THE KOREAN ECONOMIC REVIEW
Volume 16, Number 2, Winter 2000

INUSTRIALIZATION, THE EXTENT OF MARKER, AND THE MOBILITY OF LABOR: A GEOGRAPHIC PERSPECPTIVE

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A general equilibrium model with heterogeneous agents is presented to explain why the undeveloped economies are not industrialized until the late twentieth century. The model takes into account two factors related to the geographic structure of the economy. First, the poor infrastructure of an undeveloped economy leaves its domestic market spatially segregated because of the high transport costs. Second, depending on how readily the labor force in the rural areas can move into the industrial area, the cost of labor may be too expensive to run a factory profitably. The model bears several policy implications. The government's investment in infrastructure encourages the industrialization. The effect of the government's investment in the infrastructure on the geographic concentration of industries depends on the fixed cost of the manufacturing technology. A country can get around the problem of high transportation costs by targeting foreign markets and exploiting the cheaper ocean transportation costs. A reduction in the cost of migration, such as housing costs and the cost of risk-sharing, the labor force with low reservation wage can be attracted to the industrial area.

JEL Classification: D58, O18, R12

Although the industrialization has spread out all over the world throughout this century, many countries still remain undeveloped until now. (Easterlin, 1981) Explaining why it is so difficult for some economies to launch the industrialization, the model in this paper takes into account two major factors related to the spatial structure of an economy. First, the poor infrastructure of an undeveloped economy leaves its domestic markets spatially segregated. In such

Received for publication: June 2, 1999. *Revision accepted:* March 10, 2000.

* I thank Robert Townsend, Nancy Stokey, and D. Gale Johnson for the comments. I also appreciate Joon-mo Yang's comment at the annual conference of Korean Economic Association in 1998. I also thank the anonymous referee for the valuable comments. This research was supported by Yonsei University Research Grant (1998).

circumstances, each of the localized and fragmented domestic markets of an undeveloped economy may be too thin to cover the fixed costs of the modern industrial technology even if the size of the national market as a whole may be large enough. Second, the cost of labor varies depending on how readily the labor force in rural area can move into the industrial sites. In one extreme where the supply of labor may be infinitely elastic, as depicted in Arthur Lewis' hypothesis, the wage is maintained at the low level. But in the other extreme where the supply of labor is limited to the vicinity to industrial site, perhaps due to the high cost of migration, the wage may be too high to run the modern factory profitably.

The conventional wisdom on the issue of the delay in industrialization has been pointing at the inadequate access to the advanced technologies, the lack of human capital, and the insufficient national resources to finance the investment in the industrial facilities. But the persuasiveness of such explanation is eroding away when we start thinking about the environments of the world economy today. Nowadays, the industrialization of an undeveloped economy does not require the invention of its own technologies because there is the fairly-well developed market for the modern, if not the frontier, manufacturing technologies. Since the transfer of technology is usually accompanied by the provision of managers and engineers as well as the standardized blue prints and manuals, the lack of human capital became a less insurmountable hurdle than it was in the early twentieth century. The development of the global network of financial markets in the late twentieth century made it much easier for an undeveloped economy to acquire financial resources necessary for industrialization. Furthermore, all of the above problems can be resolved, if an undeveloped economy succeeds in inviting foreign direct investments.[1]

Section 1 presents the basic model of an undeveloped economy. Section 2 introduces the factory manufacturing technology and explains the behavior of the factory. Section 3 elaborates the labor market. Section 4 derives the conditions and the patterns for the industrialization. Section 5 concludes with the policy implications of the model.

I. A SPATIAL MODEL OF AN UNDEVELOPED ECONOMY

A. Demography and Geography

Consider a pre-industrialized economy where the means of living is small-scale farming or household manufacturing. In this economy, there are two kinds of

[1] The NIC's can get an access to modern technology through licensing or imitating. Japan was no exception in the early part of this century. In the case of Korea, its investment rate consistently exceeded the domestic saving rate throughout the 1960 and 1970 and the difference was made up by the external debts. Singapore has been most successful in attracting foreign direct investment, which seems to be their engine of growth.

goods: the primary good, and the processed good. The primary good refers to the products of agriculture, mining, fishery and forestry, and the processed good to the products of household manufacturing. The primary good can be either consumed or used as raw materials for the processed good. The processed good, on the other hand, can only be consumed.[2] The primary good and the processed good are denoted by the subscript $i=1, 2$, respectively. The primary good 'at the marketplace' is the *numeraire* and p is the market price of the processed good in terms of the numeraire.[3]

Suppose that the territory of the economy is a square with the homogeneous terrain. Let the size of the territory be S^2 where S is a large number. In the homogeneous two-dimensional space it is optimal that the distribution of the countable number of marketplaces is a triangular lattice system. That is, each marketplace is surrounded by the other identical marketplaces, and the distance to each of the surrounding marketplaces is the same.[4] However, we simplify the marketing structure by assuming that there are only two marketplaces in this economy. Also assume that the distance between the marketplaces is given exogenously as D and that the distance D is large enough that the market areas associated with the marketplaces do not overlap. In <Figure 1> and <Figure 2>, the dots in the center of the circles indicate the location of the marketplaces. Assume that all the trades take place only at the marketplaces. Whenever a household wants to buy or sell goods, he has to make a round trip to the nearest marketplace.

But it is costly to trade at the marketplace because it takes t units of labor to transport one unit of either of the two commodities for unit distance.[5] Note that the transportation costs are proportional to both the distance and the volume of goods.

To begin with, assume that the population density is one everywhere. That the households have exactly the same preferences, endowments, and the access to the same production technologies. Only the distance, d, of a household to the nearest marketplace distinguishes the households. Therefore, we identify the

[2] This is a simplifying assumption. By, this assumption, we abstract from the possibility that the processed good can be used as intermediate goods. In the context of an undeveloped economy where the round-aboutness of production is limited, this assumption seems less a problem than in a developed economy.

[3] In the following, it turns out that the effective price of a good varies depending on the distance to the market and the occupation of the household.

[4] For the proof of this argument see W. Christäler (1933), A. Lösch (1940), B. Bollobas and N. Stern (1972).

[5] The symmetry of transport costs does not bias the results because the households will have to transport both kinds of the goods whether it specializes in the primary good or in the processed good. Note also that the specification of the transportation costs differs from Samuelson's iceberg transportation costs according to which the goods wear out as they are being transported. The latter is valid only when the transportation technology and the production technology are identical.

households by the distance d to the nearest marketplace. Let $c_1(d)$ and $c_2(d)$ be the amounts of the primary good and the processed good consumed by the household d, respectively. A typical household d has a Cobb-Douglas utility function, $u(c_1(d), c_2(d)) = c_1(d)^{\alpha} c_2(d)^{1-\alpha}$. Each household is endowed with one unit of labor.

