costs for an economy as a whole. The present model could be extended to a setting with the fixed costs aspect of communication services. Further research is need to extend the model in this direction and examine a relation between communication technology and international trade.

## Appendix A: The Relation between $n$ and $X$ .

Taking derivatives of the factor market equilibrium conditions (1) and (2), we have the relative change in these equilibrium conditions,

$$\lambda_{HM}\widehat{X} + \lambda_{HS}\widehat{n} = \widehat{H} - \lambda_{HM}\widehat{a_{HM}} - \lambda_{HS}\widehat{a_{HS}} - \lambda_{HS}\widehat{g} \quad (\text{A1})$$

$$\lambda_{LM}\widehat{X} + \lambda_{LS}\widehat{n} = \widehat{L} - \lambda_{LM}\widehat{a_{LM}} - \lambda_{LS}\widehat{a_{LS}} - \lambda_{LS}\widehat{g} \quad (\text{A2})$$

The relative change in the unit requirement of each factor in sector  $j$  is derived as follows, (see Jones (1965) for the derivation)

$$\widehat{a_{Hj}} = -\sigma_j\theta_{Lj}(\widehat{w_H} - \widehat{w_L}), \quad \widehat{a_{Lj}} = \sigma_j\theta_{Hj}(\widehat{w_H} - \widehat{w_L}) \quad (\text{A3})$$

where  $\sigma_j$  is the elasticity of substitution in sector  $j$  ( $j = M, S$ ). Using (A1), (A2), and (A3), we have the following equation,

$$(\lambda_{HM} - \lambda_{LM})\left(\widehat{X} - \widehat{n}\right) = \widehat{H} - \widehat{L} + (\delta_H + \delta_L)(\widehat{w_H} - \widehat{w_L}) + (\lambda_{HM} - \lambda_{LM})\widehat{g} \quad (\text{A4})$$

where  $\delta_H = \lambda_{HM}\theta_{LM}\sigma_M + \lambda_{HS}\theta_{LS}\sigma_S$  and  $\delta_L = \lambda_{LM}\theta_{HM}\sigma_M + \lambda_{LS}\theta_{HS}\sigma_S$ . Taking derivatives of the marginal cost function of sector  $j$ , we have the relative change in  $c_j$  ( $j = M, S$ ),

$$\widehat{c_j} = \theta_{Hj}\widehat{w_H} + \theta_{Lj}\widehat{w_L} \quad (\text{A5})$$

where  $\theta_{ij}$  is the share of factor  $i$  in the marginal cost of sector  $j$ . Using (A5), we derive the change in the relative marginal costs.

$$\widehat{c_M} - \widehat{c_S} = (\theta_{HM} - \theta_{HS})(\widehat{w_H} - \widehat{w_L}) \quad (\text{A6})$$

Substituting (A6) into (A4), we derive the equation (3).

## Appendix B: Proof for Proposition 2.

Taking the derivative of the optimum condition for the market equilibrium (9), we have

$$(\widehat{D} - \widehat{n}) = -\sigma_D(\widehat{c}_M - \widehat{c}_S - \widehat{g}), \quad (\text{B1})$$

where  $\sigma_D > 0$  is the elasticity of substitution between varieties and aggregate consumption, and  $\sigma_D = 1$  if the utility function is given by (4). Substituting (A6) into (B1), we have the relation between the “relative demand”  $D/n$  and the relative wages  $w_H/w_L$ .

$$-\frac{1}{\sigma_D}(\widehat{D} - \widehat{n}) = (\theta_{HM} - \theta_{HS})(\widehat{w}_H - \widehat{w}_L) - \widehat{g} \quad (\text{B2})$$

At market equilibrium, relative demand  $D/n$  equals relative supply  $X/n$ . Thus, solving (A4) and (B2) simultaneously for  $\widehat{w}_H - \widehat{w}_L$ , we can obtain a change in equilibrium relative wages,

$$-\frac{\sigma_D + \sigma_S}{\sigma_S}(\delta_H + \delta_L)(\widehat{w}_H - \widehat{w}_L) = \widehat{H} - \widehat{L} + (1 - \sigma_D)(\lambda_{HM} - \lambda_{LM})\widehat{g} \quad (\text{B4})$$

where  $\sigma_S = (\delta_H + \delta_L)/(\lambda_{HM} - \lambda_{LM})(\theta_{HM} - \theta_{HS}) > 0$  is the elasticity of substitution on the supply side. In the present setting,  $\sigma_D = 1$  and thus a change in  $g$  does not affect the relative wages. From (A3), the unit requirement of factor  $i$  in sector  $j$  does not change either,  $\widehat{a}_{ij} = 0$ . Using this condition, (A1), and (A2), we can show that  $\widehat{n} = -\widehat{g}$  and  $\widehat{X} = 0$ .

