E C O N O M I C S   B U L L E T I N

Capital−Intensive Country−Specific Network Costs and Intra−Industry Trade

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Abstract

This paper examines the impacts of country−specific network costs that are provided by a capital−intensive communications sector in a two−country two−factor model, where there are two trading sectors, agriculture and manufacturing. It is shown that when firms in the manufacturing sector incur a fixed cost associated with connection to the communications network upon entry, comparative advantage will be determined by the relative endowments of capital in each country and the size of fixed costs associated with the communications sector. The capital abundant (scarce) country will have a comparative advantage (disadvantage) when the cost−sharing effect (the congestion effect) dominates.

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1 Introduction

Recently the effect of communication costs on trade has increasingly become a topic of discussion in the international trade literature. This increased attention is partially due to advances that have been made in the communications industry with the application of new technologies such as the Internet, fiber optics, and satellite based systems. The costs of building, maintaining and connecting to communications networks are usually associated with their size and complexity and the number and sophistication of users.

Communication costs have, in general, been modelled as fixed costs in the literature and this is the approach that is adopted in this paper. Harris (1995) presents a strong argument for modelling network connection as a fixed cost suggesting that once a communications network is in place the marginal cost of communication is negligible. Furthermore, the nature of a communications network as a public good necessitates consideration of consumption externalities that occur with varying volumes of use. Two types of externalities that may occur are a cost-sharing effect and a congestion effect. In the first case, the fixed cost incurred with connection decreases in the number of users as the large fixed costs of establishing the network are shared over a larger user base. In the second case, the cost of providing communication services increases with the number of users because of congestion of the network. Harris (1995) examines how trade patterns are affected by the existence of an international communications network that is characterized by the externalities described above.

Kikuchi (2002) takes a different approach by analyzing the impact of local or country-specific communications networks with cost-sharing externalities. Applying a two-country model with one factor of production, labor, he demonstrates that the larger country will derive a comparative advantage in the trade of "network goods", for which production requires the use of communications services, as a result of aggregate increasing returns to scale. Kikuchi and Ichikawa (2002) extend this analysis to allow for a negative congestion externality and show that the larger country will have a comparative advantage when the cost-sharing effect dominates and a comparative disadvantage when the congestion effect dominates. Their results have implications for the patterns of intra-industry trade in that while a dominant cost-sharing externality leads to specialization of production, a dominant congestion externality leads to intra-industry trade. Moreover, when intra-industry trade does occur the larger country may become a net importer of the "network good".

This paper extends the analysis of Kikuchi and Ichikawa (2002) to include two factors of production, labor and capital. The establishment of a communications network requires a large infrastructure which implies a high capital intensity for the communications industry. In fact, Wolf (1999) reports that between 1958 and 1987,in the United States, average annual investment in machinery, equipment, and instruments per full time equivalent employee in the communications sector, at a value of $17,872 (1987 U.S. dollars), was second only to that in the electric, gas and sanitary services sector. This is well above the value of $2613 for the entire economy. This high capital-labor ratio for the communications industry suggests a strong role for capital endowments in the determination of comparative advantage and trade patterns in a model with country-specific communications networks. This paper attempts to clarify this role by using a two-country two-factor model. To simplify the analysis an extreme case, where communications networks are produced using capital alone, is examined. Under this model comparative advantage is determined by the relative capital endowments of each country and whether the cost-sharing or the congestion effect dominates, as determined by the size of fixed costs in the communications sector. When the congestion effect dominates the country with the smaller endowment of capital may become a net exporter of manufactured goods that require the use of capital intensive communications services.

The remainder of the paper proceeds as follows. Section 2 describes the basic model for a closed economy. Section 3 examines trade patterns for two cases: a dominating cost-sharing externality and a dominating congestion externality. Section 4 provides some concluding remarks.

2 Basic Model

There are three sectors: agriculture, manufacturing, and communications across which the two factors of production, labor and capital, are perfectly mobile. Firms in the agricultural sector produce a homogeneous good, Y, under constant returns to scale. On the other hand, the manufacturing sector produces a large number of varieties of a manufactured product. Firm level increasing returns to scale, resulting from a fixed cost of entry and a large set of producible varieties, assure that each variety is produced by only one firm.[1] The communications sector provides communications services in the form of a network that is used by firms in the manufacturing sector.