B. Production Technology

We subscribe to Adam Smith's idea that the specialization improves the productivity of labor. Let L_i be the labor input to the production of the ith good. The labor input, measured in time, generates some skill or physical energy, called human capital, H_i, which is useful directly to the production of the ith good. If a household focuses on the production of only one kind of good, it may be able to use its time more efficiently. Let us denote by σ the number of *kinds* of goods a household produces, which we may interpret as the degree of specialization. In this two-good model, σ is either 1 or 2. Specifically, assume that $H_i = (1/\sigma) \cdot L_i$. This specification simplifies the analysis by eliminating the possibility of incomplete specialization.

However, specialization is not for free because a specialized household has to trade at the marketplace and it is costly to trade. Remind that it takes τ units of labor to transport one unit of either of the two commodities for unit distance. The farther away from the marketplace is a household, the higher is the effective price of the good he purchases and the lower is the effective price of the good that he sells at the marketplace. In short, the transportation costs make the specialization costly. Thus, for those who are too far away from the marketplaces, the cost of specialization may exceed the benefit so that they would rather stay in autarky.

Now, let us turn to the production technology. Assume that one unit of primary good can be produced with one unit of human capital for farming. It follows that the output of primary good is linear in the labor input;

$$y_1 = H_1 \qquad (= (1/\sigma) \cdot L_1) \tag{1}$$

where y_1 is the output of the primary good, L_1 is the labor input for the production of the primary good, and σ is the number of kinds of goods a household produces.

The production of the processed good requires not only the labor but also the raw material. In particular, a Leontief technology is assumed to underline the complementarity between the raw material and the human capital;

$$y_2 = Min\{a \cdot x,\ b \cdot H_2\} \ \ (Min\{a \cdot x,\ b \cdot (1/\sigma) \cdot L_2\}), \tag{2}$$

where y_2 is the output of the processed good, x is the amount of the primary good used as raw material, H_2 is the amount of human capital for the processed good, a and b are the output-input ratios with respect to raw material and human capital, respectively, L_2 is the labor input for the production of the processed good, and σ is the number of kinds of goods a household produces.

C. Geographic Distribution of Occupations

There are three types of occupations available: i) an autarkic household, ii) a farmer (a household who is specialized in the primary good), and iii) a handicraftsman (a household who is specialized in the processed good). The household will choose the occupation to maximize his utility.

An autarkic household, by definition, would produce all that he consumes. The tradeoff faced by such a household is to allocate his labor endowment into the production of the primary good and the processed good. That is, he solves the following optimization problem;

(An Autarkic Household)

$$\begin{aligned} &Max\ \ c_1^{\alpha}\cdot c_2^{1-\alpha} \\ &\text{s.t.}\ \ c_1 \leq (1/2)(1-L_2)-(b/a)(1/2)L_2 \\ &\qquad c_2 \leq b\cdot(1/2)L_2, \end{aligned}$$

where c_i is the consumption of the ith good, L_2 is the labor input for the production of the processed good, and $1-L_2$ is the labor input for the production of the primary good. Note that $\sigma=2$ for an autarkic household, since he produces both the primary good and the processed good. These constraints state that the consumption cannot exceed what the household has produced.

The equation (3) together with the binding constraints are the necessary and sufficient conditions for the autarkic household optimization problem.

$$\frac{\alpha\cdot c_2}{(1-\alpha)\cdot c_1}=\frac{a\cdot b}{a+b} \tag{3}$$

The equation (3) is simply the condition that the marginal rate of substitution equals the marginal rate of transformation. The optimal consumption plan of an autarkic household is $\hat{c}_1=\alpha/2$ and $\hat{c}_2=(1-\alpha)\cdot a\cdot b/2\cdot(a+b)$. Thus, his indirect utility is $u^A=\alpha^{\alpha}\cdot((1-\alpha)\cdot a\cdot b/(a+b))^{1-\alpha}/2$. Since the autarkic households do not trade at the marketplace, their indirect utility does not depend on the distance to the marketplace.

A farmer is a household who is specialized in producing the primary good. If a farmer d uses $L(d)$ units of his labor in farming he can produce $L(d)$ units of the primary good. (Note that $\sigma=1$.) Because he wishes to consume both the primary good and the processed good, he needs to trade a part of his primary good for the processed good. A farmer d transports the primary good to the marketplace for sale and transports back home the processed good for consumption. If he consumes the bundle $(c_1(d), c_2(d))$, the amount of labor necessary for the transportation is $\tau \cdot d \cdot (L(d) - c_1(d)) + \tau \cdot d \cdot c_2(d)$. Thus, a farmer d's optimization problem is given by

(A Farmer)

$$
\begin{aligned}
&Max\ c_1(d)^{\alpha} \cdot c_2(d)^{1-\alpha} \\
&\text{s.t. } c_1(d) + p \cdot c_2(d) \leq L(d) \\
&\qquad L(d) + \tau \cdot d \cdot (L(d) - c_1(d)) + \tau \cdot d \cdot c_2(d) \leq 1.
\end{aligned}
$$

The first constraint states that market value of the consumption bundle cannot exceed the market value of a farmer d's output. The second constraint states that the labor used for the production and the transportation cannot exceed the labor endowment. The two constraints above can be merged into one as follows.

$$c_1(d) + p \cdot c_2(d) \leq (1 - (1+p) \cdot (\tau \cdot d) \cdot c_2(d)) \tag{4}$$

Equation (4) states that the market value of the consumption bundle cannot exceed the market value of the maximum amount of the output of the primary good net of the required transportation costs. The necessary and sufficient conditions for the above optimization problem of a farmer d are equation (4) holding as an equality and the following first order condition,

$$\frac{\alpha \cdot c_2(d)}{(1-\alpha) \cdot c_1(d)} = p + (1+p) \cdot (\tau \cdot d) \tag{5}$$

The right hand side of equation (5) is the effective relative price of the processed good for a farmer d. Hence, the equation (5) states that a farmer d's marginal rate of substitution should be equal to the effective relative price of the processed good. Note that the effective relative price of the processed good increases in the farmer's distance from the marketplace. Let $\tilde{\lambda}(d)$ be the Lagrangean multiplier associated with the constraint (4). Then $\tilde{\lambda}(d)$ is the shadow wage for a farmer d. The farmer d's optimal consumption plan is $\tilde{c}_1(d) = \alpha$ and $\tilde{c}_2(d) = (1-\alpha)/(p + (1+p) \cdot \tau \cdot d)$. It follows that the farmer d's indirect utility is $u^F(d) = \alpha^{\alpha} \cdot (1-\alpha)^{1-\alpha} \cdot (p + (1+p) \cdot \tau \cdot d)^{-(1-\alpha)}$.