## Appendix C: Proof for the Efficiency of Free Trade Equilibrium.

Let  $D$  ( $D^*$ ) denote aggregate consumption of Home (Foreign) and  $\bar{n}$  be the total number of varieties at the free trade equilibrium. Deriving  $U_n/U_D = D/(1 - \sigma_X)\bar{n}$ , and  $U_n^*/U_D^* = D^*/(1 - \sigma_X)\bar{n}$ , we can show that the following condition holds at the free trade equilibrium.

$$\frac{U_n}{U_X} + \frac{U_n^*}{U_X^*} = \frac{gc_S}{c_M}, \quad (\text{C1})$$

In the free trade equilibrium, the number of varieties consumed is the same between countries, and thus we may regard the equilibrium number of varieties as the consumed amounts of a public good. We can regard  $X$  as a private good since the sum of the aggregate consumption of each country equals the total supply of  $M$  in the equilibrium. In fact, (C1) is equivalent to the condition for a social optimum in an economy with two agents, one private good, and one public good.

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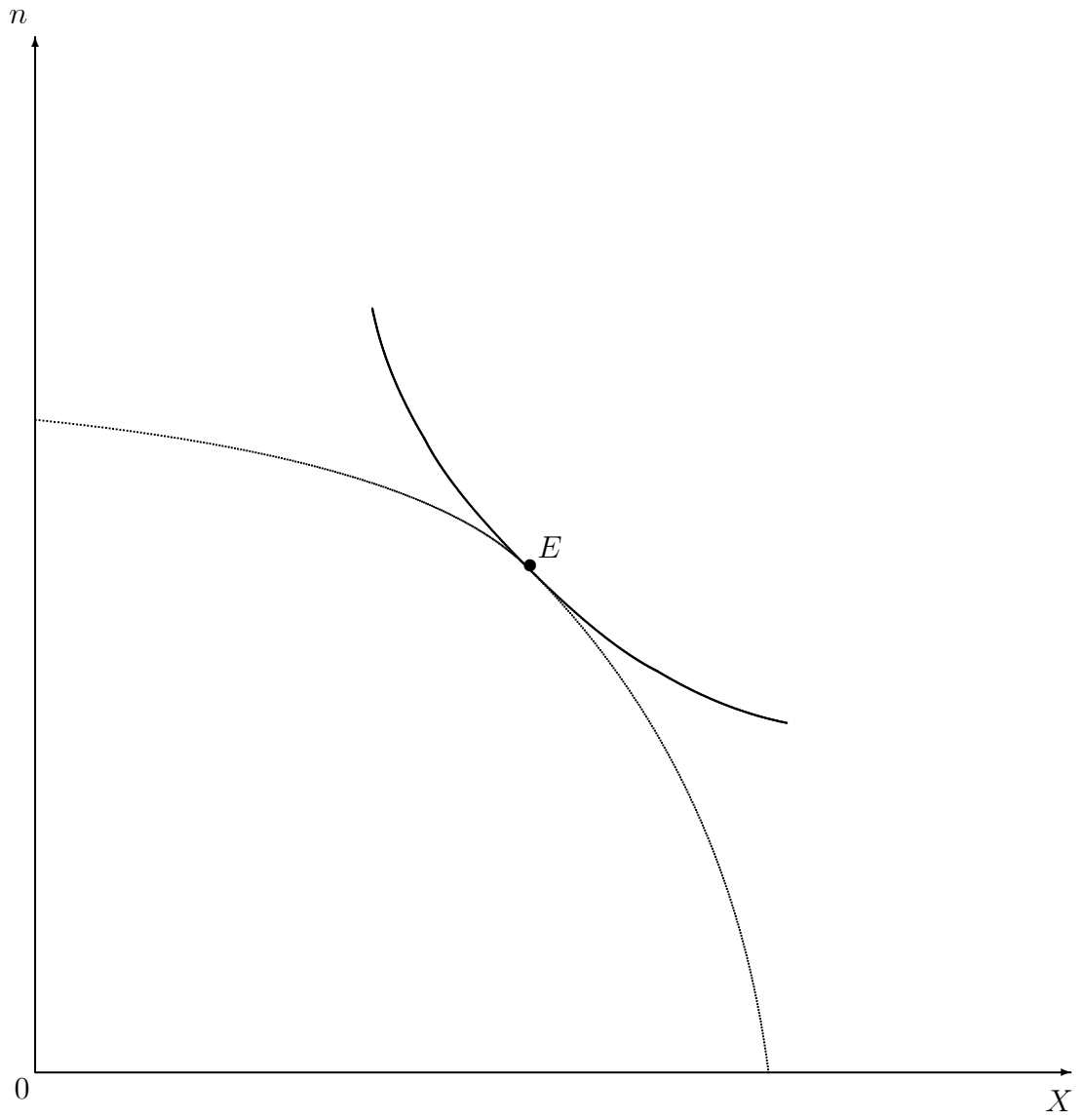