Consumer preferences are described by a Cobb-Douglas utility function $U = X^{\mu}Y^{1-\mu}$, $0 \geq \mu \leq 1$, where

$$X = \left(\sum_{i=1}^{n} c_i^{\alpha}\right)^{\frac{1}{\alpha}}, \qquad \alpha = 1 - \frac{1}{\sigma}, \qquad \sigma > 1. \tag{1}$$

X is the consumption index for the n varieties produced in the manufacturing sector, c_i is the consumption of variety i, and σ is the elasticity of substitution between varieties. Expenditures on X and Y are fixed shares

[1] See Dixit and Stiglitz (1977).

of national income, I.

$$P_X X = \mu I \qquad\qquad P_Y Y = (1-\mu)I, \tag{2}$$

where $P_X = \left(\sum_{i=1}^{n} p_i^{1-\sigma}\right)^{\frac{1}{1-\sigma}}$ is the aggregate price index for varieties of the manufactured product and P_Y is the price of the agricultural good. The demand function for any given variety is

$$c_i = \mu I P_X^{\sigma-1} p_i^{-\sigma} = \frac{\mu I}{np}, \tag{3}$$

where, assuming symmetry among varieties, the consumption and price indexes respectively reduce to $X = n^{1/\alpha}c$ and $P_X = n^{1/(1-\sigma)}p$.[2]

The agricultural good, Y, is produced for a perfectly competitive market. Assuming the unit cost of production is given by $w^{\lambda}r^{1-\lambda}$ and setting Y as the model numeraire, all firms in the agricultural sector will equate marginal revenue with marginal costs so that $w^{\lambda}r^{1-\lambda} = 1$. The Y-sector factor demands for labor and capital are obtained using Sheppard's Lemma.

$$L_Y = \frac{\lambda(1-\mu)I}{w} \qquad\qquad K_Y = \frac{(1-\lambda)(1-\mu)I}{r}, \tag{4}$$

where w is the wage and r is the rental.

The communications sector takes the form of a natural monopoly that provides network services to firms in the manufacturing sector. Production of the communications network requires a large capital investment equal to $(F + n^2)$, where F is the initial investment needed to build the network infrastructure and n^2 is the investment required for the network connection of each firm. Following Kikuchi and Ichikawa (2002) the communications monopoly charges all firms connecting to the network by applying an average-cost pricing rule.

$$\gamma(n) = \left(\frac{F}{n} + n\right), \tag{5}$$

where $(F/n+n)$ is measured in units of capital. A plot of average costs, $\gamma(n)$, therefore has a U-shaped form because the cost of connecting to the network is initially falling, the cost-sharing effect, but subsequently increasing, the congestion effect, with the number of firms.

Firms in the manufacturing sector, X, produce their varieties for a monopolistically competitive market. The costs of production include a fixed cost of entry equal to the cost of connecting to the network, $\gamma(n)$, and a unit cost given by $w^{\theta}r^{1-\theta}$. Free entry reduces the profits of each firm to zero where operating profits are just sufficient to cover fixed costs.

$$(p_i - w^{\theta}r^{1-\theta})x_i = r\gamma(n). \tag{6}$$

[2]See Helpman and Krugman (1985).

The first order condition for profit-maximization determines price, which will be a constant mark-up over unit cost for each firm, as $p = w^\theta r^{1-\theta}/\alpha$. This pricing policy along with the zero-profit condition, equation (6), infers that the zero-profit level of output is

$$x = \left(\frac{F}{n} + n\right)\left(\frac{r}{w}\right)^\theta (\sigma - 1). \tag{7}$$

When the market for differentiated goods clears, given the constant mark-up over unit costs, the demand for each variety, equation (3), can be written as $c = \alpha\mu I/nw^\theta r^{1-\theta}$ and the number of firms operating in the manufacturing sector and connecting to the communications network can be obtained as

$$n = \left(\frac{\mu I}{\sigma r} - F\right)^{\frac{1}{2}}. \tag{8}$$

From Sheppard's Lemma, the demands for labor and capital in the manufacturing sector are respectively,

$$L_X = \theta\left(\frac{w}{r}\right)^{\theta-1} nx \qquad K_X = (1-\theta)\left(\frac{w}{r}\right)^\theta nx + (F + n^2). \tag{9}$$

To close the model, assume that labor and capital markets clear so that $L = L_X + L_Y$ and $K = K_X + K_Y$. w and r are then determined by substituting equations (4) and (9) into these factor market clearing conditions and using $nx = (\alpha\mu I)/w^\theta r^{1-\theta}$ and $(F + n^2) = \mu I/\sigma r$.

$$w = A\frac{I}{L} \qquad r = (1-A)\frac{I}{K}, \tag{10}$$

where $A = \alpha\theta\mu + \lambda(1-\mu)$.