We call as a handicraftsman a household who is specialized in producing the processed good. A handicraftsman d consumes a part of his output of the processed good and trades the rest of it for the primary good. He carries the processed good to the marketplace for sale and he carries the primary good back home for consumption and production. Note that a handicraftsman needs to buy enough primary good both for the consumption and the production. If a handicraftsman d uses $L(d)$ units of his labor and $(b/a)\cdot L(d)$ units of the primary good, he can produce $b\cdot L(d)$ units of the processed good. (Note also that $\sigma=1$.) If his consumption plan is $(c_1(d),\ c_2(d))$, the amount of the labor to be allocated in the transportation is $(\tau\cdot d)\cdot(c_1(d)+(b/a)\cdot L(d))+(\tau\cdot d)\cdot(b\cdot L(d)-c_2(d))$. Thus, a handicraftsman d's optimization problem is given by

(Household Manufacturing)

$$Max\ c_1(d)^{\alpha}\cdot c_2(d)^{1-\alpha}$$
$$\text{s.t.}\quad c_1(d)+p\cdot c_2(d)\leq p\cdot(b\cdot L(d))-\frac{b}{a}\cdot L(d)$$
$$L(d)+(\tau\cdot d)\cdot(c_1(d)+\frac{b}{a}\cdot L(d))+(\tau\cdot d)\cdot(b\cdot L(d)-c_2(d))\leq 1,$$

The first constraint states that the market value of the handicraftsman d's consumption bundle cannot exceed the market value of his output of the processed good net of the cost of raw materials. The second constraint says that the labor input for production and transportation cannot exceed the labor endowment. Combining the two, the constraint is

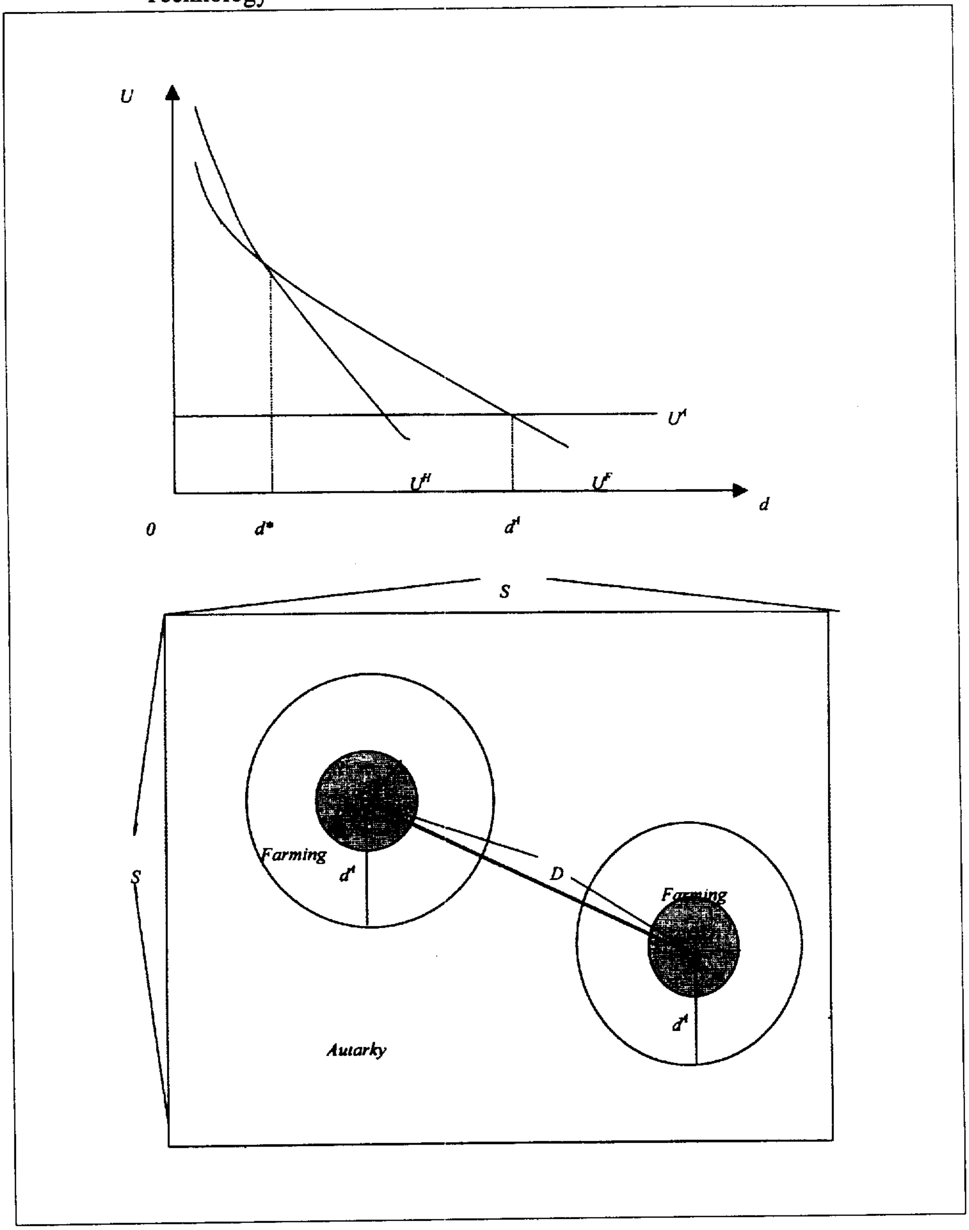
$$c_1(d)+p\cdot c_2(d)\leq\pi\cdot(1-(1+p)\cdot(T\cdot d)(b\cdot c_1(d)+\frac{b}{a}\cdot c_2(d))/\pi),\quad (6)$$

where $\pi=(p\cdot b-b/a)$ is the marginal revenue of labor net of the cost of raw material. This integrated constraint states that the market value of the consumption bundle cannot exceed the maximum earnings of a handicraftsman net of the transportation costs and the expenses for the raw material. The necessary and sufficient conditions for a handicraftsman d's optimization problem are equation (6) holding as an equality and the following first order condition.