Figure 1: Market equilibrium is optimal.

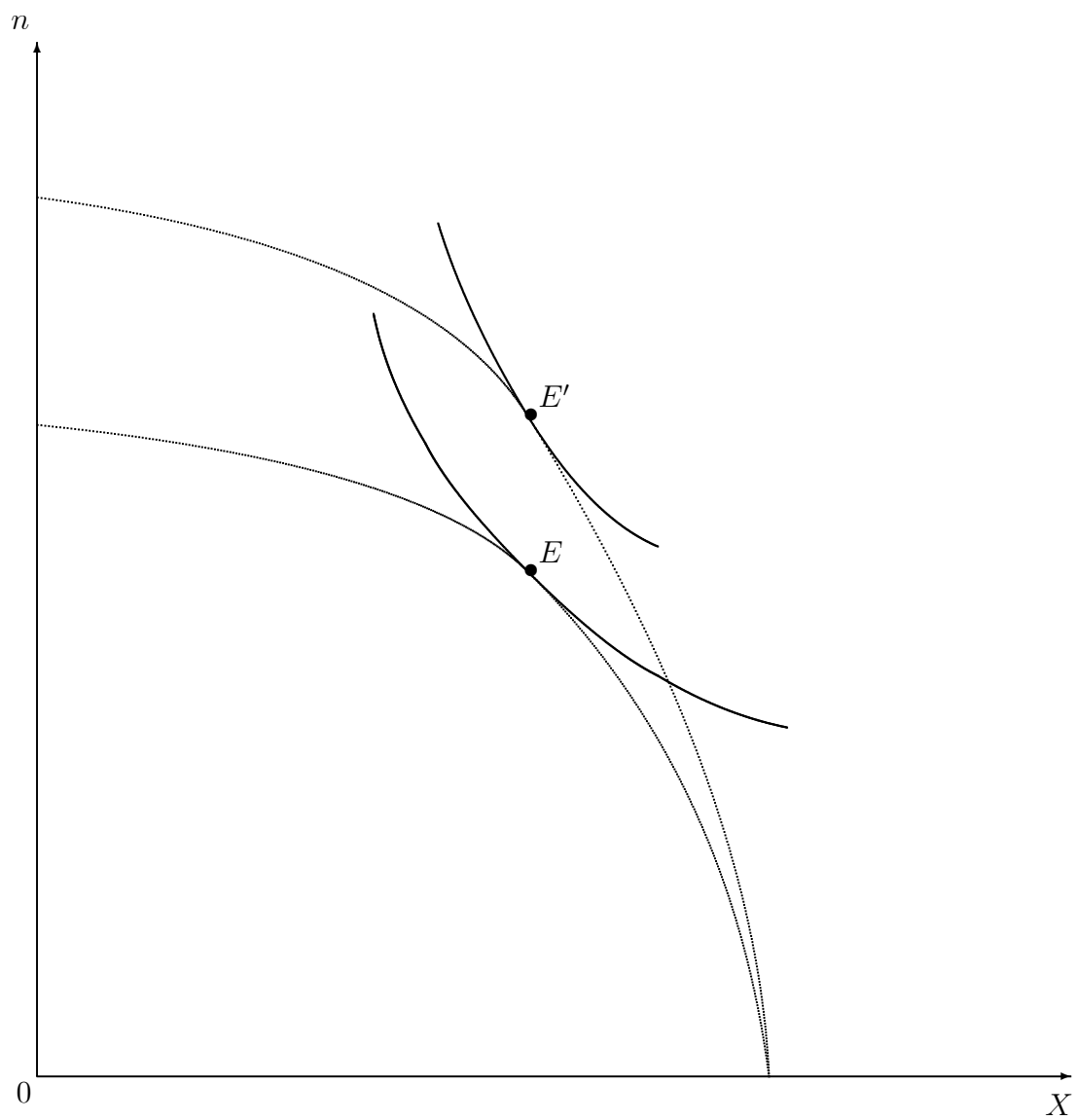


Figure 2: The effect of a reduction in  $g$  on varieties and outputs at equilibrium.