Using the equilibrium rental in equation (10) the equilibrium number of manufacturing varieties can now be written as

$$n = \left(\frac{\mu K}{\sigma(1-A)} - F\right)^{\frac{1}{2}}. \tag{11}$$

The number of varieties is a function of the capital endowment alone. This is a consequence of the assumption that capital is the sole factor used in the communications sector. Allowing for the use of labor in the production of the communications network would alter this result. However, this simplification can be rationalized with the observation that the communications industry has a high capital intensity.

In the next section, the free trade equilibrium is examined and it is shown that comparative advantage and the existence of intra-industry trade are determined by relative capital endowments and network sizes.

3 Trading Equilibrium

In this section, the effects of capital intensive communications networks on the patterns of trade are examined. Let the world endowments of capital and labor respectively be K^W and L^W. There are two countries, home and foreign, with identical technologies and preferences. The endowments of capital and labor for home and foreign respectively depend on a share parameter s, $0 \geq s \geq 1$, such that

$$\begin{aligned} K^h &= sK^W & K^f &= (1-s)K^W, \\ L^h &= (1-s)L^W & L^f &= sL^W, \end{aligned} \tag{12}$$

where h and f respectively indicate whether a variable is associated with home or foreign. Given these capital and labor endowments, the autarky equilibrium number of firms in each country will be determined by

$$(n_a^h)^2 + (n_a^f)^2 = \frac{\mu K^W}{\sigma(1-A)} - 2F, \tag{13}$$

where a indicates autarky.[3]

The price and consumption indexes for the varieties produced in the manufacturing sector are

$$P_X^i = \left[n^h(p^h)^{1-\sigma} + n^f(p^f)^{1-\sigma}\right]^{\frac{1}{1-\sigma}}, \qquad i = h, f \tag{14}$$

$$X^i = \left[n^h(c^h)^{\alpha} + n^f(c^f)^{\alpha}\right]^{\frac{1}{\alpha}}. \qquad i = h, f \tag{15}$$

Now with the assumption of free trade in the agricultural good and varieties of the manufactured product, i.e. no tariffs and negligible transport costs, factor price equalization will occur as long as neither country completely specializes in the production of manufactured goods.[4] With the wage and rental equalized, the price of manufactures, $p = \frac{w^\theta r^{1-\theta}}{\alpha}$, will be the same for manufacturing firms in both home and foreign. The free trade demand for a given variety in country i is

$$c^i = \frac{\alpha\mu[I^h + I^f]}{w^\theta r^{1-\theta}(n^h + n^f)}. \qquad i = h, f \tag{16}$$

[3]Equation (13) is obtained by adding

$$n_a^h = \left(\frac{\mu s K^W}{\sigma(1-A)} - F\right)^{\frac{1}{2}} \quad \text{and} \quad n_a^f = \left(\frac{\mu(1-s)K^W}{\sigma(1-A)} - F\right)^{\frac{1}{2}}.$$

[4]This requires that the Y sector continue to operate in both countries in the free trade equilibrium. Kikuchi (2002) examines the case where one country completely specializes in the production of "network goods".

Equating the free trade demand for each variety given in equation (16) with the zero-profit output given in equation (7) the number of varieties produced by country i will determined implicitly by

$$F + (n^i)^2 = \frac{\mu[I^h + I^f]}{r\sigma} \frac{n^i}{n^h + n^f}. \qquad i = h, f \tag{17}$$

Given the world endowments of labor and capital and using the factor market clearing conditions the free trade wage rate and rental can be obtained as

$$w^W = \frac{A[I^h + I^f]}{L^W}, \qquad r^W = \frac{(1 - A)[I^h + I^f]}{K^W}, \tag{18}$$

where $(n^h x^h + n^f x^f) = (\alpha\mu(I^f + I^h))/w^\theta r^{1-\theta}$ has been used. With the rental equalized across countries, the implicit functions for the numbers of firms in each country can now be written as

$$\gamma(n^i) = \frac{\mu K^W}{\sigma(n^h + n^f)(1 - A)}. \qquad i = h, f \tag{19}$$