$$\frac{\alpha\cdot c_2(d)}{(1-\alpha)\cdot c_1(d)}=\frac{p+(1+p)\cdot(\tau\cdot d)\cdot(b/a)}{1+(1+p)\cdot(\tau\cdot d)\cdot b}\quad (7)$$

The right hand side of equation (7) is a handicraftsman d's effective relative price of the processed good. Equation (7), thus, implies that a handicraftsman d's marginal rate of substitution should be equal to the effective relative price of the processed good. The Lagrangean multiplier associated with the constraint (7), $\tilde{\tilde{\lambda}}(d)$, is the shadow wage for the handicraftsman d. The handicraftsman d's optimal consumption pan is $\tilde{\tilde{c}}_1(d)=\dfrac{\alpha(p\cdot b-b/a)}{(1+(1+p)\cdot b\cdot(\tau\cdot d))}$ and $\tilde{\tilde{c}}_2(d)=\dfrac{(1-\alpha)\cdot(p\cdot b-b/a)}{(p+(1+p)\cdot(b/a)\cdot(\tau\cdot d))}$. Thus, his indirect utility is $u^H(d)=(\alpha/(1+(1+p)\cdot b(\tau\cdot d))^{\alpha}\cdot((1-\alpha)/(p+(1+p)\cdot(b/a)\cdot(\tau\cdot d))^{1-\alpha}\cdot(p\cdot b-b/a)$.

[Figure 1] Geography of Household Occupations in an Undeveloped Economy: The Case of Raw Material Intensive Household Manufacturing Technology



● Location of the marketplace.

D : Distance between the marketplaces.

d^A : Radius of the market area. (Location of the household indifferent between autarky and farming.)

d^* : Radius of the manufacturing area. (Location of the household indifferent between household manufacturing and farming.)

A household d will consider all three alternatives and choose the occupation that gives him the highest utility. Given the market price p, the maximized utilities of both farmers and handicraftsmen decrease in the distance from the marketplace. If we assume that the production technology of the processed good is raw material intensive, $a<b$, a handicraftsman's utility decreases in distance more rapidly than a farmer's. In such economic environments, the households who are close to the marketplace become handicraftsmen, those who are far away from a marketplace become farmers, and the rest of the households who are too far away from a marketplace stay in autarky. (See Lee (1996) for the proof of the general case.) Since we assumed that the marketplaces are far from one another, the size of the market area is determined endogenously by the location of the marginal households, d^A, who are indifferent between staying in autarky and becoming a farmer. (d^A solves $u^A = u^F(d)$.) Also the size of the manufacturing area is determined by the location of the marginal households d^* who are indifferent between being a farmer and being a handicraftsman. (d^* solves $u^F(d) = u^H(d)$.) This geographic pattern of occupation is depicted in <Figure 1>. Given this geographic pattern of occupation, the equilibrium price of the processed good, p^* is determined to clear the market.

Ⅱ. FACTORY MANUFACTURING TECHNOLOGY AND THE EXTENT OF THE MARKET

A. Factory Manufacturing Technology

We interpret the industrialization as the transition of the mode of production from the household manufacturing to the factory manufacturing. The distinguishing features of the factory manufacturing are the high start-up costs and the need for hiring many workers. Assume that the construction of a factory, including the installation of the machines and the equipment, takes a fixed cost K and that the capital goods necessary for the construction of a factory are imported from the developed countries at a fixed price. To capture the spirit of Adam Smith's pin factory parable, assume also that the narrower is the specialization of the workers in a factory, the higher is their productivity *a la* Dixit and Stiglitz: $H = z \cdot \left[\int_0^n i^\rho di \right]^{1/\rho} = n^{1+\frac{1}{\rho}}$, where $z = (1+\rho)^\rho$ and $1 \leq \rho$. The higher is the value of ρ, the improvement of the productivity due to the division of labor is weaker. Assume the strongest case where $\rho = 1$, so that $H = n^2$. In addition, we assume that the labor and the raw material are strong complements in the factory manufacturing, too.

$$y_2 = Min\{A \cdot x,\ B \cdot H\} \tag{8}$$

where the upper case letters A and B are output-input ratios of the factory manufacturing technology. Assume that the factory manufacturing is far more productive than the household manufacturing, that is, $A \gg a$ and $B \gg b$.

B. The Pricing Policy and the Size of the Market Area

Consider one marketplace and its associated market area. When an entrepreneur plans to launch a manufacturing business, it is obvious that the most favorable site for the factory is the marketplace. For analytical simplicity, assume that the factory intends to maximize the market share by exercising the predatory pricing. To keep the competitive fringe out of the market, the price the monopolist can charge is

$$p \leq [a+b]/a \cdot b. \tag{9}$$

If the factory is extremely productive relative to the household manufacturing (that is, the values for A and B are high enough), it is possible that the monopolist's profit maximizing price is lower than the right hand side of the equation (9). In this case, the predatory price will be strictly less than $[a+b]/a \cdot b$. Otherwise, the equation (9) is binding.

The size of the market area associated with a marketplace is determined by the location of the marginal household who is indifferent between autarky and specialization, $u^F(d) = u^A$. It follows that the size of the market area, d^A is

$$d^A = (2^{1(1-\alpha)} \cdot (a+b)/a \cdot b - p)/(1+p) \cdot \tau. \tag{10}$$

Note that the size of the market area, d^A, decreases in the relative price of the processed good p. Thus, when the factory exercises the predatory pricing, the size of the market area exceeds the maximum size of the market area under the household manufacturing system. It is because the lower bound of the equilibrium price of the processed good under the household manufacturing system is $(a+b)/a \cdot b$ is.

C. The Extent of the Market for the Factory and the Occupational Choices of Households.

The factory production is profitable, only if the market for the factory is large enough to cover the start-up costs. If the inter-marketplace transportation costs are so high as to prevent the inter-marketplace trades, each market area is segregated. If the demand for the processed good in one market area is not large enough to support the factory this economy will stay undeveloped even though the whole economy's demand is large enough. In this case, the geographical pattern of production is exactly the same as shown in section 1. (See <Figure 1>.)

When the start-up cost and the transportation costs are not forbiddingly high, the factory manufacturing will be adopted in the economy. Now, the entrepreneur has to decide how many factories to build. The decision depends on the relative magnitudes of the start-up cost and the inter-market transportation costs. The specific conditions are worked out in the section 4. Roughly speaking, on one hand, if the inter-marketplace transportation costs are high relatively to the start-up cost of the factory, it is optimal to construct the factories at every marketplace. On the other hand, if the start-up cost is too high relatively to the inter-marketplace transportation costs, then it is optimal to build only one factory at one marketplace. Let us call as "the industrial area" the market area where the factory is located. In the former case each market area is industrialized and is self-sufficient while in the latter case only one market area is industrialized.