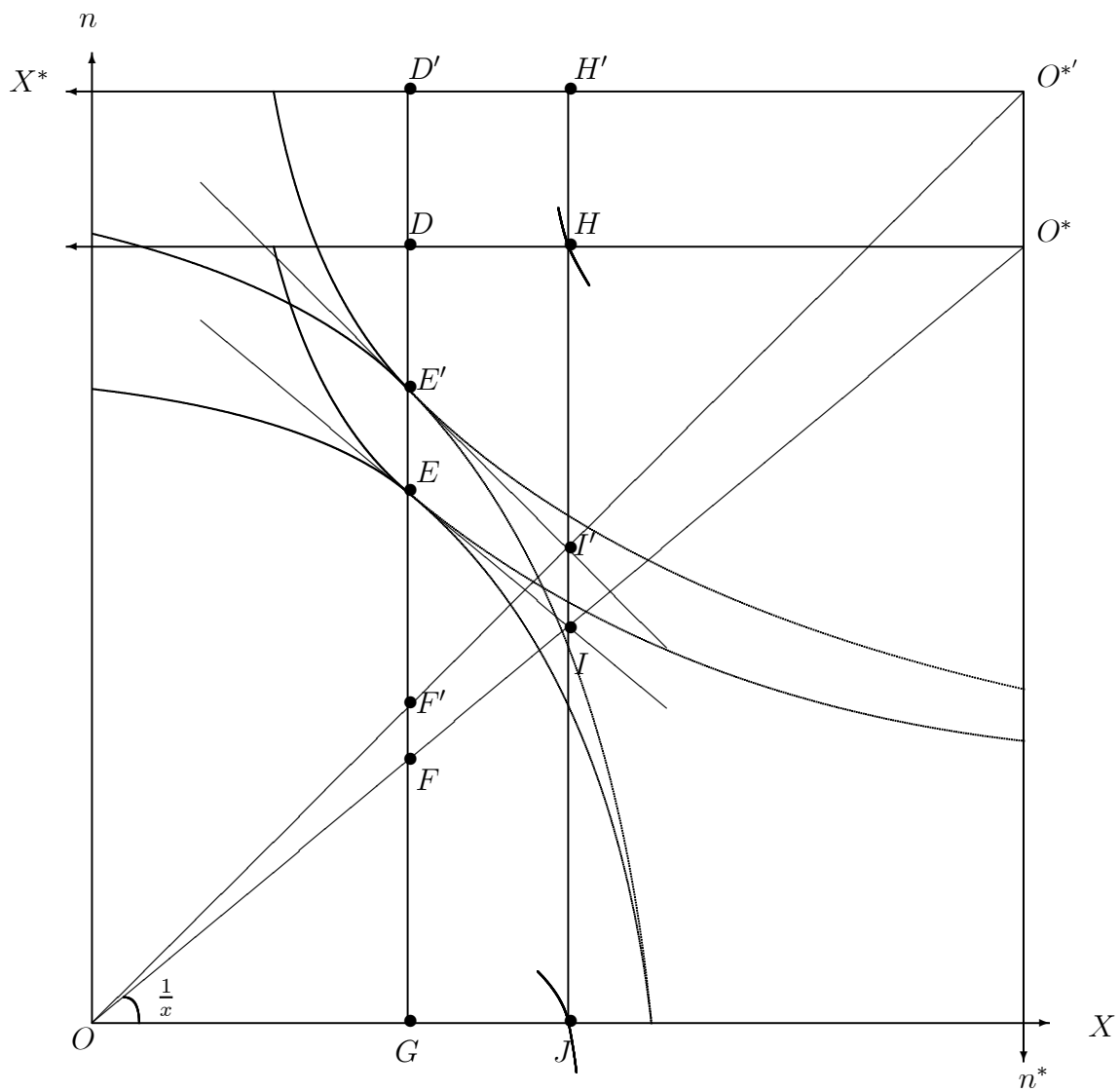


Figure 4: The effect of a reduction in  $g$  at free trade equilibrium