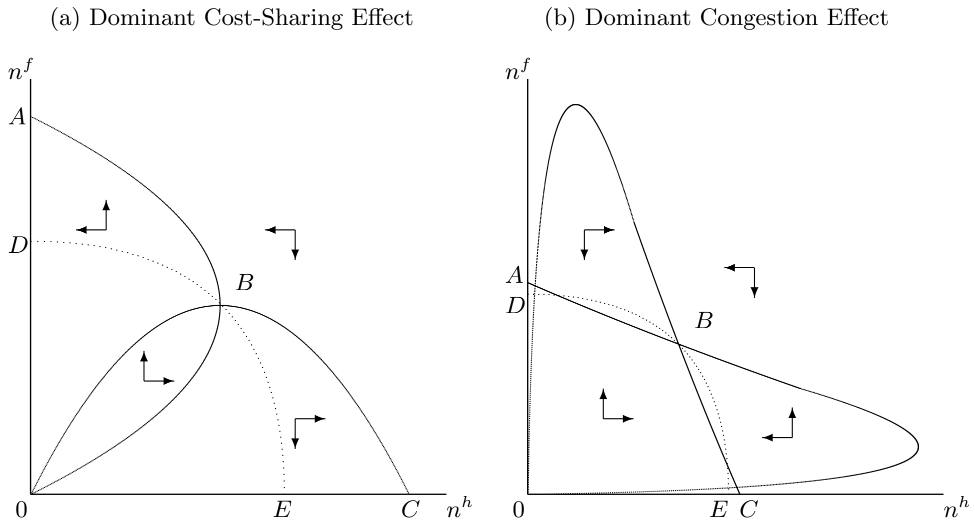
Equations (19) implicitly determine the allocation curves of home and foreign,[5] respectively shown in Figure 1 as ABO and OBC. These allocation curves show the number of zero-profit firms for each country given the number of firms operating in the other country. For numbers of firms outside these allocation curves, negative profits are earned and some firms will exit the market raising the profits of the remaining firms to zero. On the other hand, for numbers of firms inside these allocation curves positive profits are earned and market entry by new firms will reduce profits to zero. This process of entry and exit is described by the arrows in Figure 1. The locus of autarky firm numbers for home and foreign, equation (13), is shown as DBE.

Figure 1(a) describes the case where the fixed costs of the communications industry, F, are relatively large and the cost-sharing effect dominates the congestion effect in the communications industry. There are two stable equilibria, A and C, and one unstable equilibrium, B. If the capital endowments, home and foreign, differ the capital abundant country will have a comparative advantage in the production of manufacturers as a result of the aggregate returns to scale derived from the cost-sharing effect. This will lead to a shift in the location of production so that the entire manufacturing industry locates in the capital-abundant country, e.g. point A or C.

Figure 1b demonstrates the case where F is relatively small, and the congestion effect dominates. Now there are three stable equilibria: A, B, and C. If the free trade equilibrium is described by point B, then the number of varieties produced in

[5]These allocation curves have the same shape as those introduced by Kikuchi (2002) and Kikuchi and Ichikawa (2002).

Figure 1



The parameter values $\mu = 0.5$, $\theta = 0.8$, $\lambda = 0.4$, $\sigma = 2$, $K^W = 200$ are the same in both figures with the exception of F which equals 35 in (a) and 7 in (b).

each country will be the same. When the capital endowments of home and foreign differ the country with the smaller endowment of capital will be a net exporter of capital-intensive manufactured goods.

4 Conclusion

This paper extends the results of Kikuchi and Ichikawa (2002) to examine the role of capital in the determination of comparative advantage in a model with country-specific communications networks. The analysis focuses on the case where capital is the only factor used in the communications sector.

The model suggests that, when manufacturing firms require the use of a communications network, trade patterns will be determined by relative capital endowments and network externalities. A dominant cost-sharing effect leads to industry level returns to scale in the manufacturing industry creating a comparative advantage in the production of manufactured goods for the relatively capital abundant country. Then, specialization of production occurs with the relatively capital abundant country producing all manufactured goods and the relatively capital scarce country only producing the agricultural product. On the other hand, a dominant congestion effect leads to a comparative advantage for the relatively capital scare country as a result of lower network connection costs. Then, the number of varieties of the manufactured good produced in each country will be the same, network connection costs will be equalized, and intra-industry trade will occur with both countries exporting manufactured goods. In this case the country with the smaller endowment of capital may become a net exporter of the capital-intensive manufactured good.

These results suggest that relative capital endowments are an important determinant of the patterns of trade for manufactured goods that require the use of a communications network in production.

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