When there is only one factory in the economy, a part of its output will be sold at the marketplace where it is located and the rest of it will be shipped out to the surrounding marketplaces. Given that the predatory price is p at the central marketplace, the price of the processed good at the surrounding marketplaces would be $p'=p+w\tau D$, where w is the wage rate and D is the distance between the marketplaces. Since the equilibrium price of the processed good under the household manufacturing system is p^*, the inter-marketplace trade actually happens only if $p'<p^*$. As long as p' is not too low (i.e., $(a+b)/a \cdot b<p+w \cdot \tau \cdot D$), some of handicraftsmen in the surrounding market areas survive the competition with the factory.

The households in an industrial area have three alternative types of occupations; i) a farmer, ii) a factory worker, and iii) an autarkic household. In contrast, the occupations available for the households in the undeveloped areas are the same as those in an undeveloped economy: i) a farmer, ii) a handicraftsman, and iii) an autarkic household. If $p'<(a+b)/a \cdot b$, the household manufacturing cannot survive anywhere in the economy. Thus, the alternative occupations left for the households in the unindustrialized market area are merely i) a farmer and ii) an autarkic household.

Ⅲ. LABOR MARKET

A. Demand for labor

By the specification of the factory manufacturing technology, n workers in the factory can generate n^2 units of the human capital. Thus, if the factory plans to produce y units of the processed good, it should hire $(y/B)^{1/2}$ units of labor. Therefore, the factory's demand for labor is

$$n^D=(y/2B)^{1/2}, \tag{11}$$

where y is the level of output.

B. Supply of labor

We have already seen that in an undeveloped economy, those who are close to the marketplace specialize in household manufacturing, those who are moderately remote from the marketplace specialize in farming, and those who are too far away from the marketplace give up trading and stay in autarky. In an industrialized economy, we still need to identify who will work for the factory. The geographic pattern of labor supply depends on the mobility of the population. If the migration is not possible, perhaps because of the forbiding costs, the workers would have to commute. In this case, the factory will find it less expensive to employ the households close to the factory. If the migration is possible, then the factory prefers to hire the households far away from the marketplace because their reservation wage is lower.

Case 1. Fixed Residence: Workers should commute.

Suppose that the workers live in their original location and they commute to the factory for some reason. One such reason may be that the rent for the location is high enough to prevent migration into the market town. Then, the optimization problem for the worker d is given by

$$\begin{aligned} &Max\ c_1(d)^{\alpha} \cdot c_2(d)^{1-\alpha} \\ &\text{s.t.}\ \ (1+w\cdot\tau\cdot d)\cdot c_1(d)+(p+w\cdot\tau\cdot d)\cdot c_2(d)\leq w, \end{aligned}$$

where w is the wage rate and $w\cdot\tau\cdot d$ term in worker d's budget constraint accounts for the transportation costs of carrying the goods back home from the marketplace. The worker d's optimal consumption plan is $c_1^{wc}(d)=\alpha\cdot w/(1+w\cdot\tau\cdot d)$ and $c_2^{wc}(d)=(1-\alpha)\cdot w/(p+w\cdot\tau\cdot d)$. His indirect utility is $u^{wc}(d)=(\alpha/(1+w\cdot\tau\cdot d))^{\alpha}\cdot((1-\alpha)/(p+w\cdot\tau\cdot d))^{1-\alpha}$.

If $u^{wc}(d)\geq u^F(d)$, then household d will choose to be a worker. If $w<1$, the household at the marketplace $(d=0)$ wants to be a farmer since $u^{wc}(0)<u^F(0)$. At the same time, it can be shown that for all positive wage rate w, the worker's utility decreases faster in the distance to the market than the farmer's, that is, $\partial u^{wc}(d)/\partial d\leq\partial u^F(d)/\partial d$. A worker's utility is more sensitive to the distance to the marketplace than a farmer's, because a worker has to buy all that he consumes at the marketplace while a farmer produces by himself the primary good that he consumes. In sum, if $0<w<1$, no one would want to work for the factory. Therefore, the factory wage must be greater than one, $w>1$, and it should be high enough to attract enough workers.

Let d^W be the distance to the marketplace that makes a household indifferent between being a farmer and being a worker. That is, d^W solves $u^{Wc}(d)=u^F(d)$, which reduces to

$$(w\cdot\tau\cdot d)^2+(1+p)\cdot(w-1)\cdot\tau\cdot d+(w^{-1(1-\alpha)}\cdot p-1)=0. \tag{12}$$

In the industrial area, the households $d\in[0,\ d^W]$ work for the factory, the households $d\in(d^W,\ d^A)$ specialize in producing the primary good, and the households $d>d^A$ stay in autarky. Hence, the supply of labor is $\pi\cdot(d^W)^2$. Since d^W increases in w, the factory has to offer higher wage to employ more workers. Let n^D be the demand for labor. Then the equilibrium wage is determined by

$$n^D=\pi\cdot(d^W)^2 \tag{13}$$

Case 2. Migration

Suppose that the factory invests R in housing for the workers and that the workers can move into the factory housing for free[6]. In this case a factory worker's optimization problem is

$$\begin{aligned}\text{Max}\quad & u(c_1,\ c_2)=c_1^{\alpha}\cdot c_2^{1-\alpha}\\ \text{s.t.}\quad & c_1+p\cdot c_2\le w.\end{aligned}$$

The worker's optimal consumption plan is $c_1^{wm}=\alpha\cdot w$ and $c_2^{wm}=(1-\alpha)\cdot w/p$. His indirect utility is $u^{Wm}=\alpha^{\alpha}\cdot((1-\alpha)/p)^{1-\alpha}\cdot w$. Note that the worker's utility u^{Wm} doesn't depend on the distance to the marketplace, because all the workers live at the marketplace. The factory prefers to hire the households far away from the marketplace because they have lower reservation wage. Provided that the pool of autarkic households is large enough, the equilibrium wage rate w is determined by the reservation wage of the autarkic households. That is, the equilibrium wage solves the equation $u^{Wm}=u^A$. Thus, given that the factory exercises the predatory pricing, the equilibrium wage is $w^*=1/2$.

Note that this situation resembles Arthur Lewis' case of underdevelopment where the elasticity of labor supply is infinite and the equilibrium wage is set at the subsistence level. If the factory employs n autarkic households, the population mass at the market becomes n. Since the size of market area d^A is constant as far as the price is fixed, the employment of autarkic households by the factory brings the autarkic households inside the market area. In effect, this tantamounts to an additional expansion of the market area.

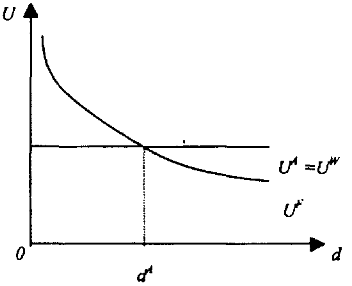
The geographic patterns of the household occupations are shown in <Figure 2>.

[6] The analytical results does not change even if the residential cost increases in proportion to the number of immigrants to the factory site. It's because the cost per unit of of labor is still a constant. However, if the residential cost increases at an increasing rate, the firm may find it more profitable to fill only a part of the job openings with the immigrants and to hire the commuters around the factory to fill the rest. Though this gives us more interesting implications on the size and the structure of a city, we assume that the residential cost is fixed for the sake of simplicity. A similar complication arises if we release the assumption that there are a large number of autarkic households. I thank an anonymous referee for raising a question on this issue.

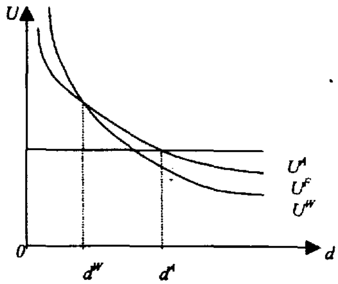
[Figure 2] Geography of Household Occupations in an Industrialized Economy

1. Choice of Occupations in the Industrial Area

A. Migration is possible (R is small).



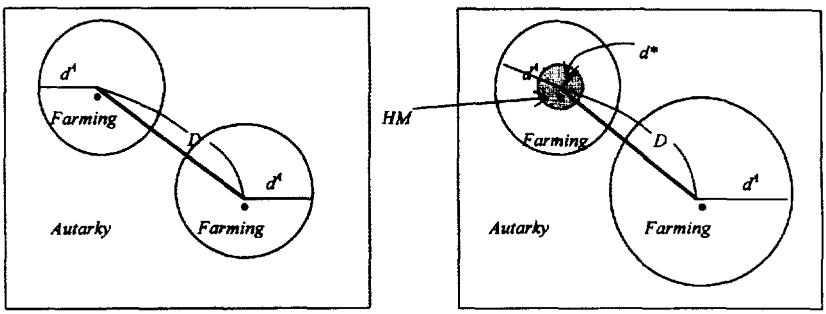
B. Migration is not possible (R is large).



2. Geography of Household Occupations

A. Migration is possible and all the market areas are industrialized.

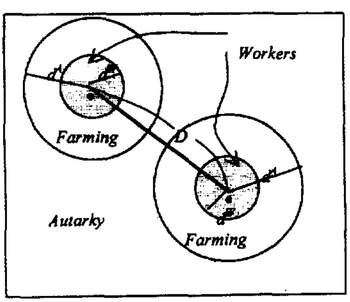
B. Migration is possible and only one market area is industrialized.



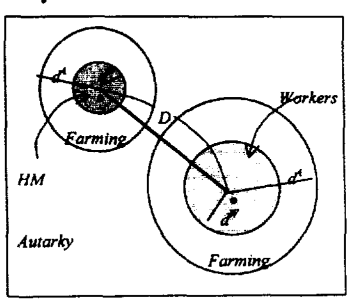
* Population density is n at the marketplaces, one in the farming areas, and less than one in the autarkic area.

** Industrialized market area is larger ($d^A > d^{A'}$) because the price of the processed good is lower.

C. Migration is not possible and all the market areas are industrialized.



D. Migration is not possible and only one market area is industrialized.



* Population density is one everywhere.

** Industrialized market area is larger ($d^A > d^{A'}$) because the price of the processed good is lower.

IV. INDUSTRIALIZATION:

A. The Demand for the Factory's Output

Because the factory technology exhibits increasing returns to scale, the size of the factory is limited by the market demand. But the amount of the market demand for the processed good depends on how the profit of the factory is distributed.[7] For the analytical simplicity assume that the factory is built by foreign direct investment and the profit is not retained in the economy.

If the transportation costs are too high, there is no trade between the marketplaces. The demand for the factory's output is comes only from its own market area. If the workers should commute, the demand for the factory's output is

$$\begin{aligned} y^c &= 2\cdot\pi\cdot(1-a)\cdot\left\{w\cdot\int_0^{d^W}\frac{r}{p+w\cdot\tau\cdot r}\cdot dr \right.\\ &\quad \left. +\int_{d^W}^{d^A}\frac{r}{p+(1+p)\cdot\tau}\cdot r\cdot dr\right\} \qquad (14)\\ &= 2\cdot\pi\cdot(1-a)\left[\frac{1}{w\cdot\tau}\left\{d^W-\frac{p}{w\cdot\tau}\cdot\ln\left(\frac{p+w\tau\cdot d^W}{p}\right)\right\}\right.\\ &\quad \left.+\frac{1}{(1+p)}\cdot\tau\cdot\left\{(d^A-d^W)-\frac{p}{(1+p)\cdot\tau}\cdot\ln\left(\frac{p+(1+p)\cdot\tau\cdot d^A}{p+(1+p)\cdot\tau}\cdot d^W\right)\right\}\right] \end{aligned}$$

But if the factory invests in housing and the workers can move into the factory site, the demand for the factory's output is

$$\begin{aligned} y^m &= (1-a)\cdot\left\{n\cdot woverp+2\cdot\pi\cdot\int_0^{dA}\frac{r}{p+(1+p)\cdot\tau\cdot r}\cdot dr\right\} \qquad (14)\\ &= (1-a)\cdot\left\{n\cdot\frac{w}{p}+2\cdot\pi\cdot\frac{1}{(1+p)\cdot\tau}\cdot\left[d^A-\frac{p}{(1+p)\cdot\tau}\right.\right.\\ &\quad \left.\left.\cdot\ln\left(\frac{p+(1+p)\cdot\tau\cdot d^A}{p}\right)\right]\right\} \end{aligned}$$

where $w=1/2$ and n is the number of workers hired at the factory.

If there is only one factory and the transportation costs are not too high, the single factory can sell its output at the other marketplace as well as at its own marketplace. The demand for its output in the other market area is

$$y' = 2\cdot\pi\cdot(1-a)\cdot\left\{(p'\cdot b-b/a)\cdot\int_0^{d^{*}}\frac{r}{p'+(1+p')\cdot(b/a)\cdot\tau\cdot r}\cdot dr\right.$$

[7] Although the Engel curve associated with the Cobb-Douglas utility function is linear, the Gorman aggregation condition does not hold because the households face different prices depending on the distance of their residence from the marketplace.

$$+\int_{d^{*}}^{d^{A}} \frac{r}{p'+(1+p')\cdot\tau\cdot r}\cdot dr\Big\}$$

$$=2\cdot\pi\cdot(1-\alpha)\cdot\Big[\frac{(p'\cdot b-b/a)}{(1+p')\cdot(b/a)\cdot\tau}\cdot\Big\{d^{*\prime}-\frac{p'}{(1+p')\cdot(b/a)\cdot\tau}$$

$$\ln\Big(\frac{p'+(1+p')\cdot(b/a)\cdot\tau\cdot d^{*\prime}}{p'}\Big)\Big\}+\frac{1}{(1+p')\cdot\tau}\cdot$$

$$\Big\{(d^{A'}-d^{*\prime})-\frac{p'}{(1+p')\cdot\tau}\cdot\ln\Big(\frac{p'+(1+p')\cdot\tau\cdot d^{A'}}{p'+(1+p')\cdot\tau\cdot d^{*\prime}}\Big)\Big\}\Big] \tag{15}$$

where the superscript "′" denotes the variable pertaining to the other market area. Thus, the total demand for the factory output is

$$y=y'+y^{c} \qquad \text{or} \qquad y=y'+y^{m}, \tag{16}$$

depending on whether or not the factory invests in housing.

B. Conditions for Industrialization

The profitability of the factory manufacturing depends on the start-up costs, the amount of the demand for the processed good, the transportation costs, and the mobility of labor. First, consider the case where the inter-marketplace transportation costs are so high as to prevent the trade between marketplaces. In this case, the market for the factory's output is confined to the market area associated with the marketplace where the factory is located. On the one hand, if the factory does not invest in housing, then the workers should commute and $w^{c}>1$. The profit of the factory with the commuting workers is given by

$$\Pi^{c}=p\cdot y^{c}-(1/A)\cdot y^{c}-w^{c}\cdot(y^{c}/B)^{1/2}-K, \tag{17}$$

where y^{c} is the demand for the factory's output when the workers have to commute, defined in the equation (14). On the other hand, if the factory makes the housing investment R, then the autarkic households will be employed by the factory and their reservation wage is $w^{m}=1/2$.. The profit of the factory with the housing investment is given by

$$\Pi^{m}=p\cdot y^{m}-(1/A)\cdot y^{m}-w^{m}\cdot(y^{m}/B)^{1/2}-K-R, \tag{17}$$

where y^{m} is the demand for the factory's output when the workers can immigrate to the factory site, defined in the equation (14′).

The factory would make the housing investment if $\Pi^{m}>\Pi^{c}$, that is,

$$(p-1/A)\cdot(y^{m}-y^{c})-\{w^{m}\cdot(y^{m}/B)^{1/2}-w^{c}\cdot(y^{c}/B)^{1/2}\}>R. \tag{18}$$

The benefit of investing in housing consists of two parts; 1) The immigration of autarkic households into the factory site increases the population of the market area, so that the factory enjoys the increasing returns to scale; 2) The factory enjoys the lower wage because the autarkic household's reservation wage is the lowest. Thus, the equation (18) states that the factory actually invests in housing only if the benefit exceeds the cost. Define $\Pi^0 = Max\{\Pi^m, \Pi^c\}$.

Now, suppose that the transportation costs between the marketplaces are moderate. If the entrepreneur builds only one factory, he saves the cost of setting up the additional factory and benefits from the increasing returns to scale. But there being only one factory, a part of the output may have to be shipped to the other marketplace and this incurs costs. The entrepreneur actually builds only one factory only if the benefits exceed the transportation costs between the marketplaces. Otherwise, it is optimal to build the factory at each of the marketplaces. If there is only one factory and a part of its output is sold in the other marketplace, the profit of the factory is

$$\Pi = p \cdot y - (1/A) \cdot y - w \cdot (y/B)^{1/2} - F - w \cdot \tau \cdot D \cdot y', \tag{19}$$

where y is the amount of the demand for the factory's output defined in equation (16), and F is the fixed cost of the factory, which is $K+R$ or K depending whether the factory invests in housing. $w \cdot t \cdot D \cdot y'$ is the transportation costs between the marketplaces. Only one market area will be industrialized if $\Pi > 6 \cdot \Pi^0 > 0$, that is,

$$\begin{aligned}&(p - 1/A) \cdot (y - 6 \cdot y^0) - \{w^0 \cdot (y/B)^{1/2} - 2 \cdot w^0 \cdot (y^0/B)^{1/2} + F \\ &> w \cdot \tau \cdot D \cdot y'\end{aligned} \tag{20}$$

where $y^0 = y^m$ or y^c, depending on whether the equation (16) holds. If the equation (20) does not hold, all the market areas will be equally industrialized.

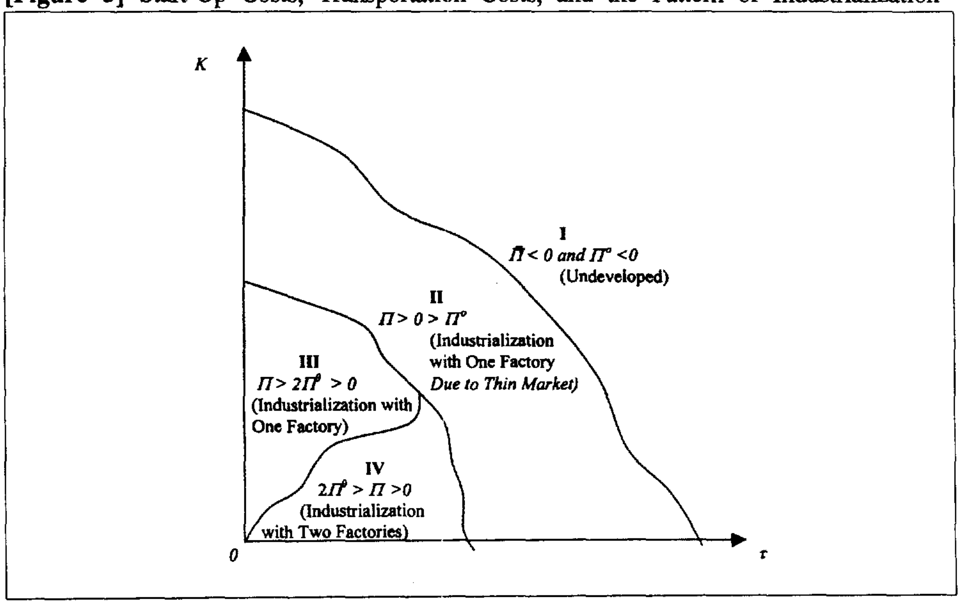
We can derive the conditions for the industrialization from the equations (17) through (20). First, if the equation (19) and Π^0 are negative, then the entire economy's demand for the processed good is too thin to support a factory and this economy cannot be industrialized. Given the transportation cost τ, it is obvious that the higher is the start-up cost, K the more likely it is that the equation (19) becomes negative. By the same token, given the start-up cost, K, the main reason for the thinness of the market for the processed good is the high transportation costs. If τ is high, the effective price of the factory's output rises sharply as the distance to the marketplace increases. Thus, with high τ, the demand within the market area as well as the demand across the market areas is small, from the equations (14), (14'), and (15). In addition, the high transportation cost between the marketplaces, which is paid by the factory, reduces the factory's profit. If τ is too high, the equation (20) may not hold, so that the factory would not sell its output in the other market area even if there is no factory there. Another reason for the thin market for the factory's output may be the expensive housing costs, R. If R is too high, then the equation (18) does not hold, and the factory would not make investment in housing. There being no migration of the autarkic households into the market area in this case, the population in the market area, and thus the demand for factory's output, would not expand. Without migration, the wage rate is higher, too.

Second, if the equation (19) is positive and Π^0 is negative, then the size of the market for the processed good is just enough to support one factory. Note that if the equation (19) is positive and Π^0 is negative, the equation (20) is automatically satisfied. In this case only one market area would be industrialized and the geographic concentration of the manufacturing industry is inevitable.

Third, if Π^0 is positive, then one market area alone can support the factory manufacturing. Thus, potentially, all the market areas can be industrialized. However, if the equation (20) holds, it is optimal to build only one factory. If it does not, all the market areas would be equally industrialized.

The discussions above are summarized in <Figure 3>. Taking other parameter values as given, the graph shows how the relative magnitudes of the start-up costs and the transportation costs affect the industrialization of the economy. Both the start-up costs and the transportation costs work against the industrialization. When the the start-up costs and the transportation costs are moderate, the geographic pattern of industrialization depends on the relative magnitudes of the two.

[Figure 3] Start-Up Costs, Transportation Costs, and the Pattern of Industrialization



Π is the profit when there is only one factory.
Π^o is the profit when there are two factories.

V. CONCLUSION

It is obvious that the industrialization improves the aggregate welfare, because it reduces the price of the processed good and expands the market area. However, it is not clear whether the industrialization leads to the *Pareto* improvement, because the handicraftsmen lose their comparative advantage and have to switch their occupation into a farmer or a laborer.

The residential investment, R, roughly captures all the costs related to urban migration such as the housing cost, the congestion cost, the loss of communal insurance as so on. The lower is R, the more readily the workers can move in to factory site. This. in turn, reduces the wage and contributes to the industrialization of the economy. In <Figure 3>, the reduction in R expands the boundaries of the regions outward. That is, the industrialization is easier as the cost of migration is lower. Thus, any effort of the government to lower the cost of urban migration can encourage industrialization.

The government's investment in infrastructure can trigger the industrialization. Suppose that the economy was originally in the region I of <Figure 3>. If the government invests in infrastructure, the transportation costs are lowered and the economy can move to the region II. Note that in region II, it is inevitable that the manufacturing industry is geographically concentrated. If the government invests further in the infrastructure, the economy shifts to either region III or region IV, depending on the size of the start-up cost of the manufacturing industry. If the economy adopted a technology with the high start-up costs (*e.g.*, heavy and chemical industry), then the economy moves to region III so that the geographic concentration of the industry continues even after the transportation costs are lowered considerably. On the contrary, if the manufacturing technology adopted by this economy does not require too much start-up costs (e.g., light and knowledge-intensive industry), then the further decrease in the transportation costs shifts the economy to the region IV. In region IV, the industrialization spread out to all parts of the economy.

As discussed above if it is the government's investment in infrastructure that can trigger the industrialization, the undeveloped economies may remain undeveloped because their government failed to make an investment in the infrastructure. The question of why a country is not developed may be reduced to the question of why its inadequate infrastructure is not improved[8]. As was

[8] An anonymous referee pointed out that the case of India and Indonesia may be a counter example of this implication. That is, though the railroad system is much better in India than in Indonesia, India is left farther behind in industrialization. According to the World Bank Data Base, the amount of goods and services transported by train per dollar worth of GDP in India is about 15 times more that that in Indonesia. This data shows that India depends more heavily on the railroad than Indonesia. But this may not be a definite evidence that the transportation infrastructure of India is better than that in Indonesia. If the India's population is evenly distributed over the territory whereas the Indonesia's population is highly concentrated along the coast because of the tropical jungles, Indonesia may not have to use railroads too much and

mentioned in the introduction, the lack of domestic resources is less a problem, because the government can borrow from the international financial market only if the benefit of such investment exceeds the cost. The analysis of this model can contribute to the evaluation of the dynamic benefit from the infrastructure investment. If we calibrate the model carefully, we may be able to get a quantitative measurement of the benefit. The characterization of the optimal investment in infrastructure in a general equilibrium model would be an interesting topic for the future research.

Now consider an undeveloped economy that cannot find the resources for the investment in infrastructure. That is, the economy is in region I and cannot move into region II. In this case, the economy may take advantage of the ocean transportation and the international market. Note that the ocean transportation costs are far cheaper than the in-land transportation costs and the international market is much larger than the domestic market. After the economy accumulate enough wealth, it can invest in the infrastructure and enlarge the domestic market. This model my be considered as a way of justifying Korea's export driven industrialization in 1960's and 1970's. This strategy also works well when the economy tries to switch into the technology with high fixed costs (e.g., heavy and chemical industry). If the existing infrastructure is not good enough (the transportation costs are not low enough) to make profitable the technology with high fixed costs, then the economy can take advantage of the cheaper ocean transportation costs and the larger international market.

instead it can take advantage of the cheaper ocean transportation. However, if the distribution of the population is not much different between the two, then the case of India and Indonesia can be considered as an example that shows the limitation of this model. India, despite the better transportation infrastructure, may suffer from the segregation of the domestic markets due to the ethnicity, religion, or caste. If this is the reason for India's underdevelopment, it is still true that the size of the market matters but our model fails to explain why the market is small in India.

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